GUIDANCE ON MEASUREMENTS AND DOCUMENTATION

Introduction

The Project Document of the UNDP-supported GEF-funded project requires the implementation of a system of measurements and documentation. The logical framework (Log Frame) analysis and table of quantifiable indicators in the Project Document are the main basis for this guidance. It is intended for project coordinators, technical consultants, and model facility staff.

General Approach

For each component of the UNDP GEF Project, this guidance describes: (1) activities required by the Project Document, and (2) activities that are optional but recommended to support sustainability of best practices and technologies. Some activities pertain to the establishment of a long-term system of measurements and documentation, while others are *final measurements and documentation related to project closure* (shown in italics). The activities marked with the symbol shown on the right are the highest priority (mandatory) activities related to project closure. Results of final measurements should be submitted to the UNDP GEF global project team (GPT) by **October 17, 2012**.

System of Measurements and Documentation

1.0 Model Healthcare Facilities

I. Healthcare Waste Management Policies

For the long-term, healthcare facilities should have written healthcare waste management policies which delineate the roles and responsibilities of all employees. Policies are updated as needed by the hospital administration.

For project closure, send the GPT a copy of the facility's written policies on healthcare waste management before the project began (make a note if no policies existed before the project) and send a copy of the facility's written policies at the end of the project.

II. Healthcare Waste Management Plan/Procedures

Healthcare facilities should have written healthcare waste management plans and procedures which describe the major elements of healthcare waste management, including waste classification, segregation, color coding, proper types and placement of containers, signs and labels, internal transport, treatment, disposal, periodic training, monitoring, continuous improvement, and the healthcare waste committee. The written plans and procedures could be used for the training of new health workers and for inspection by regulatory

authorities. For the long-term, the written healthcare waste management plans and procedures should be reviewed and updated annually by the facility's healthcare waste committee.

For project closure, send a copy of the healthcare waste management plans and procedures of each model facility to the GPT.

III. HCWM Organization

The healthcare waste management committee should meet on a regular basis (more often in the beginning, then ideally every quarter or at least once a year). For the long-term, notes of the meetings should be documented and kept on file, including the meeting dates, the list of attendees, and a brief summary of the topics discussed or decisions made.

For project closure, the date of establishment of the healthcare waste management committee, list of members, their titles or positions, and the number of meetings held every year for the last four years or since establishment should be sent to the GPT.

IV. Training

The facility should have healthcare waste training curricula appropriate for different job positions. The system of documentation should include dates of the trainings, lists of training attendees, and descriptions of the trainings provided. All workers should receive initial training and annual refresher training. The documentation could be used to keep track of who has undergone training. For the long-term, the training documentation should be reviewed and updated annually by the facility's training coordinator or healthcare waste committee.

For project closure, send the following information to the GPT for each training session conducted for the model facility (not including national training) under the project:

- *Date and location of the training*
- *Type of training (e.g., initial training, refresher training, specialized training, etc.)*
- *Duration of the training (total hours)*
- *Person(s) who conducted the training*
- *Number of people trained*
- *Description of people trained (target audience) or list of names and job titles of the people trained*
- *Brief description of the training (major topics covered, training methods used)*
- *Summary of results of evaluations, if any.*

Using the above data, calculate and report the <u>percentage of staff trained</u> (in relation to the total staff) at the end of the project. If available, send a few photos of the training sessions, including any demonstrations or hands-on training.

V. Documentation of Best Practices *(for project closure)*

(a) ***I-RAT:*** *For project closure, repeat the Individualized Rapid Assessment Tool (I-RAT) using the same procedure as was used during the baseline*

assessment. Submit a copy of the I-RAT points including the final score. [Contact the GPT for a copy of the Excel-based I-RAT.]

(b) ***Photos showing improvements in practices:*** *Send electronic copies of photos to the GPT that show "before and after" improvements. If "before" photos of poor practices were already submitted with the baseline assessment, take corresponding photos to show the improvements. Examples include:*

- *Photos of any improper and new containers*
- *Photos of incorrect and correct placement of waste containers*
- *Photos of old and new container labels or markings*
- *Photos of old and new educational posters or signs*
- *Photos of old transport methods and new transport carts*
- *Photos of old and new waste storage areas*
- *Photos of waste workers showing incorrect and correct collection and transport practices including the use of personal protective equipment.*

VI. Waste Reduction

An optional activity for the long term is an annual waste assessment. Conducting a waste assessment is a useful exercise to identify potential problems in waste segregation and to find new areas for waste minimization and cost savings. A waste reduction study protocol could be as complicated as the procedure used during the baseline assessment or as simple as a one-day sampling.

For project closure, conduct a one-day waste reduction sampling study using the method given in Appendix A. The study could be expanded to more than one day if desired. Submit the data and results to the GPT. Note that for model facilities that did not practice segregation at the start of the project, a 50% reduction in infectious waste is expected by the end of the project.

VII. Waste Segregation

Another activity for the long term is a waste segregation study. Conducting a waste segregation study is essential in improving waste classification procedures and in identifying which departments in the facility must improve their segregation practices. A simplified version of the procedure used during the baseline assessment is found in Appendix B.

For project closure, conduct a one-day waste segregation study using the method given in Appendix B. The study could be expanded to more than one day if desired. Compare the results with those obtained during the baseline assessment and submit the data and results to the GPT.

2.0 Non-Incineration Treatment Technologies

I. Basic Data *(for project closure)*

For project closure, compile the information below with the help of the technology vendor, facility engineers, and operators. Note that "technology" can refer to more than one piece of equipment, such as an autoclave and a shredder. Provide information for each major piece of equipment.

- *Name of manufacturer, brand name and model number of the technology*
- *Rated capacity of the technology*
- *Type of technology (e.g., vacuum autoclave, batch microwave, shredder, compactor, etc.)*
- *List of any auxiliary equipment purchased with the technology*
- *Dimensions (L x W x H in meters) of the treatment room or space where the technology is installed*
- *Sketch or drawing of the layout of the treatment room showing the location of the technology and the flow of waste*
- *Date of the start of installation and the number of days needed to install the technology*
- *Standard operating parameters used (e.g., temperature, pressure, exposure time, description of process cycle, etc.)*
- *Date of the start of regular operation of the technology*
- *Persons trained in the operation of the technology (names and job titles)*
- *Dates of training, duration of training (total number of hours), topics covered during the training.*

Send "before" and "after" photos of the installation, as well as photos showing the layout, the major pieces of equipment, and the technology during normal operation.

II. Treatment Process Data

An activity for the long term is the measurement and documentation of the waste treated by the technology. Some regulatory authorities require that the weight of each load and a record of the operating parameters (such as temperature graphs or printouts) be maintained and available for inspection. These records are also helpful in determining how much total waste the technology can handle if the service is offered to other hospitals, or how frequently the technology should undergo preventive maintenance. A typical system of measurements and documentation records the following for each waste load:

- Date
- Name of operator
- Actual time at the start of the process
- Total weight of the waste load
- Source of the waste (e.g., name of the hospital or department)
- Operating parameters during the process (this could be in the form of a computer printout, graph, or hand notation)
- Actual time at the end of the process
- Optional notes (e.g., abnormal conditions if any).

For project closure, measure the weights of each load and the corresponding processing time (from start to finish) of each waste load for one full day of measurements during regular operation. Data for more than one day can be provided if desired. If the facility has been recording its processing rate already, use the available data. Report the typical hours of operation of the treatment facility. If the facility operates more than one shift, report the number of shifts and the duration of each shift for a typical day of operation. Calculate and report the following: (1) the daily average treatment rate in kg of waste treated per hour based on a typical day of operation; and (2) the average duty cycle. The duty cycle is the ratio of the time that the technology is actually processing waste

divided by the total time of the operating shift; the total time includes the time when the technology is idle and not being used during the operating shift. (For example, if the technology is only in actual operation for half of the 8-hour shift, the duty cycle is 0.5.). Provide the data used to make all the calculations.

III. Microbial inactivation efficacy

It is important that every technology maintain monthly records of microbial inactivation. Many regulatory authorities require that these records be maintained and available for inspection. These records also serve as proof of decontamination and reduce the legal liability of treatment facilities. The protocol for microbial inactivation testing of autoclaves and other steam-based treatment technologies is given in "Guidance on the Microbiological Challenge Testing of Healthcare Waste Treatment Autoclaves."

For project closure, report the dates and results of all microbial tests conducted during the duration of the project. Provide data on the biological indicators and concentrations used. If any positive results (that is, growth of microorganisms) were found, describe what corrective actions were taken.

IV. Energy and water consumption

An optional activity for the long term is monitoring the consumption of energy and water by the treatment facility. This is useful in estimating an annual budget for the operation of the treatment system. When the data comes from actual measurements, data trends could be analyzed to determine if repairs or preventive maintenance may be needed. Energy and water consumption is generally recorded on a monthly basis.

For project closure, obtain data on electrical energy and water consumption for the whole treatment system (including shredders, waste bin dumpers, compactors, etc.). Different methods can be used to estimate consumption. When providing data to the GPT, describe the method of estimation used.

Method A: If the treatment system or treatment room has a separate electrical meter, record the initial kilowatt-hour (kWh) reading at the start of the day and the final kWh reading at the end of the day. Add up the total amount of waste (in kg) treated that day. Calculate the difference between the final and initial readings in kWh. Divide the difference by the total throughput (kg) that day to obtain kWh per kg of waste treated. Provide a copy of your calculations. Similarly, if the treatment system or treatment room has a separate water meter, calculate the amount of water usage (liters) for the day and divide by total throughput to obtain liters per kg treated.

Method B: One can work with a trained electrician to measure the actual current drawn by each electrical component in the treatment system. Current measurements can be done by an electrician using a clamp-on ammeter (also called a grip-on ammeter or current clamp) on one phase conductor when the electrical component is operating. One would also need to know the voltage and estimate the duty cycle (the portion of time during an hour that the electrical component is actually drawing current). Electrical consumption in kWh is calculated from voltage (volts) x current (amps) x duty cycle / 10000. For three-phase circuits, the electrician can also provide data on three-phase power. Add up all the electrical usage of the whole treatment system and divide by total throughput for the day to obtain kWh per kg. Similarly, one could temporarily install a water meter on the main supply to the treatment system to measure

actual water usage for one day. A less accurate method is to measure the amount of wastewater from the treatment system during a given day and subtract the amount of water contributed by the waste based on an estimate of the moisture content of the incoming waste (which is typically in the range of 10% to 30% by weight) and also subtract the moisture in the outgoing treated waste (which could be measured by weighing samples of the outgoing waste before and after drying). Dividing water usage by throughput gives water consumption (liters per kg).

