Tool and Guideline # 11.2

Practical Tools on Small-scale Incinerators for Biomedical Waste Management

Rwanda Environment Management Authority
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PREFACE

In 2010, REMA prepared 11 practical technical tools intended to strengthen environmental management capacities of districts, sectors and towns. Although not intended to provide an exhaustive account of approaches and situations, these tools are part of REMA's objective to address capacity-building needs of officers by providing practical guidelines and tools for an array of investments initiatives.

Tools and Guidelines in this series are as follows:

#	*TOOLS AND GUIDELINES*
1	Practical Tools for Sectoral Environmental Planning : A - Building Constructions B - Rural Roads C - Water Supply D - Sanitation Systems E - Forestry F - Crop Production G - Animal Husbandry H - Irrigation I - Fish Farming J - Solid Waste Management
2	Practical Tools on Land Management - GPS, Mapping and GIS
3	Practical Tools on Restoration and Conservation of Protected Wetlands
4	Practical Tools on Sustainable Agriculture
5	Practical Tools on Soil and Water Conservation Measures
6	Practical Tools on Agroforestry
7	Practical Tools of Irrigated Agriculture on Non-Protected Wetlands
8	Practical Tools on Soil Productivity and Crop Production
9	Practical Technical Information on Low-cost Technologies: Composting Latrines & Rainwater Harvesting Infrastructure
10	Practical Tools on Water Monitoring Methods and Instrumentation
11	11.1 Practical Tools on Solid Waste Management of Imidugudu, Small Towns and Cities : Landfill and Composting Facilities
	11.2 Practical Tools on Small-scale Incinerators for Biomedical Waste Management

These tools are based on the compilation of relevant subject literature, observations, experience, and advice of colleagues in REMA and other institutions. Mainstreaming gender and social issues has been addressed as cross-cutting issues under the relevant themes during the development of these tools.

The Tool and Guideline # 11.2 provides practical information on the siting and construction of small-scale incinerators for biomedical waste treatment in Imidugudu, small towns and cities.

These tools could not have been produced without the dedication and cooperation of the REMA editorial staff. Their work is gratefully acknowledged.

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Definitions

- "biomedical waste" means a substance that is defined as biomedical waste such as:
    - Solids: Catheters and tubes, disposable gowns and masks, disposable tools, such as some scalpels and surgical staplers, medical gloves, surgical sutures and staples, and wound dressings;
    - Liquids: blood, body fluids and tissues, cell, organ, and tissue cultures;
    - Sharps: blades, razors, scalpel blades, needles, and syringes;
    - Laboratory waste: animal carcasses, hazardous chemicals.
- "recycling" means the collection, transportation and processing of products separated from the municipal solid waste stream which are no longer useful in their present form and the use (including composting) of their material content in the manufacture and sale of new products. Recycling refers to source-separated wastes only, when used in the context of the 3 R s (Reduce, Reuse, and Recycle).
- "reduction" means decreasing the volume, weight, and/or toxicity of discarded material and includes activities which result in greater ease or efficiency of reuse of a product or recycling of materials.
- "reuse" means the repeated use of a product in the same form but not necessarily for the same purpose.

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1. INTRODUCTION

1.1 OVERVIEW

Biomedical waste consists of solids, liquids, sharps, and laboratory waste that are potentially infectious or dangerous. It must be properly managed to protect the general public, specifically healthcare and sanitation workers who are regularly exposed to biomedical waste as an occupational hazard. Biomedical waste differs from other types of hazardous waste, such as industrial or municipal waste, in that it comes from biological sources or is used in the diagnosis, prevention, or treatment of diseases.

Common producers of biomedical waste include hospitals, health clinics, nursing homes, medical research laboratories, and offices of physicians, dentists, and veterinarians. The following is a list of materials that are generally considered biomedical waste:

- Solids: Catheters and tubes, disposable gowns and masks, disposable tools, such as some scalpels and surgical staplers, medical gloves, surgical sutures and staples, and wound dressings;
- Liquids: blood, body fluids and tissues, cell, organ, and tissue cultures;
- Sharps: blades, razors, scalpel blades, needles, and syringes;
- Laboratory waste: animal carcasses, hazardous chemicals.

