ENVIRONMENTAL IMPACT ASSESSMENT

for

THE INSTALLATION OF A NEW INCINERATOR

at the

UNIVERSITY HOSPITAL OF THE WEST INDIES

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EXECUTIVE SUMMARY

Introduction

The University Hospital of the West Indies (UHWI) has been experiencing operational problems with the existing incinerator used for the management of infectious waste. The incinerator is very old, believed to have been at the hospital since the mid 1950's.

In order to address this situation, the UHWI proposes to replace the existing incinerator with a new, modern facility with appropriate emission controls enabling compliance with the regulatory requirements of the National Environment and Planning Agency (NEPA), the Ministry of Health and the National Solid Waste Management Authority (NSWMA).

As a requirement of the NRCA regulations, a permit application and Project Information Form were submitted to the NEPA. Based on the assessment of the submission by the NEPA, the UHWI was advised that an Environmental Impact Assessment (EIA) will be required for an undertaking of this nature.

The Proposed Project

The process of incineration provides the advantage of volume reduction as well as the ability to dispose of recognisable waste and sharps. On site incinerators provide a quick and easy way of disposing medical waste. This is the most widely accepted and feasible method of managing highly infectious waste. It is the method approved by the Ministry of Health in Jamaica.

The incinerator will be of the controlled air type, designed for 8-hour-day operations and rated at 200kg per hour. The incinerator plant will include the following:

- Continuous loading using hydraulic ram feeder
    - Burners and fuel system
    - Fans
    - Pumps
    - Controls and Instrumentation
    - Chimney and flue connections
    - Incinerator loader for loading hoppers or carts
    - Ash handling equipment
- 1 year spare parts
- Waste weighing equipment
- Fuel Tank
- Wheeled 2.0m^3 waste storage hoppers (number to be decided by hospital managers)
- Incinerator loader
- Incinerator building, including fire safety equipment
- Platform and portholes designed to USEPA standards to facilitate stack testing.

If the incinerator has a throughput of 200kg/hour, it will only operate for 4 hours each day. There are two options that can be considered.

- A smaller incinerator could be considered with a throughput of near to 100 kg/hour so that it operates for an eight hour period or
- The hospital can accommodate waste from external sources so that its additional capacity is utilised.

If incineration is to be pursued, it is strongly recommended that the latter option be pursued as fees could be charged that would help to offset the operating cost of the incinerator and it would assist other public hospitals and health care facilities, particularly those within close proximity that do not have an acceptable means of disposing of infectious waste or do not have incinerators that are functioning properly. It is also in keeping with recommendations to the Ministry of Health by consultant Scott Crossett to reduce incinerator operating costs within the public sector by having regional incinerators rather than an incinerator at each hospital or healthcare facility.

Screen Model

The following conclusions and recommendations can be made as result of the air quality assessment that was performed for the proposed incinerator:

- The emission rates as calculated from the emission factors for particulate matter, sulphur dioxide, carbon monoxide and volatile organic carbons can safely be applied to the proposed incinerator, since these emission rates are less than the emission standards for a new incinerator.
- The height of the stack can safely be designed as 10.5 m. In any case, the design stack height should not exceed the GEP stack height of 14.25 m.
- A combination of APC devices should be utilized as part of the mitigation measure to safeguard against non-compliant chlorinated dioxin concentrations. As recommended by the project document by Harty (2002), this combination should be a wet scrubber and a fabric filter.
- The stack exit gas velocity can safely be set as 5.287 m/s with the air pollution control devices being applied.
- As much as possible, every attempt must be made to design the incinerator with emission rates that will avoid the inclusion of the APC device, in order to save costs.
- Since emission factors were used to estimate the emission rates, and this technique is fourth in order of priority, it should be observed that the NEPA may be approached with the notion of purchasing and installing the state-of-the-art incinerator, and then to conduct a stack emission testing exercise during its commissioning. A recommendation should then be made to utilise the stack testing data and re-run the modeling analyses so that a more representative prediction of ambient air quality concentrations can be made. This approach actually follows the decision tree as recommended in the NRCA Ambient Air Quality Guideline Document.