Method C: If actual measurements of electricity or water cannot be done, estimates could be made using rated capacities and duty cycle. Contact the technology vendor (or look at the nameplate ratings) to get the rated capacity (usually in watts) for each electrical component. Estimate the duty cycle for each electrical component. The electrical consumption (in kWh) of each component equals rated capacity (W) x duty cycle / 1000. Add up all the electrical usage of the whole treatment system and divide by total throughput for the day to obtain kWh per kg. The technology vendor may already have estimates of electrical consumption or estimates of water usage for daily operation. Divide water usage by throughput to estimate water consumption in liters per kg.

Method D: If none of the above methods are possible, use estimates from electrical and water monthly bills. First, determine the dates when the technology started operation until the present. Second, obtain the electrical utility bill and the water bill from the same months the year before the technology was installed. (For example, if the technology has been in operation from May to September 2012, obtain the electrical utility bills from May to September 2011). Calculate the average monthly electrical energy consumption of the model facility during the time the technology has been in operation in kWh per month. Calculate the average monthly consumption from the same period of the previous year before the installation of the technology. Calculate the difference between the average monthly consumption before and after the technology was installed. Using data from the processing rate (Section 2.0 (II) above), divide the difference by the average monthly throughput rate to obtain an average kWh per kg of waste treated. Check with the facility engineer to ensure that any increase in energy consumption can be attributed mostly to the new treatment system. If not, ask the facility engineer to estimate the energy consumption of other new loads and get the assistance of the engineer to adjust the monthly consumptions to account for the other loads. Provide a copy of your calculations. Similarly, one can obtain the monthly water bill and employ a method analogous to that explained above to estimate average liters of water consumed per kg of waste treated. Check with the facility engineer to ensure that any increase in water consumption can be attributed mainly to the new treatment system. Dividing the monthly water usage by the average amount of waste treated in a month then gives an estimate of the liters of water consumed per kg of waste treated. Whichever method you use, provide a copy of your calculations.

If the technology uses natural gas or liquefied petroleum gas (LPG or LP gas), measure the amount of gas (in cubic meters) consumed at the start and end of the day that the throughput rate is also measured. Report the type of gas used and calculate the average cubic meters of gas per kg of waste treated. If the technology uses diesel or other liquid fuel, use the analogous method to calculate liters of liquid fuel per kg of waste treated. Report the type of fuel used and provide a copy of your calculations.

V. Evaluation of the Technology in Relation to Institutional Needs *(for project closure)*

For project closure, interview the administrator or head of the model facility, HCWM coordinator, facility engineer or technology operator, and any other key staff involved in waste treatment. The objectives of this brief survey are to determine if the management is satisfied with the technology, what health professionals think about the technology in relation to their work, how the engineer and operator think about its use, and how the technology could be improved. The survey questions are given in Appendix C.

VI. Documentation of Periodic Maintenance and Repairs

For the long term, implementing a system of documenting periodic maintenance and repairs is an option that could prove useful in identifying frequent equipment problems, analyzing underlying causes of problems, improving preventive maintenance requirements, minimizing equipment downtime, and reducing costs.

First of all, it is important that the facility work with the technology vendor to develop written inspection and maintenance procedures including:

- Daily inspection and maintenance procedures
- Weekly inspection and maintenance procedures
- Monthly, semi-annual and annual inspection and maintenance procedures.

These written procedures should be part of the training of the operators. Secondly, the facility could keep inspection and maintenance logs to document that the preventive maintenance procedures have been undertaken and who had done them. Any problems should be noted. Thirdly, the facility could keep records of all repairs, including the starting date and duration of downtime due to equipment problems, description of equipment problems, causes of the problem, date of repair, duration of repair, and description of the repair. Appendix D presents statistical methods used in analyzing repair data. The data could be shared with the technology manufacturer to improve their maintenance services.

3.0 Mercury

I. Mercury Awareness-Raising and Training on Safe Handling, Clean-up and Disposal of Mercury Waste

For project closure, send the GPT the following information related to mercury training conducted at the model facility level and/or at national levels.

- *Date and location of the training*
- *Target audience*
- *Duration of the training (total hours)*
- *Person(s) who conducted the training*
- *Number of persons trained, or if available, the list of names and job titles of persons trained*
- *Topics covered during the training*
- *Results of training evaluation, if any.*

For each model facility, calculate the percentage of staff trained (in relation to the total number of staff) at the end of the project. If the model facility has policies or guidelines on mercury, send a copy of the policies or guidelines along with the data on the percentage of staff trained on mercury.

II. Mercury waste equipment and storage

Take photos of mercury clean-up equipment such as mercury spill clean-up kits, stored mercury waste, and mercury/chemical storage areas if constructed or renovated by the UNDP GEF project. Send "before" and "after" photos if available to the GPT.

III. Replacement with non-mercury alternatives

Send the following information to the GPT based on procurement data or receipts:

- *Types of non-mercury devices provided by the project to the model facilities and/or other facilities (e.g., thermometer, sphygmomanometer)*
- *For each type, provide information on the non-mercury replacement:*
  - *Brand name, model number (if available)*
  - *Brief description (e.g., digital thermometer with flexible probe)*
  - *Number of devices provided*
  - *Per unit cost in US dollars*
- *Average per unit cost in US dollars of mercury devices (mercury thermometers and mercury sphygmomanometers) originally used at the facility.*

For each model facility, use the information from the baseline assessment or from other sources to estimate the number of mercury devices regularly in use before the project and calculate how many of each type of device has been replaced by the end of the project. The Project Document expects that at least 80% of mercury devices will have been replaced in each model facility by the end of the project.

IV. Evaluation of mercury-free devices

For the long term, healthcare facilities should have standard procedures for validation testing, calibration, and maintenance of mercury-free devices. (This also applies to mercury devices although it has been often ignored.) Appendix E provides sample procedures for testing and calibration of non-mercury thermometers and sphygmomanometers. In addition to ensuring that the devices remain accurate during use, the test data can also be used for identifying devices of low quality to guide future procurements. Testing, calibration and maintenance could be done every six months.

For project closure (except for Lebanon), conduct a user survey of the mercury-free devices. The target audience should be selected personnel who use the mercury-free devices. The objectives of the survey are to find out the degree of awareness, user acceptance, and adoption of the technology. Use separate survey forms for thermometers and sphygmomanometers (see Appendix F). Submit a summary of the survey results to the GPT.

4.0 National Training

For project closure, provide the GPT with data on the following for each national training session conducted under the project.

- *Date and location of the training*
- *Type of training (e.g., Training of Trainers, general training, specialized training)*
- *Duration of the training (total hours)*
- *Person(s) and/or training institution who conducted the training*
- *Number of persons trained*
- *Description of people trained (target audience) or list of names and job titles of the people trained*
- *Percentage of women among the trainees (provide an estimate if the actual percentage cannot be calculated)*
- *Topics covered during the training*
- *Summary of results of evaluations*
- *Type of certificate provided to attendees (e.g., attendance certificate, academic education credit, graduate certificate, license, etc.).*

Pages 53 and 61-62 of the Project Document requires that at least six training sessions of about 25 persons each, of which two sessions are at a national level, should be completed by the end of the project. National level sessions could include national or regional dissemination workshops.

If you have not yet sent a copy of your training materials to the GPT training team, send a copy of any curricula, training modules, or slides. If available, also send a few photos to the GPT of the training sessions, including any demonstrations, simulations, or hands-on training. If the national training program has been incorporated into the curricula of medical, nursing or other professional schools or colleges, provide information about this to the GPT.

5.0 National Policies

For project closure, provide the GPT with answers to the following questions.

- *Was a review conducted of national policies/regulations related to healthcare waste management? If yes, provide a description of the results of the review or provide a copy of the report to the GPT.*
- *Was a meeting held by policy working groups or national authorities regarding national policies on healthcare waste management? If yes, provide a description of the meeting or meetings, who attended, and what the results were.*
- *Were there changes to national policies/regulations on healthcare waste management (including mercury in healthcare) that were a direct or indirect result of the project? If yes, provide a description of the changes or improvements in national policies/regulations, or provide copies of the revised policies/regulations.*

6.0 National Dissemination

For project closure, provide the GPT with answers to the following questions.

- *Was a national dissemination conference or workshop planned under the project? If yes, provide the date and location of the conference and target audience.*
- *If the conference or workshop already took place, provide the conference agenda, number of participants, list of resource materials distributed, and a brief description of the extent of outreach to stakeholders.*

- *Provide a few photos of the conference if available.*
- *Provide information on other ways in which information about the project and its results were disseminated locally, nationally or regionally.*
- *Describe the extent of stakeholder participation and involvement in the project as a whole. List examples of stakeholders that were engaged in the project.*

The Project Document requires each country to organize <u>at least one national conference or workshop</u> to disseminate the results of the project.

ESTIMATION OF DIOXIN/FURAN AND MERCURY REDUCTIONS FROM THE PROJECT

1.0 Unintentional POPs *(for project closure)*

The Guidance on Estimating Baseline Dioxin Releases for the UNDP GEF Global Healthcare Waste Project will be used for dioxin/furan estimation instead of the UNEP dioxin toolkit. The GPT can do most of the calculations if you provide the data requested. Since project countries started at different dates, the reference year is flexible. The period of the PDF-A (2003) could be considered the general reference year for dioxin estimation. However, if the model facility did not have an incinerator at that time, use an earlier or later reference year.

I. UPOPs (dioxins and furans) reduction at model facilities *(for project closure)*

Report the reference year corresponding to the data below. Then for <u>each model hospital or health post</u>, provide the following data:

a) Using the baseline data or other available data, estimate and report the total amount of healthcare waste burned or incinerated by the model facility during the reference year in tonnes per year. When using baseline or current data, note that the hospital most likely may not have practiced segregation during the reference year.

b) Ask a hospital engineer or staff who was around during the reference year to identify which of the 22 types of medical waste incinerators described in Annex C of the Baseline Dioxin Guidance most closely describes the incinerator used by the model hospital during the reference year. The list includes open burning. Report the name(s) of your source(s) and the type of incinerator.

c) If the method used was not open burning, provide a description of the type of incinerator used during the reference year (capacity in kg per hour, the number chambers, the average temperatures in °C in each chamber, the residence time in seconds in the secondary chamber if known, and the type

of air pollution control). Report the brand name and model number if known. Provide photos of the incinerator if available.

d) Report the total number of employees (administrative and clerical staff, health professionals, auxiliary staff including waste workers) working at the model facility at the end of the project.

e) Use a map and census data, or interview the city planner or a local demographer to approximate the total population of people living and working within a radius of 1 km in all directions from the location of the incinerator used.[1] This value could be an order of magnitude estimate.