Biomedical waste treatment facilities are licensed by the local governing body which maintains laws regarding the operation of these facilities.

1.2 PURPOSE

This technical guideline provides information of low cost small-scale incinerators used to dispose of health-care waste in imidugudu, small towns and cities of Rwanda, specifically sharps waste (used and possibly infected syringes and needles). Without appropriate management and treatment, infectious health-care waste has the potential to cause a significant disease i.e. Hepatitis B, C and HIV infections and deaths due to reused and contaminated syringes. Safe and effective waste treatment using small-scale incinerators is suggested.

Although not intended to provide an exhaustive account of approaches and situations, this tool is intended to address capacity-building needs of officers by providing information of scale-scale incinerators. This tool can be used as field guides or as checklists of elements for discussion during training and during implementation and monitoring of small-scale incinerators.

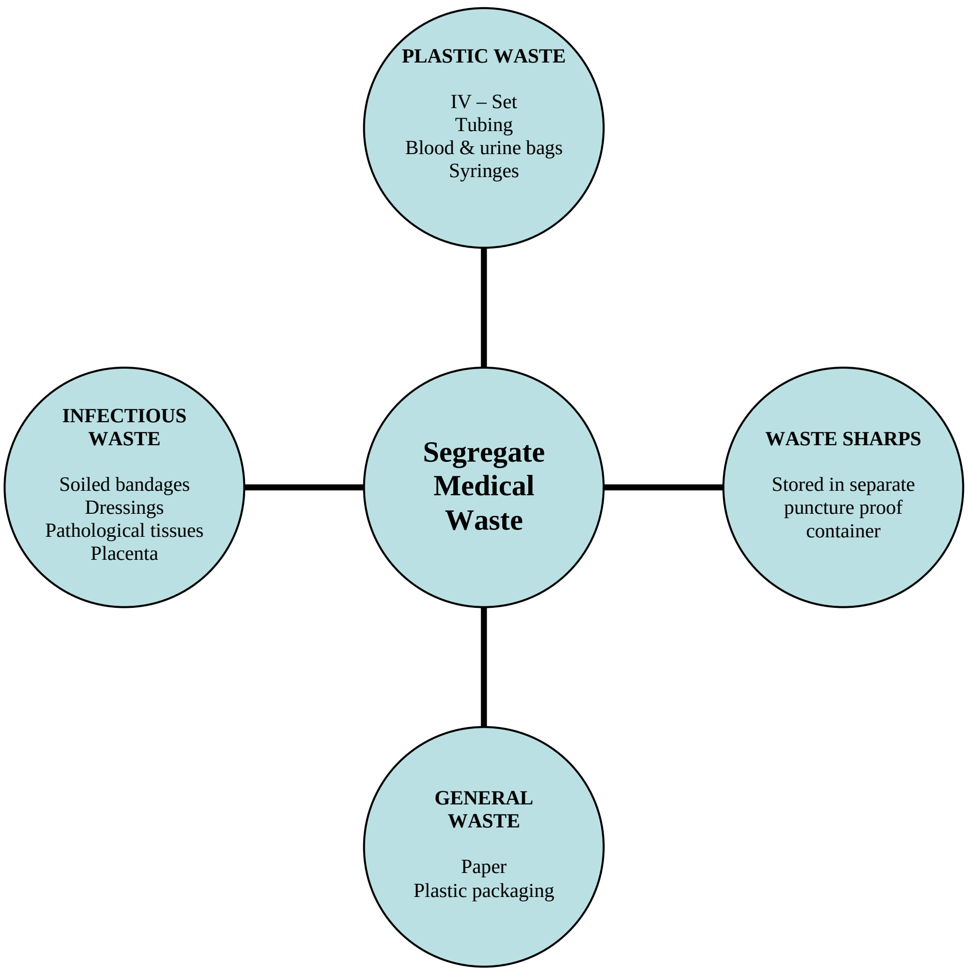
This document was produced to address REMA's proposed policy action to strengthen the resource capacity of environmental and related institutions at national and district level for environmental assessment, policy analysis, monitoring, and enforcement.