Incinerator capital and operating costs

Capital cost of proposed incinerator

Item	Cost (US$)
Incinerator (200 kg/day throughput) with accessories • Closed transport carts • 1 year spare parts • Incinerator loaders • Fire extinguisher system • Emission Compliance testing • Installation and Commissioning • Compliance testing • Waste weighing equipment • Training	320,000
Pollution Abatement Equipment	185,000
Building Construction	120,000
Subtotal	625,000
10% Contingency	62,500
Total	**680,000**

Source: George Harty, January 2004

Operating and Maintenance Costs

Item	Unit Cost	Cost (J$)
Licencing fee to NEPA		10,000 (every 5 years)
Annual Stack testing (consultant)		1,300,000 annually
Discharge fees (assuming compliant operations)		2,000 annually
Operation & Maintenance		260,000 annually
Fuel [#2 Diesel](6000 L/week)	$25.07/L[1]	8,000,000 annually
Electricity (7000 kWh/week)	$0.642/kWh[2]	250,000 annually
Total		**9,812,000 annually[3]**

Alternatives to Incineration

Most of the alternative methods to incineration have one or two disadvantages when compared to incineration.

- They are more expensive
- They require additional mechanical equipment such as shredders to render the waste unrecognisable and reduce volume

[1] This is the unit cost of #2 diesel from Petrojam at January 2004
[2] This is the unit cost for a JPSCo. Rate 40 customer (low voltage) at January 2004
[3] This total annual cost does not include the Licencing Fee to NEPA

- They have limitations in the type of waste that can be burned e.g. cytotoxic, pathological and chemotherapeutic waste
- The technologies are relatively new

Autoclaving with shredding and compaction however is a technologically and financially feasible alternative to incineration. The technology is proven as it has been in use for decades and the effectiveness of the technology has been improved by having the shredding function integral to the process. It will achieve the same volume reduction and sterilisation as incineration without the adverse impacts of hazardous emissions. The capital cost of the autoclave/shredder system is significantly less than the cost of an incinerator with the same waste throughput and the operating cost is about 1/5 of the cost of operating an incinerator.

The estimated cost of an Ecodas T 1000 (195 kg/hr throughput) autoclave with shredding features incorporated is approximately US$15,500 (J$1M) while the cost of an incinerator with pollution abatement equipment and 200kg/hr throughput is US$680,000 (J$40M).

Third party services could be offered to other healthcare facilities for a fee for use of an incinerator or an autoclave.

ENVIRONMENTAL IMPACT ASSESSMENT

1.0 PURPOSE AND NEED FOR THE PROJECT

The University Hospital of the West Indies (UHWI) has been experiencing operational problems with the existing incinerator used for the management of infectious waste. The incinerator is very old, believed to have been at the hospital since the mid 1950's. The following outlines some of the problems being experienced with the incinerator:

- Excessive soot blowing for a few minutes when the boilers are fired up
- Incineration of medical waste is confined to night hours as there is excessive soot and fumes generated during incineration. This is a source of pollution and discomfort to the staff and patients at the hospital. There may also be long term health impacts from emissions associated with the incomplete combustion of the waste incinerated that have not yet been identified.
- Disposal of the residue from incineration (including waste which has not completely burned) with the regular garbage which is ultimately taken to the Riverton disposal site.

Pictures of the existing incinerator are at Appendix 1

In order to address this situation, the UHWI proposes to replace the existing incinerator with a new, modern facility with appropriate emission controls enabling compliance with the regulatory requirements of the National Environment and Planning Agency (NEPA), the Ministry of Health and the National Solid Waste Management Authority (NSWMA).