Report the reference year corresponding to the data below. Then, for <u>each model central treatment plant</u> that the project worked with, provide the following data:

a) Using the baseline data or other available data, estimate and report the total amount of healthcare waste burned or incinerated by the central treatment plant during the reference year in tonnes per year.

b) Provide a description of the type of incinerator or incinerators used during the reference year (capacity in kg per hour, the number chambers, the average temperatures in ^{o}C in each chamber, the residence time in seconds in the secondary chamber if known, and the type of air pollution control). Report the brand name(s) and model number(s) if known. Provide photos of the incinerator(s) and air pollution control, if available.

c) Ask a hospital engineer or staff who was around to identify which of the 22 types of medical waste incinerators described in Annex C of the Baseline Dioxin Guidance most closely describes the incinerator used by the central plant during the reference year. Report the name(s) of your source(s) and the type of incinerator(s).

d) If the central treatment plant still uses incinerator(s), estimate the change in the amount of healthcare waste incinerated by the central treatment plant at the end of the project compared to the reference year. Report the change as a percent (that is, a percent of the amount reported in (a) above). Provide the amount incinerated at the end of the project and your calculations.

e) If the central treatment plant still uses incinerator(s) and the incinerator(s) have been upgraded since the reference year, provide an estimate of the reduction in dioxin/furan concentrations (ng I-TEQ per Nm^3) due to the upgrade. Provide the basis for your dioxin/furan reduction values (e.g., dioxin/furan stack sampling or emission factor estimation). Describe the upgrade that was done, including improvements in design (number chambers, average temperatures in ^{o}C in each chamber, residence time in seconds in the secondary chamber, feed system, controls, auxiliary burners, ash handling, etc.) and details of the type of air pollution control.

f) Report the total number of employees (administrative and clerical staff, engineers and operators, auxiliary staff including waste workers) working at the central treatment plant at the end of the project.

g) Use a map and census data, or interview the city planner or a local demographer to approximate the total population of people living and working

[1] This information will be used to estimate the number of people that may have been exposed to a high risk of POPs exposure. A WHO health risk assessment by S. Batterman in 2004 estimated that the maximum airborne concentrations of dioxins/furans occurred within 800 m of small medical waste incinerators, with the distance increasing under stable atmospheric conditions.

within a radius of 10 km in all directions from the location of the incinerator(s) used.[2] This value could be an order of magnitude estimate.

II. UPOPs (dioxins and furans) reduction through replication *(for project closure)*

*Two scenarios (5 years from now or **2017**, and 10 years from now or **2022**) will be used to estimate the potential UPOPs reductions that might be possible due to future replication of the UNDP GEF Project. If relevant information is not found in national plans, interview Ministry officials and other stakeholders to come up with some reasonable projections.*

First, obtain an estimate of the total number of hospitals and health facilities in the country and their corresponding total number of beds; this information is generally available in the Ministry of Health and WHO websites. Obtain an estimate of the number of incinerators operating on site a health facilities; this information may be available at the Ministry of Health or Environment and in the country's Dioxin Inventory and/or National Implementation Plan under the Stockholm Convention. Based on these data, report the number of health facilities currently treating their healthcare waste on site through incineration or burning. Also report the number of beds corresponding to those health facilities.

For the hospitals, health posts and other health facilities that treat their waste on site, provide the following additional data:

a) *2017 scenario: What percentage of those health facilities that currently incinerate or burn their waste could shift to non-incineration treatment technologies by 2017? What corresponding percentage of current beds could shift to non-incineration in 2017 (that is, percent of current number of beds)?*
b) *2022 scenario: What percentage of those health facilities that currently incinerate or burn their waste could shift to non-incineration treatment technologies by 2022? What corresponding percentage of current beds could shift to non-incineration in 2022 (that is, percent of current number of beds)?*

Similarly, obtain a list or an estimate of the total number of central treatment facilities in the country and their estimated processing rate (tonnes of waste treated per year); this information may be available in the Ministry of Health or Ministry of Environment. Obtain an estimate of the number of central treatment facilities that use incineration; this information may be available at the Ministry of Health or Environment and in the country's Dioxin Inventory and/or National Implementation Plan under the Stockholm Convention. Based on these data, report the number of central treatment facilities currently treating their healthcare waste through incineration or burning and the total tonnes of waste treated at those incineration facilities.

[2] The 10 km radius is based on studies by P. Michelozzi *et al*. (*Occup. Environ. Med.* 55, 616-615, 1998), P. Elliott *et al*. (*Br. J. Cancer*, 73, 702-710, 1996) and T. Tango *et al*. (*J. Epidemiol.*, 14:83-93, 2004). The Michelozzi study found a significant risk in laryngeal cancer among men living within 10 km of an incinerator and other sources. The Elliott study observed statistically significant risks for all cancers, but especifically stomach, colorectal, liver and lung cancers, within 7.2 km of incinerators. The Tango study indicated an association with infant deaths and infant deaths with congenital anomalies up to 10 km, with a peak at around 1-2 km.

For the central treatment facilities, provide the following additional data:

a) 2017 scenario: What percentage of central treatment facilities that currently incinerate or burn their waste could shift to non-incineration treatment technologies by 2017? What percentage of waste currently incinerated at those facilities could be shifted to non-incineration treatment in 2017?
b) 2022 scenario: What percentage of central treatment facilities that currently incinerate or burn their waste could shift to non-incineration treatment technologies by 2022? What percentage of waste currently incinerated at those facilities could be shifted to non-incineration treatment in 2022?

2.0 Mercury *(for project closure)*

I. Mercury reduction at the model facilities *(for project closure)*

For mercury thermometers and sphygmomanometers: Use data from the baseline assessment on annual breakage if available and data on percent replacement from Section 3.0(iii) above to estimate and report the amount of mercury (in kg of mercury per year) eliminated by the project at the model facility as of the end of the project. You can multiple the annual breakage figures times the average mercury content of 1 g of mercury per thermometer, and 200 g of mercury per sphygmomanometer. If annual breakage figures were not obtained during the baseline assessment, use 0.002 kg of mercury released per bed per year for thermometers and sphygmomanomters combined times the number of beds to obtain annual mercury reduction in kg per year. If mercury devices were removed from use at the model facilities and placed in storage, also estimate and report the amount of mercury sequestered (i.e., taken out of use and stored safety) in grams or kilograms using the average mercury content mentioned and the known number of thermometers and sphygmomanometers removed from use.

For other mercury-containing materials: If the project supported or provided technical assistance in replacing other mercury-containing materials (such as fluorescent lamps, esophageal dilators, histology fixatives, etc.), estimate and report the amount of mercury reduced on an annual basis (grams or kilograms of mercury reduced per year).

For dental facilities: If the project supported or provided technical assistance to dental facilities to reduce their mercury releases, provide an estimate of the amount reduced in grams or kilograms of mercury per year.

II. Mercury reduction through replication *(for project closure)*

*Two scenarios (5 years from now or **2017**, and 10 years from now or **2022**) will be used to estimate the potential mercury reductions that might be possible due to future replication of the UNDP GEF Project. Interview Ministry officials and other stakeholders to come up with reasonable projections.*

Assuming 0.002 kg of mercury per bed per year from thermometers and sphygmomanometers, estimate how many hospitals and their corresponding beds will shift to non-mercury devices in 2017 and 2022, and compute the amount of mercury reduced per year.

a) 2017 scenario: How many kg of mercury per year could be eliminated by 2017 as hospitals shift to non-mercury devices?

b) 2022 scenario: How many kg of mercury per year could be eliminated by 2022 as hospitals shift to non-mercury devices?

3.0 CO_2 and other GHGs *(for project closure)*

Both UNDP and GEF are interested in reductions in carbon dioxide and other greenhouse gases (GHGs), if any, resulting from UNDP GEF projects. This section gathers data that will be used to compare roughly estimated emissions of CO_2 and other GHGs before the project with those resulting from best environmental practices and technologies implemented by the project. The proposed comparison adopts the IPCC methodology and the assumptions are listed in Appendix G.

I. CO_2 emissions at the model facilities before the project *(for project closure)*

For each model facility (hospital, health post, or central treatment plant), report estimates for the items below using the baseline data, interviews with knowledgeable facility staff, other sources, and expert judgment. For items listed as "optional," provide information if data are available, otherwise the assumptions listed in Appendix G will be used.

During the reference year or some year before the project started:

a) Estimate the amount of total waste generated or processed by the model facility in tonnes per year.
b) Estimate the fraction of the total amount in (a) that was incinerated.
c) Estimate the fraction of the total amount in (a) that was open-burned.
d) Estimate the fraction of the total amount in (a) that was disposed in a solid waste disposal site (dumpsite or landfill), excluding ash from incineration or open burning.
e) If the fractions in (b)+(c)+(d) do not add up to 1, explain how the rest of the total waste was treated.
f) OPTIONAL: If data are available, estimate the composition of the waste streams in (b), (c) and or (d) in terms of the percentage of the following: food, garden (yard), paper, wood, textiles, diapers (nappies), rubber/leather, plastics, metal, glass/ceramics, others.
g) OPTIONAL: If data are available, estimate the percent moisture content and/or percent degradable organic carbon of each of the waste streams in (b), (c) and or (d).

II. CO_2 emissions at the model facilities at the end of the project *(for project closure)*

For each model facility (hospital, health post, or central treatment plant), report estimates for the items below using the baseline data, interviews with knowledgeable facility staff, other sources, and expert judgment. For items listed as "optional," provide information if data are available, otherwise the assumptions listed in Appendix G will be used.

For 2012, estimate the percent increase in activity of the model facility compared to the reference year or year before the project started as defined in (I) above. This estimate could be based on the increase in bed capacity, occupancy rate, outpatient services, population growth, etc.

a) Estimate the amount of total waste generated or processed by the model facility in tonnes per year.
b) Estimate the fraction of the total amount in (a) that was recycled directly (excluding treated waste that was recycled afterwards).
c) Estimate the fraction of the total amount in (a) that was treated in a non-incineration treatment technology.
d) Estimate the fraction of the amount treated in a non-incineration technology in (c) that was recovered and recycled afterwards.
e) Estimate the fraction of the amount treated in a non-incineration technology in (c) that was disposed in a solid waste disposal site (dumpsite or landfill).
f) If the fractions in (d)+(e) do not add up to 1, explain what was done to the rest of the waste treated in a non-incineration technology.
g) Estimate the fraction of the total amount in (a) that was composted.
h) Estimate the fraction of the total amount in (a) that was disposed directly in a solid waste disposal site (dumpsite or landfill), excluding ash from incineration, excluding compost, and excluding waste treated in a non-incineration technology and later disposed in a landfill.
i) Estimate the fraction of the total amount in (a) that was incinerated.
j) If the fractions in (b)+(c)+(g)+(h)+(i) do not add up to 1, explain how the rest of the total waste was treated.
k) OPTIONAL: Provide data, if available, to replace any default value shown in Appendix G.