1.3 BIOMEDICAL WASTE MANAGEMENT

Biomedical wastes must be segregated first from "regular" wastes and then according to the following categories:

1) Non-sharp infectious waste (such as laboratory cultures and objects contaminated by blood or body fluids);
2) Pathological waste (such as human body parts, blood, and body fluids);
3) Sharp infectious waste (such as needles, scalpels, and infusion equipment);
4) Pharmaceutical waste (such as drugs, vaccines, and serums);
5) Chemical waste (such as formaldehyde);
6) Waste containing heavy metals (such as thermometers and blood pressure gauges);
7) Radioactive waste (such as radionuclides);
8) Genotoxic waste (such as cytotoxic products used in cancer therapies); and
9) Health care wastewater (which is treated through physical or chemical means, biological purification, lagooning, or sand filtering).

At the site where it is generated, biomedical waste is placed in specially-labelled containers for removal by biomedical waste transporters.



Other forms of waste should not be mixed with biomedical waste as different rules apply to the treatment of different types of waste. Storage areas must have a restricted access, be able to withstand climatic conditions, be adequately ventilated, and be far away from food storage areas and water sources. The floor of the storage areas must also be impermeable, and cleaning and protective equipment must be available. Containers must be hermetic and leak proof (as well as puncture-proof in the case of sharp infectious waste). Containers are typically yellow and accompanied by the international symbol for infectious substances. They are typically sent to treatment and disposal when they are three-quarters full.

1.4 TREATMENT OPTIONS

Biomedical waste is treated by any or a combination of the following methods: incineration or steam, chemical, or microwave sterilization. Any tools or equipment that come into contact with potentially infectious material and are not disposable or designed for single-use are sterilized in an autoclave. Disposing of these materials with regular household garbage puts waste collectors at risk for injury and infection, especially from sharps items. Programs should be in place for the disposal of household biomedical waste.

Source reduction of biomedical wastes is important. For example, to avoid generating pharmaceutical wastes in the form of expired medication, small amounts of the required products should be ordered in a centralized manner, and products should be used in the order of their expiration dates. Only products designed specifically for re-use are to be re-used after appropriate cleaning and sterilization (through an autoclave, for example).

For small-scale initiatives, minimal requirements typically call for the incineration, encapsulation and/or safe burial of biomedical wastes, considering the context. Other more efficient and/or more sustainable methods of treatment and disposal of biomedical wastes exist (such as chemical disinfection, wet thermal treatment, and microwave irradiation). However, these tend to be more complex and more expensive. If on-site incineration is the preferred option of treatment, considering the context, it should take place preferably in a static-grate, single-chamber on-site incinerator.

As a secondary option, on-site incineration may take place in a drum or brick on-site incinerator. Appropriately controlled incineration is generally adequate for non-sharp infectious wastes, pathological wastes, and sharp infectious wastes. The residues from burning (or ashes, which should contain less than 3 % of unburned matter) are then buried using safe on-site burial methods or disposal in an authorized sanitary landfill.

Table 1 : Treatment and Disposal Options

Treatment/ disposal method	*Description*	*Effective for*	*Advantages*	*Disadvantages*
Double-chamber ("pyrolitic") incineration	A permanent furnace of masonry/concrete, refractory materials, and metal. Waste thermally decomposes in the first, oxygen-poor (pyrolitic) chamber, which operates at 800–900°C. The second, post combustion chamber, burns the gases produced in the first chamber at 900–1200°C.	Infectious & highly infectious wastes Pathological wastes and sharps Most chemical and pharmaceutical waste. (should be 5% or less of total burn load)	Disinfects very effectively Fewer toxic emissions, odor and smoke than single-chamber and drum incinerators (but still should not be used to incinerate PVC) Reduces waste volume by ~95%	Effective performance requires qualified operators and regular maintenance. Sharps in ashes will still pose physical hazard. Higher costs than other incineration, burning and burial options in this table.