As a requirement of the NRCA regulations, a permit application and Project Information Form were submitted to the NEPA. Based on the assessment of the submission by the NEPA, the UHWI was advised that an Environmental Impact Assessment (EIA) will be required for an undertaking of this nature.

The EIA is being conducted in accordance with Terms of Reference approved by the NEPA. (See Appendix 2)

2.0 APPLICABLE ENVIRONMENTAL POLICY, LEGAL, REGULATORY AND APPROVAL FRAMEWORKS

2.1 Applicable Legislation

The legislation applicable to this project includes:

- The Natural Resources Conservation Act, 1991
- The Natural Resources (Prescribed Areas) (Prohibition of Categories of Enterprise, Construction and Development) Order, 1996
- The Natural Resources Conservation (Permits and Licences) Regulations, 1996
- The Natural Resources Conservation (Air Quality) Regulations, 2002 (Draft)

- The Natural Resources Conservation, (Ambient Air Quality Standards) Regulations, 1996
- National Solid Waste Management Act 2001
- The Clean Air Act, 1964
- The Public Health Act, 1985
- The Public Health (Nuisance) Regulations, 1995

The Natural Resources Conservation Act, 1991

This Act gives the Natural Resources Conservation Authority [NRCA](now embodied within the National Environment and Planning Agency [NEPA]) the power to take the necessary steps for the effective management of the physical environment of Jamaica so as to ensure the conservation, protection and proper use of its natural resources among other things. In performing its functions it may among other things, formulate standards and codes of practice to be observed for the improvement and maintenance of the quality of the environment generally, including the release of substances into the environment in connection with any works, activity or undertaking. Based on the powers and functions of the NRCA, this proposed project falls within their jurisdiction.

The Natural Resources (Prescribed Areas) (Prohibition of Categories of Enterprise, Construction and Development) Order, 1996

Hazardous waste storage, treatment and disposal facilities is a category listed in this Order as requiring a permit from NEPA. Since the proposed project plans to incinerate medical waste which comprises some hazardous and toxic waste streams, this type of project requires a Permit from NEPA. Some of the hazardous/toxic waste streams which are included in medical waste are:

- Infectious
- Sharps
- Human Tissue
- Cytotoxic
- Pharmaceutical
- Chemicals
- Radioactive waste
- Heavy metal (e.g. mercury)

The Natural Resources Conservation (Permits and Licences) Regulations, 1996

A Permit Application and a Project Information Form are to be submitted to NEPA in accordance with this regulation for the construction and operation of hazardous waste storage, treatment and disposal facilities. An Environmental Impact Assessment may be requested by NEPA for the proposed activity.

A permit application and Project Information Form dated January 2, 2003 was submitted for this project and a response was received from NEPA dated March 25, 2003 indicating that an EIA would be required as a part of the review process.

The Natural Resources Conservation Authority (Air Quality) Regulations, 2002 (Draft)

These regulations require industrial sources (with emissions greater than a specified amount) to obtain air pollutant discharge licences. It also establishes stack emission standards for new sources and ambient air quality guideline concentrations for a wide range of toxic air pollutants. These regulations complement the National Ambient Air Quality Standards for common air pollutants.

The Natural Resources Conservation, (Ambient Air Quality Standards) Regulations, 1996

These regulations set the acceptable limits for common air pollutants in ambient air. Since this project proposes to incinerate medical waste, controls would need to be in place to ensure the emissions do not contribute negatively to ambient air quality.

National Solid Waste Management Act, 2001

This Act gives the National Solid Waste Management Authority (NSWMA) the power to take all steps as are necessary for the effective management of solid waste in Jamaica in order to safeguard public health, ensure that waste is collected, stored, transported, recycled, reused or disposed of in an environmentally sound manner and promote safety standards in relation to such waste. A project such as the one being proposed would need to be reviewed by the NSWMA so that they are satisfied that their requirements are met. Of particular importance would be the disposal of ash from the new incinerator and the disposal of the parts from the old (decommissioned) incinerator.