III. CO_2 emissions at the model facilities after the project *(for project closure)*

Assume a future scenario (5 or 10 years from now) that maximizes source reduction (e.g. green procurement policies that minimize packaging, good inventory control), recycling (e.g., plastic, paper, cardboard, glass, and metal recycling from regular waste, as well as recovery and re-melting of treated plastic, glass and metal from infectious waste), and composting (e.g., food waste, flowers, yard trimmings, etc.) at the model facility.

For the future scenario, estimate the projected percent increase in activity of the model facility compared to 2012. This estimate could be based on the projected increase in bed capacity, occupancy rate, outpatient services, population growth, etc. For the future year:
a) Estimate the amount of total waste generated or processed by the model facility in tonnes per year assuming good source reduction.
b) Estimate the fraction of the total amount in (a) that could be recycled directly (excluding treated waste recycled afterwards).
c) Estimate the fraction of the total amount in (a) that was treated in a non-incineration treatment technology.
d) Estimate the fraction of the amount treated in a non-incineration technology in (c) that could be recovered and recycled afterwards.
e) Estimate the fraction of the amount treated in a non-incineration technology in (c) that would be disposed in a solid waste disposal site (dumpsite or landfill).
f) If the fractions in (d)+(e) do not add up to 1, explain what happens to the rest of the waste treated in a non-incineration technology.
g) Estimate the fraction of the total amount in (a) that could be composted.
h) Estimate the fraction of the total amount in (a) that would be disposed directly in a solid waste disposal site (dumpsite or landfill), excluding ash from incineration, excluding compost, and excluding waste treated in a non-incineration technology and later disposed in a landfill.

i) Estimate the fraction of the total amount in (a) that would be incinerated.
j) If the fractions in (b)+(c)+(g)+(h)+(i) do not add up to 1, explain what happens to the rest of the waste.

ESTIMATION OF COSTS OF HCWM AND CO-FINANCING

This section deals with the costs of implementing HCWM at the model facility. The objectives are:

- *To determine the true costs of introducing and sustaining HCWM systems at an individual health facility*
- *To provide data for estimating budget allocations and for determining the costs of replicating the project*
- *To evaluate the cost-effectiveness of approaches to achieve specific desired outcomes, such as the reduction of dioxin and mercury releases at an individual health facility.*

The costs should include not just the GEF funding to the facility but also estimates of in-kind contributions or co-financing provided by the facility and other project partners working with the model facility. The cost data should not include costs related to national project management and coordination, national training, national dissemination, national policy, and mercury activities outside the model facility.

Cost figures should be given in US dollars (USD) using an average currency exchange rate for 2012. Submit the data to the UNDP GEF global project team.

1.0 Initial costs of HCWM

The initial costs are the expenses related to the initial activities needed to transform the facility: conducting a baseline assessment including a waste assessment, developing facility policies, creating a healthcare waste organization, participatory planning and development of a healthcare waste management plan. If exact costs are not available, provide the best estimate.

I. Baseline Assessment (for project closure)

Baseline Assessment includes material costs (e.g., weighing scale, PPE) and labor costs (e.g., technical consultant and staff time). For each model facility (hospital, health post, or central treatment plant), report estimates for the following:

a) Approximate duration of the activity (in months)
b) GEF project funding in USD to the model facility
c) Estimated co-financing or in-kind contribution in USD by the facility

II. Developing facility policy, creation of a healthcare waste organization, planning and development of healthcare waste management plans/procedures (for project closure)

These are primarily labor costs. For each model facility (hospital, health post, or central treatment plant), report estimates for the following:

a) Approximate duration of the activities (in months)
b) GEF project funding in USD to the model facility
c) Estimated co-financing or in-kind contribution in USD by the facility

III. Initial training of staff in the facility (for project closure)

Training may include some material costs (e.g., photocopies of handouts, pencils, demonstration equipment, refreshments) and labor (e.g., trainer fees, staff time). For each model facility (hospital, health post, or central treatment plant), report estimates for the following:

a) Approximate duration of the activities (in months)
b) GEF project funding in USD to the model facility
c) Estimated co-financing or in-kind contribution in USD by the facility

IV. Capital costs for small equipment for healthcare waste management (for project closure)

These are one-time materials costs for bins, needle cutters, posters, waste carts, and other durable items. For each model facility (hospital, health post, or central treatment plant), report estimates for the following:

a) GEF project funding in USD to the model facility
b) Estimated co-financing or in-kind contribution in USD by the facility

V. Capital costs for storage of healthcare waste (for project closure)

These are one-time materials and labor costs for building or renovating the storage site. For each model facility (hospital, health post, or central treatment plant), report estimates for the following:

a) GEF project funding in USD to the model facility
b) Estimated co-financing or in-kind contribution in USD by the facility

VI. Capital costs for the treatment technology (for project closure)

These are total costs for the treatment technology including cost of equipment and accessories, shipping costs, customs and other fees, construction and renovation of the treatment side, installation costs, costs of testing (e.g., incubator) and commissioning, and operator training. For each treatment technology, report estimates for the following:

a) GEF project funding in USD for procurement
b) Estimated co-financing or in-kind contribution in USD by the facility

VII. Costs of mercury replacement (for project closure)

These include material and labor costs related to mercury spill kits, awareness raising and training, construction of mercury storage site, non-mercury thermometers, non-mercury sphygmomanometers, other non-mercury devices, etc. For each model facility (hospital, health post, or central treatment plant), report estimates for the following:

a) Approximate duration of the activity (in months)
b) GEF project funding in USD related to mercury
c) Estimated co-financing or in-kind contribution in USD by the facility

2.0 Recurrent costs of HCWM

The recurrent costs are expenses that are incurred annually. Recurrent costs are related to daily operation, maintenance, and repair. They typically involve materials, labor, and utilities such as energy and water consumption. Record the monthly costs in US dollars.

I. Recurrent costs for small equipment for healthcare waste management (for project closure)

These are consummable items such as plastic bags, sharps containers, PPE, spill kits, cleaning supplies, disinfectants, etc. The cost could be based on actual data or an estimated percent rate of replacement. For each model facility (hospital, health post, or central treatment plant), report an estimated annual cost in USD.

II. Recurrent costs related to the treatment technology (for project closure)

Estimate the annual costs for operating the treatment technology, including consumable items (e.g., biological indicators, cleaning supplies, PPE, disposable filters), electrical utilities, water, fuel, sewage fees, equipment maintenance, external transport, landfill disposal fees, etc. Report an estimated annual cost in USD.

III. Recurrent costs related to mercury (for project closure)

Estimate the annual costs for replacement and maintenance of non-mercury devices. Report an estimated annual cost in USD.

IV. Recurrent costs related to annual refresher training (for project closure)

Estimate the annual costs for periodic training, including photocopying, trainer fees, refreshments, staff time, etc. Report an estimated annual cost in USD.

V. Recurrent costs related to the HCWM organization, monitoring and evaluation, continuous improvement (for project closure)

These refer mainly to labor costs associated with period meetings, work of the healthcare waste management coordinator, and other staff time. Report an estimated annual cost in USD.

3.0 Revenues from HCWM

If the facility obtains revenues from the sale of recycled materials from regular waste, materials recovered from sterilized waste, or from sale of compost, report an estimated annual revenue in USD.

J. Emmanuel
With input from J. Gusca, M. Rathi and M. Gaba
September 2012

Appendix A

Waste Reduction Study Procedure

Review the results of the baseline assessment and select *one* day of the month or of the week when the waste generation rates (kg/*occupied* bed per day) for total waste and infectious waste were within ± the standard deviation (σ) of the mean (daily average)[3], that is,

$$\left[\frac{kg_{TOT}}{bed \cdot day}\right]_{Day\ Y} = \begin{cases} < \left[\frac{kg_{TOT}}{bed \cdot day}\right]_{AVE} + \sigma \\ > \left[\frac{kg_{TOT}}{bed \cdot day}\right]_{AVE} - \sigma \end{cases}$$

$$\left[\frac{kg_{INF}}{bed \cdot day}\right]_{Day\ Y} = \begin{cases} < \left[\frac{kg_{INF}}{bed \cdot day}\right]_{AVE} + \sigma \\ > \left[\frac{kg_{INF}}{bed \cdot day}\right]_{AVE} - \sigma \end{cases}$$

where kg_{TOT} is the total waste, kg_{INF} is infectious waste, bed refers to *occupied* bed (i.e., total beds in the facility x the occupancy rate for that day), σ is the standard deviation, $[\ ]_{AVE}$ is the average, and $[\ ]_{DAY\ Y}$ is the average of these values on day Y. Select a test day (day Y) that meets the conditions in the equations above or is a close as possible to the specified intervals.

For example, a hospital obtained the data shown below for one week.

Monday	136	
Tuesday	107	
Wednesday	94	
Thursday	112	
Friday	98	
Saturday	36	
Sunday	0	No waste collection

Using an Excel spreadsheet and the Excel functions AVERAGE and STDEV, one finds an average of 83 and a standard deviation of 48. The equation above gives a range of 36 to 131. Hence, Monday, Saturday and Sunday should be avoided and the test day could be Tuesday, Wednesday, Thursday or Friday.

On that *same* test day (day Y) of the month or week (for example, the 15th day of the month or the Wednesday of the week), conduct a waste generation measurement to obtain the following data (see below for a sample documentation form similar to that used for the baseline assessment):

- Occupancy rate for day Y
- Number of outpatients for day Y
- Quantity of total waste generated on day Y (including regular or non-risk, infectious, hazardous chemical, pharmaceutical and radioactive wastes)
- Quantity of infectious waste (including sharps and pathological waste) generated on day Y
- Quantity of chemical, pharmaceutical and radioactive waste generated on day Y
- Quantity of total regular (non-risk or non-infectious, non-hazardous) waste generated on day Y

[3] Calculating the standard deviation is described in any introductory textbook on statistics. It can be calculated using the STDEV function in Excel.

- Quantity of regular (non-risk or non-infectious, non-hazardous) waste separated *for recycling, reuse or composting* on day Y (this should not include regular waste that ends up on a landfill or waste dump)

Calculate the following for day Y:

- Total waste generation rate in kg per *total* bed per day
- Total waste generation rate in kg per *occupied* bed per day
- Total waste generation rate in kg per *total patient* per day (where total patient equals bedded patients plus outpatients)
- Infectious waste generation rate in kg per *total* bed per day
- Infectious waste generation rate in kg per *occupied* bed per day
- Infectious waste generation rate in kg per total patient per day
- Chemical, pharmaceutical and radioactive waste generation rate in kg per *total* bed per day
- Chemical, pharmaceutical and radioactive waste generation rate in kg per *occupied* bed per day
- Chemical, pharmaceutical and radioactive waste generation rate in kg per *total patient* per day
- Total regular waste generation rate in kg per *total* bed per day
- Total regular waste generation rate in kg per *occupied* bed per day
- Total regular waste generation rate in kg per *total patient* per day

Compare the results with the data obtained during the baseline assessment and note areas where there were improvements. If desired, you can conduct a waste reduction study involving more days. Submit results to the GPT.