Treatment/ disposal method	*Description*	*Effective for*	*Advantages*	*Disadvantages*
Single-chamber incineration	A permanent simple furnace of solid construction, e.g., concrete. Waste is placed on a fixed grate. Burning is maintained by the natural flow of air. Operating temperature reaches <300°C. May need to add kerosene or similar fuel to maintain combustion.	Infectious waste Sharps waste Pathological waste	Disinfects effectively. Reduces waste volume by ~80%; burning efficiency of 90–95%. Low investment and operating costs.	Emits pollutants such as fly ash, acid gases, and some toxins. May produce odors. Should not be used to incinerate PVC plastics. Sharps in ashes will still pose physical hazard. Not good for most pharmaceutical or chemical waste.
Drum or brick incinerator	A simple furnace with less mass and insulating value than a single chamber incinerator. Constructed out of an empty oil drum or a short chimney of bricks placed over a metal grate and covered with a fine screen. Operating temperature < 200°C. May need to add kerosene or similar fuel to maintain combustion.	Infectious waste Sharps waste Pathological waste	Disinfects reasonably well, destroying 99% of microorganisms. 80–90% burning efficiency.	Emits black smoke, fly ash, acid gases, and some toxins. May produce odors Should not be used to incinerate PVC plastics. Sharps in ashes will still pose physical hazard. Not good for most pharmaceutical or chemical waste.

Incineration is generally not recommended for pharmaceutical wastes, chemical wastes, genotoxic wastes and radioactive wastes. Furthermore, pressurized containers, halogenated plastics (PVCs), and wastes containing heavy metals are not to be incinerated. On-site encapsulation is a method of treatment and disposal sometimes recommended for sharp infectious wastes and small amounts of pharmaceutical wastes. Encapsulation alone is not recommended for non-sharp infectious wastes, but may be used in combination with and after their incineration. Encapsulation is generally not recommended for pathological wastes, chemical wastes, genotoxic wastes, radioactive wastes, and wastes containing heavy metals. Safe on-site burial may be conducted for small amounts of non-sharp infectious wastes, small amounts of pathological wastes, small amounts of sharp infectious wastes (and ashes from the incineration of these three categories of biomedical wastes), and small amounts of pharmaceutical wastes (with the same protective and control measures as those proposed for landfills). Safe, on-site burial of prescribed wastes is practicable for only relatively limited periods of time (e.g. one to two years) and for relatively small quantities of such wastes (approximately up to 5 to 10 tonnes in total).

1.5 ENVIRONMENTAL ISSUES

Biomedical wastes are associated with the same types of environmental effects as other types of wastes. However, in the case of biomedical waste the potential for disease transmission is greater. Biomedical wastes may lead to injuries (through sharp waste), short-term and long-term health problems (e.g. related to radioactive waste), as well as to the spread of diseases (e.g. hepatitis, HIV/AIDS, cholera, diphtheria, and other communicable respiratory, gastro-intestinal, ocular, and skin diseases).

Environmental and health and safety training (including first aid measures, good hygiene practices, and the use of protective clothing and equipment) are essential, as is the assignment of specific tasks and responsibilities for the management of biomedical wastes (including its segregation, collection/handling, storage, transportation, treatment, and final disposal, as well as accident, spill, and emergency response).

2. SMALL-SCALE INCINERATOR

2.1 DESIGN CRITERION

Proper design and operation of small-scale incinerators should achieve desired temperatures, residence times, and other conditions necessary to destroy pathogens, minimize emissions, avoid clinker formation and slagging of the ash, avoid refractory damage destruction, and minimize fuel consumption. Good combustion practice elements also should be followed to control dioxin and furan emissions. Table 1 provides design parameters for small-scale intermittent incinerators.