The Clean Air Act, 1964

This Act deals with the control of emissions of gases such as smoke, fumes, other gases or dust by the Ministry of Health through its inspectorate.

Under section 5 of this Act an inspector on production of his authority if so required may enter any affected premises at any time while work is being carried on there, or while there is any discharge of smoke or fumes gases or dust into the air from any part of such premises and may inspect and examine such premises or any part thereof and may make such enquiries, tests and take such samples of any substance, smoke, fumes, gas or dust as he considers necessary or proper for the performance of his duties.

The proposed project would therefore have to ensure that any discharges into the atmosphere are of an acceptable quality to ensure that there are no legal repercussions under Section 5 of this Act.

Public Health Act, 1985

Under section 20 (1) of the Public Health Act a medical officer (health) or any other person authorised in writing in that behalf by the Minister or by a Local Board, or by the Medical Officer may at all reasonable times enter any premises for the purpose of ensuring compliance with the provisions of this Act, or any regulations made hereunder and shall, if required to do so by the person in charge of the premises, produce his authority for so entering to such person.

Under section 20(2) where a Medical Officers is satisfied that it is necessary in the interest of the public health so to do, he may by himself or by some other person duly authorised by him in that behalf enter any premises with or without the consent of the owner or occupier, and take such action as he considers necessary in the interest of the public.

This Act is particularly relevant since a significant quantity of the waste being managed by the hospital is infectious and toxic, thereby posing a potential hazard to staff, waste handlers and the wider public if it is not disposed of appropriately. Additionally some of the by-products of the incineration process (emissions and solid waste) are considered hazardous and require special management to protect the public.

Public Health (Nuisance) Regulations, 1995

In these regulations nuisance includes any nuisance specified in the schedule to these Regulations. No person shall cause or permit a nuisance on any premises owned or occupied by him or aid and abet any other person to cause or permit nuisance on any premises.

Under section 4 (3) the Local Board, on receipt of a report may institute legal proceedings against the person for non-compliance with the notice or authorise in writing any person to enter upon the premises and to do such things as are necessary to abate or prevent a recurrence of the nuisance

Nuisances can include dust, smoke, fumes, gases or deposits of solid waste emitting from any manufacturing process or caused by the carrying on of any trade or business or otherwise by the action of any person.

2.2 Input from other agencies

The following agencies have a role to play in the management of waste. Some have particular interest in incineration while other are particularly focused on the management of medical waste.

- Ministry of Health
- Environmental Health Unit, Ministry of Health
- Jamaica Fire Brigade

The Jamaica Fire Brigade

This entity is interested in the incineration process, particularly the height of the flue and the disposal of ash. A proposal for the installation of an incinerator must be submitted to the Jamaica Fire Brigade for approval.

The Environmental Health Unit (EHU) in the Ministry of Health

The EHU checks proposals to construct incinerators for:
- Appropriateness of the design for the intended use
- Maintenance Plan
- Air Pollution

The Ministry of Health

The Ministry of Health has a general policy which requires infectious waste to be incinerated to ensure destruction of pathogens.

3.0 DESCRIPTION OF PROJECT, OWNER AND APPLICANT

3.1 History and Function of the Hospital

In 1948, the Faculty of Medical Sciences, Mona, Jamaica became the University College of the West Indies - a regional university responding to the need for a first class training facility for those preparing to become doctors, nurses, and other health-delivery professionals. Accordingly, the University College Hospital of the West Indies became the region's first teaching hospital, sponsored by the University of London and established by law No. 40 in 1948 by the Jamaican Government. Its main objectives were: Teaching, Research and Patient Care.

The hospital's first aim was a preliminary training school for nurses, established in 1949 in the old Gibraltar Barracks on the campus of the University College. By August 1950, five batches of nurses had been trained there in the theoretical aspects of nursing and sent to the Kingston Public Hospital for practical applications.