Sample Documentation Form

General Data:

- Date _____
- Number of Occupied Beds or Outpatients on this day _____
- Person(s) Conducting the Waste Measurement _____

Type of waste*	Department	How full**	Weight (kg)

* Use the national classification standard. If no national standard exists, use the following terms: general (non-risk, non-infection) waste, sharps waste, infectious waste, pathological waste, chemical waste, pharmaceutical waste, or radioactive waste.

** For example: ¼ full, ½ full, ¾ full, overfilled, etc.

Appendix B

Waste Segregation Study

First, review the results of the baseline assessment and select the one test day of the month when the waste generation rates (kg/occupied bed per day) for both total waste and infectious waste were within ± 1.645 x the standard deviation of the mean, as was done in Appendix A. That test day could be the same Day Y identified in Appendix A or another day as long as conditions in the equations are met or are as close as possible to the specified intervals in the equations.

As was done during the baseline assessment, each waste bag, bin, or container, regardless of the level of fill, must be counted as one sample before it gets removed each day or before it is combined with waste from other containers. Hence, the basis of a sample is the waste bag, bin, or container regardless of the amount it contains before it is collected. If the waste from one container is collected three times a day, that container is the source of three samples and the container should then be counted as three separate samples. If the waste is collected three times a week, it counts as 3/7 (or 0.43) of a sample.

Begin with the survey (conducted during the baseline assessment and any updates) of all of the waste containers, their locations, noting what type of waste each container is intended for, and finding out how often the waste is collected. Depending on the frequency of collection, calculate the variables below. [Note: "Samples" here refer to waste in containers, bag holders, plastic bags, or bins before they are removed or combined with other waste.]

(i) For containers, bags, or bins collected only ONCE PER DAY:

GW = Number of general (domestic) waste samples collected once per day
IW = Number of infectious waste samples collected once per day
SW = Number of sharps containers collected once per day

(ii) For containers, bags, or bins collected SEVERAL TIMES A DAY:

GWX = Sum of (each general waste sample multiplied by the number of times on average that it is collected in one day)
IWX = Sum of (each infectious waste sample multiplied by the number of times that it is collected in one day)
SWX = Sum of (each sharps container multiplied by the number of times that it is collected in one day)

(iii) For containers, bags, or bins collected LESS OFTEN THAN DAILY:

GWY = Sum of (each general waste sample divided by the number of days on average between collections)
IWY = Sum of (each infectious waste sample divided by the number of days on average between collections)
SWY = Sum of (each sharps container divided by the number of days on average between collections)

Use equation (1) below to calculate *N*, the approximate total number of samples in plastic bags, containers, bins, and sharps containers used for regular and infectious waste (including sharps waste) per day. If *N* is not a whole number, round *N* off to the nearest whole number.

Equation 1: $$N = GW + GWX + GWY + IW + IWX + IWY + SW + SWX + SWY$$

Method 1: Designate a number, from 1 to *N*, for each waste container, bin, or bag holder. For containers, bins, or bag holders that have two, three, or more samples per day, designate two, three, or more numbers corresponding to the number of samples. For containers, bins, or bags that are collected less frequently than once per day, add all their fractions and round the sum off to the nearest whole number. Consider all those bins as constituting that whole number of samples.

During the designated test day, conduct a visual inspection of each waste sample in the facility. Containers that are the source of three samples should be checked three times per day, once for each sample. If all of the containers that are collected infrequently (e.g., every week or every few days) add up to the equivalent of four samples, select four of those containers randomly and check only those four. Make note if you find any waste that should not be inside the bag or container. (NOTE: Staff or

consultants that are trained in infection control, occupational safety, and/or the use of personal protective equipment (PPE) may examine open containers using long tongs or poles to move waste around and see further down into the containers, taking special care not to puncture the bag, break waste material, splatter blood, or release aerosols. The consultant should use gloves, an apron cover to protect clothing, and a face mask. The tongs or poles should be disinfected before handling general waste to avoid cross-contamination.)

Keep a record of your findings as shown in the example below.

Date of Test:							
Waste sample #	Type of container	Good segregation	Sharps waste found in IW or GW	Infectious waste found in GW or SW	General waste found in IW or SW	Chemical waste found in IW, GW or SW	Notes
1	IW	√					
2	IW				√		empty saline bottle
3	GW	√					
4	SW				√		plastic wrap
5	GW					√	thermometer*
Etc.							

* see photograph 7.

EXAMPLE

A small health facility has 23 containers (10 for general waste, 8 for infectious waste, and 5 sharps containers. The consultant records their locations and, based on how frequently they are collected, sets up the following letter designations:

> 10 general waste containers:
- A to F for each of the six containers removed once per day
- G1 and G2 for the one container that is emptied two times per day
- H1, H2 and H3 for the one container that is emptied three times per day
- I1, I2, I3 and I4 for the one container that is emptied four times per day
- J for the container that is emptied once per week

> 8 infectious waste containers:
- K to M for each of the three containers collected once per day
- N1, N2, O1, O2, P1 and P2 for the three containers (N, O, P) that are collected two times per day
- Q1, Q2 and Q3 for the one container that is collected three times per day
- R for the one container that is collected three times per week

5 sharps containers:
- S1 and S2 for the two sharps containers from one department that is filled up every day
- T to V for the three sharps containers collected three times per week
- W for the one sharps container that is collected once every two weeks

Therefore:
GW = 6, GWX = (1 x 2) + (1 x 3) + (1 x 4) = 9, GWY = 1/7 = 0.14
Total "samples" of general waste = 15.14
IW = 3, IWX = (3 x 2) + (1 x 3) = 9, IWY = 3/7 = 0.43
Total "samples" of infectious waste = 12.43
SC = 0, SCX = (1 x 2) = 2, SCY = (1/7 + 1/7 + 1/7 + 1/14) = 0.5
Total "samples" of infectious waste = 2.5

From equation (1), N = 30.1 (round off to 30)

The containers (J, R, T, U, V and W) that are infrequently collected add up to 1.1 samples (round off to 1). During the day of testing, the consultant must check 30 "samples" of waste even though there are only 23 containers in the whole facility. Those containers that are emptied more than once per day should be checked as many times in one day corresponding to the number of times they are collected in order to be able to view each waste sample. The six containers that are collected less often than once per day should be considered one sample since they add up to 1.1. The consultant should randomly select one of the six containers to check.

Below is the sampling plan:
Check the following ONCE during the day before the waste is removed: A B C D E F K L M
Check the following TWICE during the day, timing the visits to try to check each waste sample before collection: G N O P S
Check the following THREE TIMES during the day to check each sample before collection: H Q
Check the following FOUR TIMES during the day to check each sample before collection: I
A random selection of the six containers (J R T U V W) gave the following random choice: U
Therefore, during the day of the test, the consultant checks U once.

Method 2: Alternative Procedure for Large Facilities:

If the facility is large and there are too many bags, bins, and containers to inspect in one day (e.g. *N* is greater than 100), do the inspection on a smaller sample size. To calculate a statistically significant sample size *n*, use equation (2) below[4]:

Equation 2:

$$n = \frac{N}{1 + 0.01 \cdot N}$$

During the day of the test, randomly select *n* samples from the list of *N* containers, bins, and bags used per day. Random selection can be done by cutting *N* pieces of paper and marking them with the waste designations, placing the papers in a box, and randomly pulling *n* pieces of paper from the box to get a random selection each day. You can also use the RAND and RANK functions in Excel to come up with a random selection. See for example: http://www.mrexcel.com/td0034.html

Remember that containers that are collected several times per day are considered more than one sample. So in the above example (see box), the pieces of paper should include H1, H2, H3, N1, N2, O1, etc. as separate samples. If I2 and I4 are selected, that means that container I must be checked two times that day, during the second and fourth waste samples. For those that are collected less frequently than once per day, add all of their fractions and round the sum off to the nearest whole number. Consider all of those bins as constituting that whole number of samples. Give them new designations and include them in the pieces of paper as a group. In the above example (see box), containers J, R, T, U, V and W should be considered one sample and can be given the letter designation of Z. If Z is selected, then choose one of the six containers randomly for checking. Make sure that the selected container is checked only once.

Visually inspect the contents of the *n* randomly selected bags and containers before they are sealed. Check to see how well the waste is segregated. Note down your results in a form similar to that shown below:

Date of the test:							
Waste sample #	Type of container	Good segregation	Sharps waste found in IW or GW	Infectious waste found in GW or SW	General waste found in IW or SW	Chemical waste found in IW, GW or SW	Notes
68	GW			√			syringe*
12	IW				√		food, paper
6	GW	√					
34	SW	√					
75	IW				√		empty box
Etc.							

* see photograph 3.

Regardless of whether Method 1 or 2 was used, at the end of the test, add the number of general waste and infectious waste samples containing sharps (syringes, lancets, etc.) and divide by *N* or *n* (depending on whether you used Method 1 or 2, respectively) to compute the ratio S-GI. Then add the number of general waste samples or sharps waste samples that contained non-sharps infectious waste (such as blood soaked bandages or contaminated gloves) in them and divide by *N* or *n* to get the ratio I-GS. Add the number of infectious waste samples or sharps waste samples that contained general waste (such as packaging, paper, food, empty bottles or tubes, etc.) and divide the number by *N* or *n* to compute G-IS. Add the number of waste samples that contained hazardous chemical waste (such as broken mercury thermometers, laboratory chemicals, expired medicines, etc.) and divide it by *N* or *n* to compute C-GIS. Add S-GI, I-GS, G-IS, and C-GIS to get BS, the total fraction of badly segregated waste samples. Calculate the averages of the three days. Report the results below:

[4] Based on the Cochran formula for estimating sample size of categorical data for a confidence limit of 95%, precision of ±10%, and a maximum variance estimate of 0.25.