Table 2 : Incinerator Design Parameters

TYPE	*PARAMETER*	*RECOMMENDATION*
Capacity	Destruction rate	• Proper sizing is important. Ideally, unit should burn for long periods (~4 hrs) to save fuel.
Temperatures	Primary chamber and/or Secondary chamber	• >850/1100 C
Residence times	Gas (secondary chamber)	• >1 s
Air flows	Total combustion air	• 140 – 200% excess
	Supply and distribution of air in the incinerator	• Adequate
	Mixing of combustion gas and air in all zones	• Good mixing
	Particulate matter entrainment into flue gas leaving the incinerator	• Minimize by keeping moderate air velocity to avoid fluidization of the waste, especially if high (>2%) ash waste is burned. The residues from burning (or ashes, which should contain less than 3 % of unburned matter) are then buried using safe on-site burial methods or disposal in an authorized sanitary landfill.
Controls & Monitoring	Temperature and many other parameters	• Continuous for some, periodic for others
Waste	Waste destruction efficiency	• >90% by weight
	Uniform waste feed	• Uniform waste feed, and avoid overloading the incinerator
	Minimizing emissions of HCl, D/F, metals, other pollutants	• Avoid plastics that contain chlorine (polyvinyl chloride products, e.g., blood bags, IV bags, IV tubes, etc.) • Avoid heavy metals, e.g. mercury from broken thermometers etc.
	Load/charge only when incinerator operating conditions are appropriate	• Pre-heat incinerator and ensure temperatures above 800 C. • Avoid overheating.
Enclosure	Roof	• A roof may be fitted to protect the operator from rain, but only minimum walls.
Chimney	Height	• At least 4 – 5 m high, needed for both adequate dispersion plus draft for proper air flow
Pollution control equipment	Installing air pollution control devices	• Most frequently used controls include packed bed, venturi or other wet scrubbers, fabric filter typically used with a dry injection system, and infrequently electrostatic precipitator. • Modern emission limits cannot be met without installing air pollution control devices.

2.2 SITING CRITERIA

In practice, incinerators are usually located within clinics and hospitals for reasons of convenience, management, etc., and they often are located adjacent to or within populated areas.

The location of an incinerator can significantly affect dispersion of the plume from the chimney, which in turn affects ambient concentrations, deposition and exposures to workers and the community. In addition to addressing the physical factors affecting dispersion, siting must also address issues of permissions/ownership, access, convenience, etc.

Best practices siting has the goal of finding a location for the incinerator that minimizes potential risks to public health and the environment. This can be achieved by:

- Minimizing ambient air concentrations and deposition of pollutants to soils, foods, and other surfaces, e.g.,
    - Open fields or hilltops without trees or tall vegetation are preferable. Siting within forested areas is not advisable as dispersion will be significantly impaired.
    - Valleys, areas near ridges, wooded areas should be avoided as these tend to channel winds and/or plumes tend to impinge on elevated surfaces or downwash under some conditions.

- Minimizing the number of people potentially exposed, e.g.,
    - Areas near the incinerator should not be populated, e.g., containing housing, athletic fields, markets or other areas where people congregate.
    - Areas near the incinerators should not be used for agriculture purposes, e.g., leafy crops, grasses or grains for animals.

Appropriate sizes for buffer surrounding incinerators are required. For typical small-scale units, 750 m buffer surrounding the facility is advisable. This distance is based on ideal conditions, e.g., relatively flat and unobstructed terrain.

Adequate plans, drawings, and quality control are necessary to construct incinerators. Dimensional drawings, tolerances, material lists, etc. are necessary. Shelters, protective enclosures, and pits need to be constructed in all sites.

2.3 OPERATIONAL AND PERFORMANCE CRITERION

2.3.1 General Operation

Proper operation is critical to achieving design parameters. In general, the manufacturer or designer of the equipment should provide a manual that explains operating practices including start-up procedures, shutdown procedures, normal operation, troubleshooting, maintenance procedures, recommended spare parts, etc. These will be equipment-specific. Some general operation issues are listed in the next table.