The University College of the West Indies did not get its charter and full university status until 1967. Its name was changed to the University of the West Indies and the University College Hospital became the University Hospital of the West Indies (UHWI).

Today, the University Hospital of the West Indies is an internationally recognized institution with 514 beds. The Government of Jamaica funds 82 percent of its budget, while the Governments of other Caribbean territories cover the remainder.

Teaching, research and patient care remain the three key objectives of the Hospital, which is now managed by an 18-member Board. The University Hospital of the West Indies employs the full range of employees found in any modern teaching hospital, and the Professors and Lecturers from the Faculty of Medical Sciences provide consultant services in Clinical areas.

3.2 Location

UHWI is situated on the Liguanea Plains of Saint Andrew, Jamaica, adjacent to the Mona Campus of the University of the West Indies.

3.3 Mission Statement of the University Hospital of the West Indies

"The University Hospital of the West Indies is committed to teaching, research and the provision of quality health care to the region. In striving for excellence, we maintain an environment conducive to an efficient, cost-effective, responsive health care promotion and delivery system by incorporating the participation of all categories of staff and students, patients, their families and the wider community".

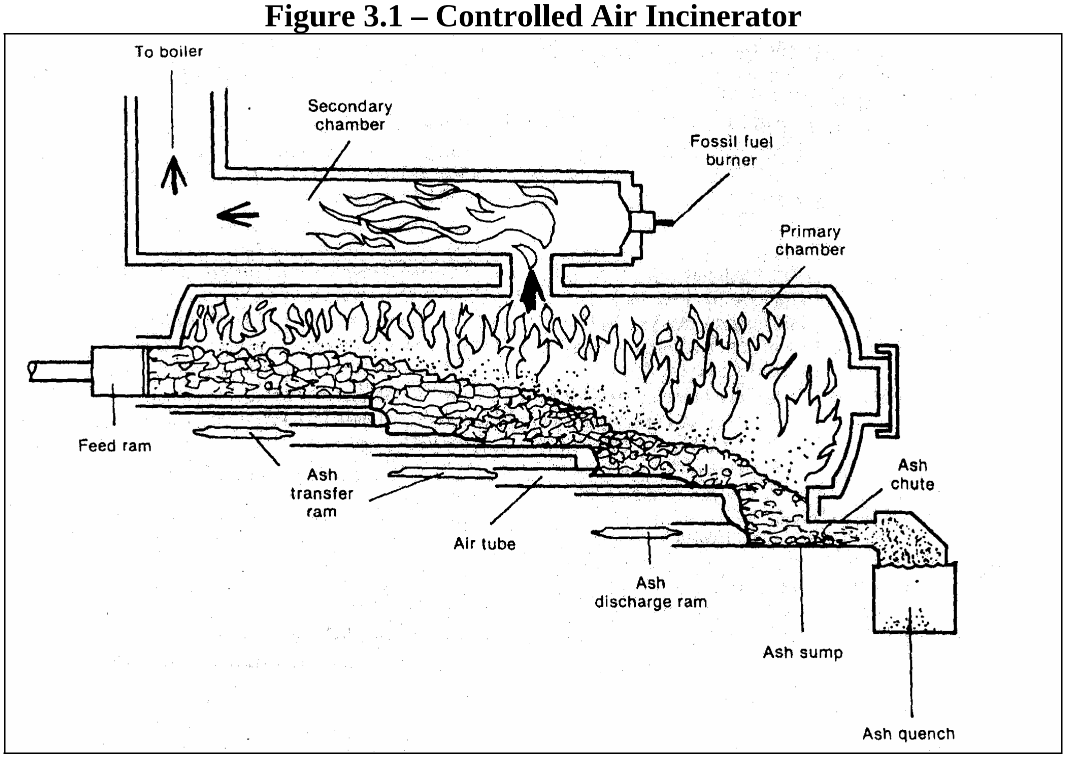
3.4 Vision Statement of the University Hospital of the West Indies

"The University Hospital of the West Indies envisions itself as a dynamic, environmentally safe, adequately equipped organisation with trained and highly motivated staff dedicated to promoting teaching, research and the delivery of the highest quality health care to meet the needs of the region".