Number *N* of bags & containers:						
or Sample size *n* if Method 2 was used:						
Month #	**DATE**	**S-GI**	**I-GS**	**G-IS**	**C-GIS**	**BS**
1						
2						
3						
4						
5						
6						
7						
8						
9						
10						
11						
12						

Appendix C

Template Survey Questionnaire Regarding the Treatment Technology

---

QUESTIONS FOR THE HOSPITAL MANAGEMENT (Head of the hospital, administrator, or director)

Date _____
Name of person conducting the survey _____
Name of person interviewed _____
Position of person interviewed _____

1. *How would you rate the technology with regards to meeting the facility's needs?*

Very dissatisfied — Very satisfied

1	2	3	4	5
☐	☐	☐	☐	☐

2. *Did you have direct contact with the technology vendor's representatives in the last year?*

YES	NO
☐	☐

3. *If YES: how would you rate your overall experience during your last contact with them?*

Very dissatisfied — Very satisfied

1	2	3	4	5
☐	☐	☐	☐	☐

4. *How would you rate the technology's capital cost in comparison to the benefits it provides?*

Very dissatisfied — Very satisfied

1	2	3	4	5
☐	☐	☐	☐	☐

5. *How would you rate the technology's operating cost in comparison to benefits it provides?*

Very dissatisfied — Very satisfied

1	2	3	4	5
☐	☐	☐	☐	☐

6. *How likely are you to recommend this technology to other health facilities?*

Very unlikely — Very likely

1	2	3	4	5
☐	☐	☐	☐	☐

7. *Additional Comments:*

QUESTIONS FOR HEALTH PROFESSIONALS (HCWM coordinator, infection control officer, head of environmental services or environmental health officer, and/or other health professionals)

Date _____
Name of person conducting the survey _____
Name of person interviewed _____
Position of person interviewed _____

1. *Overall, how satisfied are you with the treatment technology?*

Very dissatisfied 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ Very satisfied

2. *How would you rate the technology as to its intended purpose of treating healthcare waste and protecting public health and the environment?*

Very bad 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ Excellent

3. *Does the technology make your work easier, not affect your work, or make your work harder?*

Harder 1 ☐ No effect 2 ☐ Easier 3 ☐

4. *If the technology makes your work harder, please explain:*

5. *Based on past treatment technologies you have used or are aware of, is the new treatment technology better, the same, or worse than others?*

Worse 1 ☐ Same 2 ☐ Better 3 ☐

6. *How likely are you to recommend this technology to other health facilities?*

Very unlikely 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ Very likely

7. *What are some things that can be done to improve the treatment technology?*

8. *Additional Comments:*

QUESTIONS FOR THE ENGINEER AND OPERATOR:

Date _____
Name of person conducting the survey _____
Name of person interviewed _____
Position of person interviewed _____

1. *Overall, how satisfied are you with the treatment technology?*

Very dissatisfied 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ Very satisfied

2. *How would you rate the technology as to its intended purpose of treating healthcare waste?*

Very bad 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ Excellent

3. *Did you have direct contact with the technology representatives in the last year?*

YES ☐ NO ☐

4. *If YES: how would you rate your overall experience during your last contact with them?*

Very dissatisfied 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ Very satisfied

5. *If YES: How would you rate the knowledge of the technology representative?*

Very dissatisfied 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ Very satisfied

6. *If YES: How would you rate the helpfulness of the technology representative in providing assistance?*

Very dissatisfied 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ Very satisfied

7. *Does the technology make your work easier, not affect your work, or make your work harder?*

Harder 1 ☐ No effect 2 ☐ Easier 3 ☐

8. *If the technology makes your work harder, please explain:*

9. *Based on past treatment technologies you have used or are aware of, is the new treatment technology better, the same or worse than others?*

Worse 1 ☐ Same 2 ☐ Better 3 ☐

10. *What features do you like about the new technology?*

11. What features don't you like about the new technology?

12. What are some things that can be done to improve the treatment technology?

13. How likely are you to recommend this technology to other health facilities?

Very unlikely				Very likely
1 ☐	2 ☐	3 ☐	4 ☐	5 ☐

14. *Additional Comments*:

Appendix D

Statistical Methods for Analyzing Equipment Repair Data (Optional)

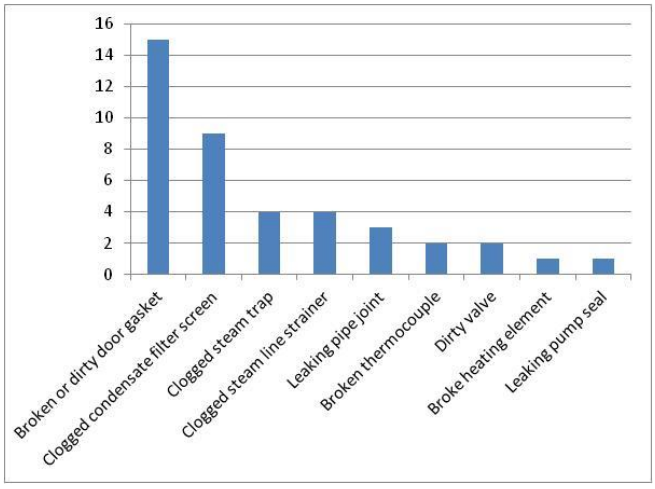
Some common methods for computing reliability statistics[5] are described below. Begin by defining the *starting date of normal operations*. Once a year, review the repair logs, input the data in an Excel sheet, analyze, and calculate, tabulate or plot the following:

Failure mode analysis – lump the same kind of equipment failures and causes together and create a table such as the one shown below.

Date of failure	Failure mode	Cause	Effect	Occurrence	Description of repair	Starting date of repair	Duration of repair	Down-time	Severity rating

Failure mode is a brief description of the equipment problem or the manner in which the treatment system failed (e.g., autoclave did not heat up). *Cause* is the underlying technical cause of the problem which may be a defective part, design, or process (e.g., broken heating element). *Effect* is the immediate consequence of the problem on the operation or function as perceived by the operator (e.g., waste could not be treated). *Occurrence* is the number of times the failure occurred due to the same cause (e.g., two times since the starting date of normal operation). *Description of repair* is a description of the action taken to correct the problem (e.g., replaced the heating element). *Duration of repair* (in hours or days) is the time it took to diagnose and repair the problem. Note that duration of repair is different from downtime. *Downtime* is the total duration of time (in hours or days) that the equipment was not in operation because of the malfunction, but downtime includes administrative delay, the time spent waiting for the arrival of the repair technician or replacement part, etc. *Severity rating* is a judgment by the facility engineer considering the worst potential consequence of a failure relative to the potential degree of worker injury, serious property damage, or serious system damage that could ultimately occur. The severity rating ranges from 1 (no danger, not serious) to 10 (critical). A severity rating of 9 or 10 is generally reserved for problems which would cause injury to a user.

Pareto analysis – plot the number of failures according to failure causes as shown in the example below. It is often found that a large proportion of failures are due to only a small number of causes (the so-called Pareto principle). This analysis allows a facility to solve the majority of problems with the most economical use of resources.



Failure rate (λ) and mean time between failures (MTBF) – Using data on throughput rates, estimate the total operating hours since the starting date of normal operation. Compute the failure rate by dividing

[5] More information can be found in standard textbooks on reliability statistics.

the total number of failures (that resulted in downtime since the starting date of normal operation) by the total operating hours since the starting date of normal operation and multiply by 1000. Compute the mean time between failures as the reciprocal of the failure rate. See equations below. After the second year of operation, add total number of failures and operating time to those of the previous year to compute a cumulative failure rate and MTBF.

$$\lambda\ (in\ failures\ per\ 10^3 operating\ hrs) = \frac{total\ number\ of\ failures}{total\ operating\ hours}\ x\ 1000$$

$$MTBF\ (in\ 10^3 operating\ hrs) = \frac{1}{\lambda}$$

Mean time to repair (MTTR)[6] and availability – Using data from the repair log and the equation below, add up the total number of hours for repair (i.e., the total time to diagnose and repair problems, but *not* including administrative delays, time needed to order and receive parts, shipment delays, time for a repair technician to arrive, etc.) since the starting date of normal operation and divide it by the total number of failures since the starting date of normal operation to get the mean time to repair (MTTR). Calculate availability using MTBF, MTTR, and the equation below.

$$MTTR\ (in\ 10^3 repair\ hrs) = \frac{total\ repair\ hours}{total\ number\ of\ failures}\ x\ 1000$$

$$Availability = \frac{MTBF}{MTBF+MTTR}$$

MTBF and MTTR are statistical measures of reliability that can be provided to the technology vendor. MTBF gives a statistical indication of the failure rate that can be expected during the useful life period. Manufacturers can use MTBF to plan service requirements, repairs and stocking of spare parts.

[6] Note the specific definitions used here. Some reliability statistics references define a mean time to restore or mean time to recovery (using the same abbreviation MTTR) which would be equivalent here to a mean downtime (MDT).

Appendix E

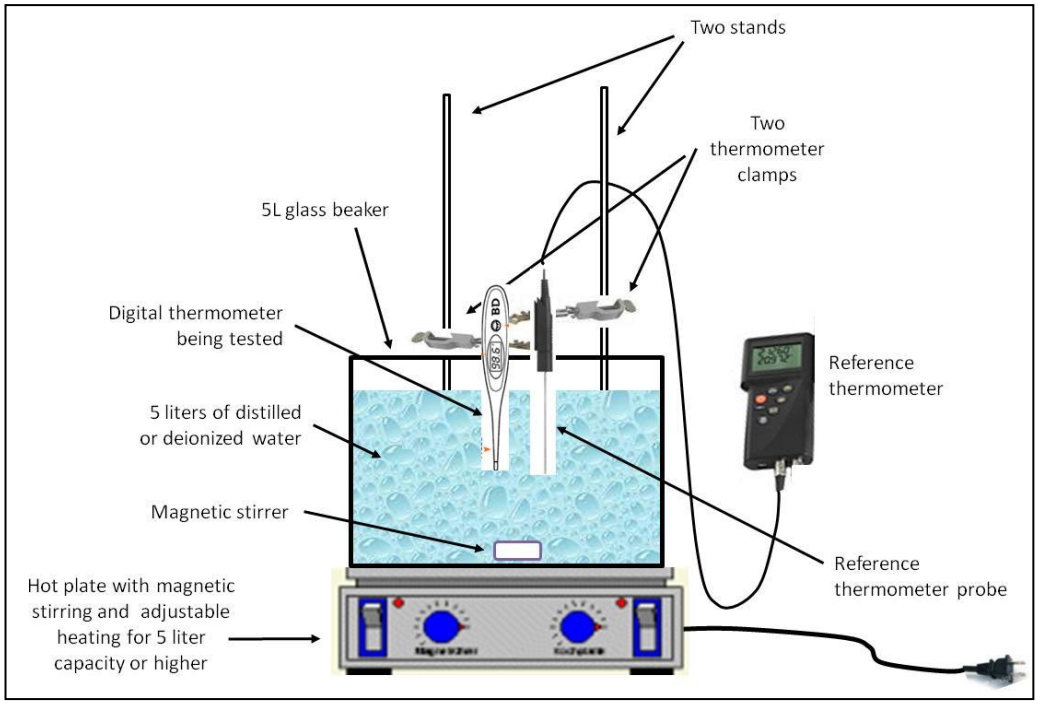
Validation Testing and Calibration of Non-Mercury Devices

These procedures are based on existing protocols. Healthcare facilities are encouraged to refer to the original protocols for more details.