Table 3 : Operation and Maintenance Issues for Incinerators

FACTOR	***EXAMPLE***
Waste selection	Restricted wastes
Waste-feed handing	Volume, moisture
Incineration operation, monitoring and control	Recharge, fuels, temperature
Air pollution control systems, if any	Filters
Maintenance	Hourly, weekly, monthly, annual, control equipment
Control and monitoring instrumentation	Temperature, pressure, smoke/opacity
Recordkeeping	Operating records, maintenance records
Safety	Infection control during waste handling, equipment safety, fire safety

These are several recommendations that may apply to various small-scale incinerators:

- The incinerator must be fully heated up before wastes are added, requiring about 30 min or longer, depending on ambient temperature, type of fuel, fuel moisture content, etc.
- If firewood is uses, it must have a low moisture content (<15%).
- Temperature monitors should be used to be able to determine if suitable temperature have been reached.
    - Grey or black smoke indicates poor combustion and low temperatures.
    - Low cost dial type readout temperature sensors should be available for a reasonable cost and it is strongly suggested that units incorporate a quantitative temperature gauge, and that waste only be combusted when the temperature is in the correct range.
- Operation requires the constant presence of an operator when burning waste. Dry fuels must be added every 5 – 10 min.
- Flame must not be extinguished during burnings.
- Grates must be regularly checked and raked to keep clear.

2.3.2 Waste Loading

Proper waste loading is critical to achieving combustion.

- Proper amount of fuel should be present (2/3 full) before adding wastes.
- Operator care, judgment, and experience necessary to deal with different load types:
    - Charging every 10 minutes appears to be an optimal rate for charging the incinerator.
    - Very wet loads should be separated with drier material, and in extreme case supplemented by an extra increment of diesel/kerosene.
    - High heat fuels (plastics, paper, card and dry textiles) are helpful to maintain temperature.
    - Waste mixing is desirable. Mixing may be possible by separating waste types at the source in bags, labelling each, and loading in appropriate combination or sequence.
    - Operators should not sort and mix waste prior to incineration due to hazards.
    - Supplemental fuel may be need for wastes with a high moisture content or low fuel value.
    - Restricted wastes should never be burned, including radioactive wastes, mercury thermometers, or hazardous chemicals.
    - Because of the lack of emission controls, wastes containing chlorine, sulphur, nitrogen and toxic metals should be avoided.
- Measures may be necessary to hold wastes in position long enough to burn and to prevent them from failing through grate without being destroyed. This is especially important for smaller wastes, e.g., pills, sharps, etc. Sharps should be mixed with other waste.
- When the loading door is closed or opened rapidly, burning gases may come through the under air ports (air holes).
- Possible operator exposure due to smoke, flames, heat when loading door is opened or rapidly shut.
- The operator should open the door while standing at the front of the incinerator (to protect from blowback), wait a few seconds for any blowback to subside, and load from the side.
- Sufficient time must be provided for the ‘fixed carbon’ in the waste bed to combust.

2.3.3 Monitoring

Combustion and emission monitoring is used routinely for several purposes, including determining whether incinerators are properly operated. Additionally, monitoring is used to assure compliance with regulatory limits and, to an extent, to help build public trust. Monitoring may be classified into the following categories:

- Sensory observations, e.g., visual assessment of stack emissions or assessment of odours. Sensory monitoring is clearly unable to detect many emissions of concern, and is very subjective.
- Stack tests, e.g., measurement of emissions for brief periods of time. These tests are expensive, and provide emission data for only a brief period of time that may not be representative.
- Continuous emission monitoring, e.g., in-stack monitoring of opacity (particle surrogate), SO_2, CO, O_2, NOx, HCl and recently Hg is regularly conducted at modern incinerators. Continuous monitoring of temperature and other parameters (e.g., pressure drop across filters) is also used. Continuous emission monitoring data have been used as surrogates of emissions and to indicate the suitability of combustion conditions, although there are issues, e.g., correlation of CO to products of incomplete combustion is poor at low CO levels.
- Environmental monitoring. While used infrequently, monitoring of ambient air, soil, food, etc., around incinerators has been used to confirm predictions of multimedia exposure models.

Low-cost and locally-built incinerators have minimal if any capability to monitor operations, including emissions or combustion conditions, other than the use of sensory observations.

2.3.4 Safety

Safety considerations include prevention of infection, equipment safety (to prevent operator injury), and fire safety. Some specific recommendations include:

- Eye protection and a face mask should be worn when opening loading door or visually checking the unit to protect against glass shards from exploding ampoules and glass bottles.
- Heavy-duty gloves and apron should be worn when handling health-care waste.
- Ash must not be handled by hand.
- An adequate cool-down period (3 to 5 hrs) is necessary before ash removal.
- Appropriate disposal of ash is necessary (i.e. burial).