A. Validation and Calibration of Thermometers

The simplest method of validating and calibrating thermometers is with the use of a constant temperature bath and a calibrated reference thermometer. Thermometers that may be tested in this manner include mercury thermometers as well as non-mercury thermometers such as galinstan thermometers, alcohol thermometers, and other liquid-in-glass thermometers, and digital thermometers, electronic fever thermometers and other thermistor-type thermometers.

A large heat-resistant glass flask with a continuous magnetic stirrer can be used. The volume of the bath water should be at least 100 times the volume of whatever devices are put in it in order to avoid non-uniformities in temperature.[7] Distilled water should be used. Heat loss from the bath can be minimized by using 5 to 7 cm of insulation around the bath and top cover.[8] Before any comparison or measurement, the temperature of the bath should be monitored for several minutes to make sure the bath is in thermal equilibrium. The device to be tested should be placed as near as possible to the reference thermometer but adequate space should be maintained between them to make sure there is adequate flow of water between the reference thermometer and the tested device. Make sure that all devices are immersed to the proper levels according to manufacturers' instructions. Tests should be conducted at two or more points within the practical temperature range of the device, such as at 36, 38, 40 and 42 ºC. A sample test set-up is shown below.



More than one mercury-free thermometer can be tested simultaneously. Conduct the tests three times to determine repeatability. This method can also be used to screen out samples of low-quality mercury-free thermometers. It can also be used to reject low-quality mercury thermometers currently

[7] Clinical and Laboratory Standards Institute. Temperature Calibration of Water Baths, Instruments, and Temperature Sensors--Second Edition. Wayne, PA: Clinical and Laboratory Standards Institute; ANSI/NCCLS Document 12-A2, (1992)
[8] National Institute of Standards and Technology. NIST Measurement Services: Liquid-in-Glass Thermometer Calibration Service. Gaithersburg, MD: NIST (1988)

in use. In the 1990s, Leick-Rude and Bloom,[9] during routine accuracy testing in a study, reported that 25% of the glass/mercury thermometers tested differed from the reference thermometer by >0.2 degrees Centigrade. This finding was consistent with the authors' review of prior work. Conducting these validation tests with the hospital staff may allay concerns regarding the comparative accuracy of the mercury versus mercury-free devices.

The table below gives an example of acceptable standards of accuracy. It shows the maximum error allowed for mercury and electronic thermometers for medical use set by the American Society of Testing and Materials[10] for the range of 96.4 - 106 ºF.

		Maximum Error over Temperature Range Shown				
Thermometer Type	**ASTM Procedure**	**<96.4 F**	**96.4 < to 98 F**	**98.0 to 102 F**	**>102 to 106 F**	**>106 F**
Mercury in Glass	E667-86 (reapproved 1991)1	±0.4	±0.3	±0.2	±0.3	±0.4
Electronic Thermometers	E1112-86 (reapproved 1991)1	±0.5	±0.3	±0.2	±0.3	±0.5

With regards to a reference thermometer, a common one is the platinum resistance thermometer which makes use of a metal that changes predictably in electrical resistance with changing temperature to give highly accurate and repeatable temperature measurements. These reference thermometers have accuracies in the order of ±0.1ºC to ±0.05ºC or even ±0.002ºC.

The reference thermometer should be traceable through an unbroken chain of comparisons to national or international standards with stated uncertainties. These reference thermometers are generally calibrated and validated by sources that work with national bodies such as the Instituto Argentino de Normalización y Certificación, Bureau of Indian Standards, Latvian Standard (LVS), Lebanese Standards Institution, Industrial Technology Development Institute (ITDI) of the Philippine Department of Science and Technology (DOST), Association Senegalaise de Normalisation, Tanzania Bureau of Standards, and Vietnam Standards Centre.

The reference thermometer itself should be check periodically for accuracy using distilled/deionized water at its freezing and boiling points. (The latest international standard uses the triple point of water as a reference point but this is not necessary for our purposes.) The boiling point is taken at a rolling boil and must be corrected for the elevation (altitude) above or below sea level and the actual barometric pressure at the time of the test. Similarly, the freezing point must be obtained by adding crushed ice to water to form a uniform ice slush bath.

Document the dates of the tests, name and model of the reference thermometer, names and models of the thermometers tested, results of comparative readings at two or more points repeated at least three times, as well as any manufacturer specified maintenance requirements, costs, and average lifespan of the mercury-free devices.

B. Validation and Calibration of Non-Mercury Sphygmomanometers

The International Protocol for the validation of blood pressure measuring devices in adults[11] can be obtained for free from the website: http://journals.lww.com/bpmonitoring/toc/2002/02000. The description below provides a summary of the procedures.

[9] MK Leick-Rude and Bloom LF, "A comparison of temperature-taking methods in neonates", Neonatal Network; August, 1998, Volume 17 No. 5, pp. 21-37

[10] 1997 Annual Book of ASTM Standards, Roberta A. Storer, Editorial Services Director, American Society of Testing and Materials (ASTM), West Conshohocken, PA

The validation team should consist of three or four persons experienced in blood pressure measurement: two observers and a supervisor (generally nurses), and an 'expert' (a doctor overseeing the entire procedure). If the doctor can be present throughout the entire validation procedure, he/she can take over the role of supervisor thus reducing the validation team to three people. The validation procedure consists of the following steps:

1. Observer training and assessment. Two observers are trained in accurate blood pressure measurement.
2. Familiarization session. The validation team becomes familiar with the workings of the mercury-free devices and any accompanying software.
3. Validation measurements. Observer and device measurements are recorded on subjects in two phases. In the first phase, 15 subjects are recruited; devices passing this primary phase proceed to the secondary phase, for which a further 18 subjects are recruited.
4. Analysis. An analysis of the recorded measurements is carried out after each phase.
5. Reporting. The results are presented in tabular and graphical forms.

In selecting 33 subjects (15 for the phase 1, and a further 18 for phase 2) with a wide range of blood pressure it is probable that there will be a representative range of arm circumference, but subjects should not be selected on the basis of their arm circumference.

Number	Phase 1 - Fifteen subjects Phase 2 - Thirty-three subjects
Sex	Phase 1 - At least five male and five female Phase 2 - At least 10 male and 10 female
Age range	All subjects should be at least 30 years of age
Arm circumference	Distribution by chance
Blood pressure range	See International Protocol

Procedure:

1. The subject is introduced to the observers, and the procedure is explained. Arm circumference, sex, date of birth and current date and time are noted. The subject is then asked to relax for 10–15 minutes (in order to minimize anxiety and any white-coat effect, which will increase variability).
2. Nine sequential same-arm measurements using the test instrument and a standard mercury sphygmomanometer are recorded as follows:

BPA	Entry blood pressure, observers 1 and 2 each with the mercury standard. The mean values are used to categorize the subject into a low, medium or high range separately for systolic BP and diastolic BP (see International Protocol).
BPB	Device detection blood pressure, observer 3. This blood pressure is measured to allow the test instrument to determine the blood pressure characteristics of the subject; more than one attempt may be needed with some devices; this measurement is not included in the analysis. If the device fails to record a measurement after three attempts, the subject is excused.
BP1	Observers 1 and 2 with the mercury standard.
BP2	Supervisor with the test instrument.
BP3	Observers 1 and 2 with the mercury standard.
BP4	Supervisor with the test instrument.
BP5	Observers 1 and 2 with the mercury standard.
BP6	Supervisor with the test instrument.
BP7	Observers 1 and 2 with the mercury standard.

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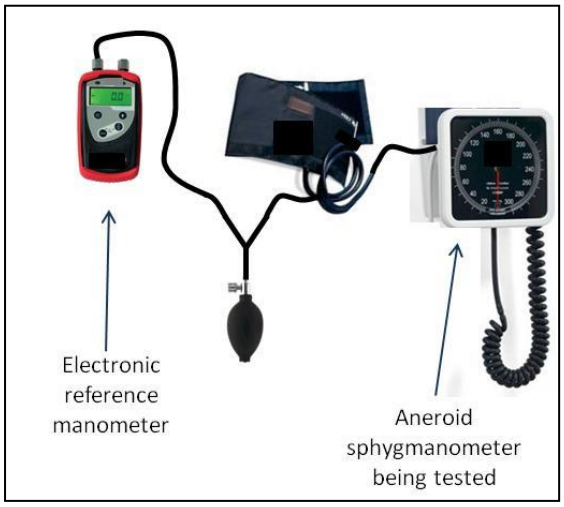
[11] E. O'Brien *et al*., Working Group on Blood Pressure Monitoring of the European Society of Hypertension International Protocol for validation of blood pressure measuring devices in adults," *Blood Pressure Monitoring* 2002, 7:3-17.

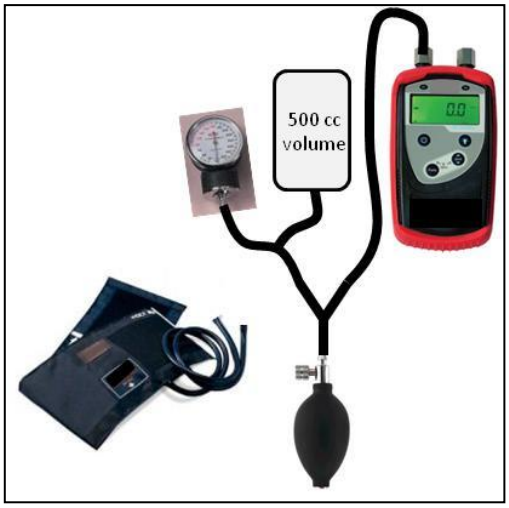
3. Documentation must be provided for data omitted for legitimate technical reasons. Once a subject has been included, the data for that subject should not be excluded from the study if blood pressure values are obtainable; if blood pressure measurements using either the reference method or the test instrument are unavailable, data entry for that individual may be excluded, with an accompanying explanation. Additional individuals must then enter into the study to ensure a sample size of 33.

The International Protocol includes discussions of statistical considerations.

CALIBRATION

The testing and calibration of non-mercury (as well as mercury) sphygmomanometers is fairly simple. Sample set-ups are shown below. Although mercury sphygmomanometers are often viewed as the "gold standard," the accuracy of a mercury sphygmomanometer is ±3 mm Hg. On the other hand, electronic reference manometers have accuracies ranging from ±1 mm Hg to ±0.7 mm Hg or even ±0.1 mm Hg.





Below are typical procedures for calibration. However, in all cases, follow the manufacturer's instructions for calibration.