2.3.5 Maintenance

Regardless of how well equipment is designed, wear and tear during normal use and poor operation and maintenance practices will lead to the deterioration of components, a resultant decrease in both combustion quality, an increase in emissions, and potential risks to the operator and public. Operation and maintenance also affect reliability, effectiveness and life of the equipment. Essentially all components of small-scale incinerators are prone to failure and require maintenance. Maintenance on an hourly to semi-annual schedule is required. A typical maintenance/schedule for a small-scale incinerator is shown in the next table.

Table 4 : Typical Maintenance Schedule for Incinerators

ACTIVITY	***FREQUENCY***	***COMPONENT PROCEDURE***
Hourly	Ash removal	Inspect and clean as required
Daily	Temperature, pollution monitors, if any	Check operation
	Under fire air ports	Inspect and clean as required
	Door seals	Inspect for wear, closeness of fit, air leakage
	Ash pit	Clean after each shift
Weekly	Latches, hinges, wheels, etc.	Lubricate if applicable
Monthly	External surfaces of incinerator and chimney (stack)	Inspect external hot surfaces. White spots or discoloration may indicate loss of refractory
	Refractory	Inspect and repair minor wear with refractory cement
	Upper/secondary combustion chamber	Inspect and remove particulate matter accumulated on chamber floor
Semi-annually	Hot external surfaces	Inspect and paint with high temperature paint as required
	Ambient external surfaces	Inspect and paint as required

For small-scale low cost incinerators, components particularly prone to failure include:

- Firebox access doors and frames that warp, hinges that seize and break, and assemblies that break free of mortar.
- Grates that distort, break, or become clogged.
- Chimneys (stacks) that are badly corroded and chimney supports (guy wires) that are not adequately attached, broken, loose or missing.
- Masonry, bricks and particularly mortar joints that crack.
- Grills damaged or missing.
- Steel tops that warp and short-circuit the secondary combustion chamber.

Incinerators typically require major maintenance after 3 years, costing approximately
70% of initial construction costs. Funds must be made available to provide for both routine and major maintenance.

2.3.6 Facility Inspection

As currently used, stack gases or necessarily even basic combustion process parameters like temperature are not monitored in small-scale incinerators. There is a need for even basic facility inspections to ensure that the unit is in proper repair and that compliance with best operating practices is feasible. Facility inspections should include:

- Visual inspections of the facility for corrosion, leaks, mortar and seal failures, etc.
- Testing of doors and other moving parts.
- Regular schedule, e.g., monthly to quarterly.
- Documentation of use, maintenance, and complaints.
- Reporting of findings to higher authorities.

A trained operator can provide this inspection. Ideally, a District Environment Officer, along with the certified operator, would conduct an inspection twice per year.

2.3.7 Record Keeping

Records must be maintained for maintenance activities to prevent premature failure of equipment, increase life, track performance, evaluate trends, identify potential problems areas, and find appropriate solutions.

2.3.8 Training and Management

Proper operation of incinerators is necessary to minimize emissions and other risks. Only a trained and qualified operator should operate or supervise the incineration process. The operator must be onsite while the incinerator is operating. Without proper training and management support, incinerators cannot achieve proper treatment and acceptable emissions, and the resultant risks due to incineration can greatly increase and may be unacceptable.

The manufacturer or designer of the incinerator should provide operation and maintenance training and provide manuals with specific instructions for their equipment. These manuals should be provided in English and Kinyarwanda. These manuals should be incorporated into a best practices guide for each type or version of incinerators.

A certification process for operators and supervisors is suggested to ensure proper operation and use to minimize emissions and other risks associated with incinerator. Additionally, proper operation and maintenance will improve equipment reliability and performance, prolong equipment life, and help to ensure proper ash burnout. Typically, certification involves both classroom and practical training.

An approved program would include the following components:

- Coverage of the following i.e. fundamental concepts of incineration; risks associated with health-care waste and waste incineration; waste reduction, segregation and handling goals and practices; design, operation, maintenance of the specific incinerator used; operation problems and solutions (e.g., white smoke, black smoke, etc.); operator safety and health issues; community safety and health issues; best practices guide for the specific equipment including appropriate fuels, frequency of burns, etc. This will need to be tailored to both the equipment plus waste stream at the site; inspection and permitting; and record keeping (operation and maintenance activities).
- Reference material covering the course.
- Practical training is necessary in addition to classroom training.

2.3.9 Regulations Affecting Incinerators

There are no specified emission standards or guidelines for small-scale incinerators. Such standards require quantitative emission limits on each type of pollutant, and standards require the use of inspection, testing, monitoring and certification programs for incinerators and operators to ensure compliance. Small-scale low cost incinerators will not meet modern emission standards for many pollutants, e.g., carbon monoxide, particulate matter, dioxin/furans, hydrogen chloride, and possibly several toxic metals.

To meet emission standards, incinerators must be designed to use air pollution control equipment (removing particles, acid gases, etc.), combustion process monitoring (temperature, flow rates, etc.), and process controls (waste, fuel, air flows). Few of these technologies are adaptable to small-scale low cost incinerators that do not have exhaust fans, pollution controls, dampers, monitoring, electrical power, etc. These technologies will greatly increase the cost and complexity of incinerators, and they are unlikely to perform reliability in many settings given the need for careful operation, regular maintenance, and skilled operators.

Where incineration is used, it may be appropriate to utilize emission limits and other requirements to ensure effective waste treatment, minimize emissions, and decrease exposure and risks to workers and the community. This should include:

- The use of approved incinerator designs that can achieve appropriate combustion conditions (e.g., minimum temperature of 800 C, minimum chimney heights);
- Appropriate siting practices (e.g., away from populated areas or where food is grown);
- Adequate operator training (including both classroom and practical training);
- Appropriate waste segregation, storage, and ash disposal facilities such as burial sites;
- Adequate equipment maintenance; managerial support and supervision; and
- Sufficient budgeting.

Annex 1: References and Useful Resources

- REMA (2009): Rwanda State of Environment and Outlook Report, Rwanda Environment Management Authority, P.O. Box 7436 Kigali, Rwanda http://www.rema.gov.rw/soe/
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- *Management of Solid Health-Care Waste at Primary Health-Care Centres: A Decision-Making Guide.* World Health Organization, Geneva, 2005, 57 pages. ISBN 92 4 159274 5. Available at: http://www.who.int/water_sanitation_health/medicalwaste/decisionmguide_rev_oct06.pdf
- *Findings on an Assessment of Small-scale Incinerators for Health-care Waste*. S. Batterman. WHO, Geneva, 2004, 77 pages. Available at: http://whqlibdoc.who.int/hq/2004/a85187.pdf.
- *Resources for low-cost pyrolitic (double-chamber) incinerators.* A number of moderate to low-cost incinerator designs are available. Of these, DeMontfort incinerators are probably the most widely deployed and evaluated. Developed specifically as a technically effective, appropriate-technology, low cost option in the developing country context, they have been used and tested widely by a number of organizations including WHO, UNICEF and UNDP. They are preheated by burning paper, coconut husks or other biofuel, bringing temperature in the combustion chamber up to ~600C prior to the introduction of infectious waste. Except for very wet loads, they do not require additional fuel (e.g. kerosene or diesel) to maintain combustion.
- *Managing Health Care Waste Disposal: Guidelines on How to Construct, Use, and Maintain a Waste Disposal Unit*. WHO Africa /IT Power India, 2005, 93 pages. Available at http://www.healthcarewaste.org/documents/WDU_guidelines2_en.pdf. Provides specifications, including construction diagrams, installation, operation and maintenance instructions for a Waste Disposal Unit based on the "De Montfort" Mark 8 pyrolitic incinerator.
- *De Montfort" medical waste incinerators website.* Provide siting, technical specifications, and operations and m aintenace guidance for the "De Montfort" series of low-cost pyrolitic incinerators. (Estimated materials costs $250–$1000). www.mw-incinerator.info/en/101_welcome.html.