1. Check to make sure the pointer of the aneroid dial is pointed to zero or that the digital display shows zero when no pressure is applied. If the pointer or display is not at zero, follow the manufacturer's instructions to set the zero point. (Some aneroid units have an adjustment screw to set zero. For other aneroid dials, adjustment may entail removing the glass from the front of the gauge and carefully taking off the pointer and replacing it in the correct position. Digital units may have a button to set zero.)
2. Connect a bulb to the bottom of a Y tubing.
3. Connect one side arm of the Y tubing to the aneroid dial or to the digital meter of the sphygmomanometer being calibrated.
4. Connect the other side arm of the Y tubing to a reference manometer. (Note: For some aneroid units, it may be necessary to also attach a 500 cc volume.)
5. Squeeze the bulb to pressurize the gauge or digital meter to about 280 mmHg and close the valve. Observe is the pressure is stable (± 2 mmHg). If not, check the calibration set-up for air leaks.
6. If the pressure is stable, increase the pressure to slightly above 300 mmHg and bleed down the pressure no faster than 10 mmHg per second.
7. Stop at 300, 250, 200, 150, 100, 60, and 0 mmHg based on readings of the reference manometer. Record the readings of the sphygmomanometer being tested and the reference manometer at each pressure.

8. Calculate the difference between the two readings. Add the error of the reference manometer to the error of the sphygmomanometer being tested to determine the accuracy of the sphygmomanometer.
9. If the errors are ≤ ± 3 mmHg, the sphygmomanometer is within the required accuracy.
10. If the errors are > ± 3 mmHg, determine if the errors are linear (readings deviate by about the same amount) or non-linear (readings deviate by different amounts).

Idealized example of linear error

Sphygmomano-meter reading	Reference pressure	Difference
295	300	-5
245	250	-5
195	200	-5
145	150	-5
95	100	-5
55	60	-5

Idealized example of non-linear error

Sphygmomano-meter reading	Reference pressure	Difference
290	300	-10
245	250	-5
200	200	0
155	150	+5
110	100	+10
80	60	+20

11. Follow the manufacturer's instructions to re-calibrate the instrument.
    a. For aneroid dials, this may entail the following: removing the retaining ring and glass from the gauge; carefully removing the needle and dial face to reveal the bellows; locating the concave triangle with a pin at its center; and moving the pin toward the sides of the triangle, right or left, to fix a linear error; or moving the pin linearly within the triangle, up or down, to fix a non-linear error (very small adjustments have to be made); and replacing the dial face, needle, glass and retaining ring,
    b. For digital units, re-calibration may entail adjusting pressure readings moving plungers or rotating screws according to manufacturer's instructions.
12. Repeat the test above to ensure that the accuracy is at or within ± 3 mmHg. If not, repeat the re-calibration adjustments until the required accuracy is achieved.

ANNEX F

Template Survey Questionnaire Regarding User Knowledge and Acceptance of Mercury-Free Devices

---

Date of survey _____

Name of person conducting the survey _____

Name of person interviewed _____

Title/Position of person interviewed _____

Fill up a separate survey form for each mercury-free device.

1. Check which mercury-free device this survey form refers to:

Mercury-free Thermometer	Mercury-free Sphygmomanometer	Name & model number
☐	☐	_____

2. Frequency of use of the mercury-free device marked in #1 above—select one:

   ☐ If you use it at least every day, on average how many times in one day: _____

   ☐ If you use it less often than everyday but at least once a week, on average how many times in one week: _____

   ☐ If you use it less often than once a week but at least once a month, on average how many times in one month: _____

   ☐ If you use it less often than once a month, on average how many times in one year: _____

3. Overall, how satisfied are you with the mercury-free device?

Very dissatisfied				Very satisfied
1	2	3	4	5
☐	☐	☐	☐	☐

4. How would you rate the accuracy of the mercury-free device in measuring either temperature or blood pressure?

Very inaccurate				Very accurate
1	2	3	4	5
☐	☐	☐	☐	☐

5. How would you rate the ease of use of the mercury-free device?

Very easy 1 ☐ 2 ☐ 3 ☐ 4 ☐ Very difficult 5 ☐

6. Does the mercury-free device make your work easier, not affect your work, or make your work harder?

Harder 1 ☐ No effect 2 ☐ Easier 3 ☐

7. If the mercury-free device makes your work harder, please explain:

8. How familiar are you with the procedure for using the mercury-free device?

Not at all familiar 1 ☐ 2 ☐ 3 ☐ 4 ☐ Very familiar 5 ☐

9. If your answer in #8 above was not '1', describe how you use the mercury-free device:

10. How familiar are you with the maintenance requirements of the mercury-free device?

Not at all familiar 1 ☐ 2 ☐ 3 ☐ 4 ☐ Very familiar 5 ☐

11. If your answer in #10 above was not '1', describe the maintenance requirements of the mercury-free device:

12. What features do you like about the mercury-free device?

13. What features do you dislike about the mercury-free device?

14. What are some things that can be done to improve the mercury-free device?

15. How likely are you to continue using this mercury-free device?

Very unlikely				Very likely
1	2	3	4	5
☐	☐	☐	☐	☐

16. Are you aware of why the hospital is phasing out or has stopped using mercury-based devices?

YES	NO
☐	☐

17. If YES: Please state the reasons why:

ANNEX G

Assumptions for CO_2 Emission Calculations

1. Composition of waste streams[12]

Materials	Percent in overall healthcare waste	Percent in infectious healthcare waste	Percent in recyclable healthcare waste
Food	12	0	0
Garden/yard	1	0	0
Paper	23	20	34
Wood	2	0	0
Textiles/cloth	13	20	0
Diapers (nappies)	5	0	0
Rubber/leather	1	5	0
Plastics	35	45	49
Metal	3	5	4
Glass/ceramics	5	5	13

2. Moisture content[13]

Materials	Percent moisture content	Dry matter fraction
Food	45	55
Garden/yard	40	60
Paper	16	84
Wood	37*	63
Textiles/cloth	30	70
Diapers (nappies)	60**	40
Rubber/leather	15	85
Plastics	15	85
Metal	2	98
Glass/ceramics	2	98

* average of IPCC default values for end of life and harvest; ** based on IPCC default value

3. Degradable organic carbon, total carbon and fossil carbon fraction

Materials	Percent degradable organic carbon		Percent total carbon of dry waste	Fossil carbon fraction as % of total carbon
	of dry waste	of wet waste		
Food	38	15	38	-
Garden/yard	49	20	49	0
Paper	44	40	46	1
Wood	50	43	50	-
Textiles/cloth	30	24	50	20
Diapers (nappies)	60	24	70	10
Rubber/leather	47	39	67	20
Plastics	-	-	75	100
Metal	-	-	-	-
Glass/ceramics	-	-	-	-

[12] Values estimated based on data published in J. Emmanuel, *Compendium of Technologies for Treatment/Destruction of Healthcare Waste*, International Environmental Technology Centre, Division of Technology, Industry & Economics, United Nations Environment Programme, Osaka, Japan, 2012.
[13] ibid.

4. Incineration Calculations

Assume no heat recovery. Assume a typical batch, dual chamber medical waste incinerator.

$$CO_2\ Emissions = MSW \bullet \sum_j \left(WF_j \bullet dm_j \bullet CF_j \bullet FCF_j \bullet OF_j\right) \bullet 44/12$$

Where

MSW = total amount incinerated or open-burned per year
WF_j = fraction of material component j (see #1 above)
Dm_j = dry matter fraction of material j (see #2 above)
CF_j = fraction of carbon in the dry matter of material j (see #3 above)
FCF_j = fraction of fossil carbon in the total carbon of material j (see #3 above)
OF_j = oxidation factor (100% for incineration, 58% for open burning)

CO2 emissions from fuel used by the incinerator:

$$CO_2\ Emissions = Fuel\ Consumption_{fuel} \cdot Emission\ Factor_{fuel}$$

Where

Fuel Consumption and Emission Factor depend on the fuel used.
For example, the Fuel Consumption for diesel is given by MSW x 0.35 kg diesel/kg MSW incinerated; and the Emission Factor is 3.15.

CH_4 emissions

Incineration: use 60 kg CH_4/Gg of waste incinerated (wet basis)
Fuel used for incineration: These will be based on Fuel Consumption and Emission Factor depending on the fuel used.
Open burning: use 6500 g CH_4/tonne waste open burned (wet basis)

N_2O emissions

Incineration: use 60 g N_2O/tonne waste incinerated
Fuel used for incineration: These will be based on Fuel Consumption and Emission Factor depending on the fuel used.
Open burning: use 150 N_2O/tonne waste open burned

5. Land disposal

Assume no methane capture and zero oxidative factor; assume unmanaged shallow site, and first order decay model. For the purpose of this comparison, assume that the amount of waste deposited in the landfill or dumpsite is deposited at the end of year T-1, ignoring any previous depositions. The C to CH_4 conversion factor of 1.33 is used. The amount of CH_4 generated at the end of year T is given by the equation:

$$CH_4\ generated_T = DDOCm\ decomp_T \bullet F \bullet 16/12$$

Where

F = fraction of methane in generated landfill gas (use 0.5)
and DDOCm $decomp_T$ is given by the first order equation:

$$DDOCm\ decomp_T = DDOCma_{T-1} \bullet \left(1 - e^{-k}\right)$$

Where

k = reaction rate constant in y^{-1} using the following values:

Type of waste	Boreal & temperate climate		Tropical climate	
	Dry	Wet	Dry	Wet
Food	0.06	0.185	0.085	0.4
Garden/yard	0.05	0.1	.065	0.17
Paper, textiles, diapers	0.04	0.06	0.045	0.07
Wood	0.02	0.03	0.025	0.035

and $DDOCma_{T-1}$ is the amount of DDOCm deposited at the end of year T-1, ignoring accumulated depositions of previous years.

In general, the DDOCm is given by:

$$DDOCm = W \bullet DOC \bullet DOC_f \bullet MCF$$

Where

DDOCm = quantity of organic carbon that degrades under anaerobic conditions or the mass of decomposable DOC deposited

W = mass of waste deposited in landfill or dumpsite

MCF = methane correction factor for aerobic decomposition (use 0.4)

DOC = degradable organic carbon fraction in the year of deposition as calculated using the equation below for each material i (see #3 above)

$$DOC = \sum_i \left(DOC_i \bullet W_i \right)$$

DOC_f = degradable organic carbon fraction that decomposes (use 0.5)

W_i = mass of waste component i deposited in landfill or dumpsite

The IPCC Waste Model in Excel will be used to evaluate GHG emissions from one year of deposition.

6. Composting

Assume no methane recovery.

CH_4 Emissions = M x $EF_{methane}$

N_2O Emissions = M x EF_{N2O}

Where

M = mass of organic waste composted

$EF_{methane}$ = CH_4 emission factor for composting: 10 g methane/kg dry waste composted; 4 g methane/kg wet waste composted

EF_{N2O} = N_2O emission factor for composting: 0.6 g N_2O/kg dry waste composted; 0.3 g N_2O/kg of wet waste composted