3.5 Incineration

Incineration is the process of reducing combustible waste to inert residues by high temperature combustion. Incineration entails burning of waste at temperatures ranging from 1,800ºF to 2,000ºF (982ºC to 1093ºC). The waste is fed into the first chamber where it is exposed to very high temperatures causing and maintaining combustion. The second chamber continues to burn the waste and convert it to carbon dioxide and water. The incineration process does not destroy matter, it merely changes the chemical composition and toxicity of the substances burnt.

Figure 3.1 – Controlled Air Incinerator



Source: Finding the Rx for Managing Medical Wastes, Office of Technology Assessments, USA, September 1990

The process of incineration provides the advantage of volume reduction as well as the ability to dispose of recognisable waste and sharps. On site incinerators provide a quick and easy way of disposing medical waste. This is the most widely accepted and feasible method of managing highly infectious waste. It is the method approved by the Ministry of Health in Jamaica.

However, there are some potential negative environmental issues associated with the use of incinerators and these will be discussed in more detail below.

Table 3.1 – Advantages and Disadvantages of Incineration

ADVANTAGES	DISADVANTAGES
Significant volume reduction (90-95%)	Emission control methods necessary
Assured destruction of all wastes	Potential pollution to landfill with fly ash
Sterilization achieved	Temperature regulation necessary
Weight reduction	Air pollution and the creation of hazardous emissions like dioxins. The increased use of PVC materials causes dioxins to be generated during incineration and this pollutant is a human carcinogen and affects the immune and reproductive systems
Ability to manage most types of wastes with little processing before treatment	Unable to deal with radioactive waste or pressurized containers
Control of odour and smoke by ensuring good secondary combustion	Potential health risks from: • heavy metals in ash e.g. cadmium which is a neurotoxic chemical • acid gases which cause eye and respiratory irritation and acid rain. • particulate emissions which cause chronic lung diseases
Rapid disposal of flammable material	
Production of inert residues, which may be disposed of without leaching problems	
Improvements in incineration technology	

3.6 Incinerator in Jamaica similar to the proposed Incinerator

The incinerator that is proposed for the University Hospital of the West Indies is similar to one installed at the St. Ann’s Bay Hospital in the year 2000. Figures 3.2 to 3.5 show different views of the incinerator at the St. Ann’s Bay Hospital. The specifications for the incinerator are outlined in Appendix 2.

This incinerator is reportedly working well. Its capacity is more than adequate for the hospital as it is not operated every day due to insufficient waste generation. Some spare parts are on hand and the only issue of concern raised by the incinerator operator was that a condenser which became defective a number of months ago had not yet been replaced. He hastened to add that this did not affect the effective operation of the incinerator.

Figure 3.2 Outside View of the Incinerator at the St. Ann's Bay Hospital

Figure 3.3 – Incineration Chamber

Figure 3.4 Sharps awaiting incineration

Figure 3.5 Stack Emissions during start up of the Incinerator

3.7 The Proposed Incinerator[4]

While the design of the proposed incinerator is based on the one at the St. Ann's Bay Hospital, the manufacturer and supplier are not yet known as NEPA's approval is required before requesting bids for the supply and installation of the incinerator. The specifications outlined below will form the basis of the Tender Document.

The incinerator will be designed for a useful life of 20 years once it is operated and maintained according the manufacturers instructions.

The incinerator will be of the controlled air type, designed for 8-hour-day operations and rated at 200kg per hour. The configuration may be vertical or horizontal. All equipment and steel works designed and supplied under this performance specification will be protected against the following:

- Marine environment
- Hurricane force winds of at least 240 kmph
- Earthquake conditions in accordance to the local building codes

The incinerator plant will include the following:

- Continuous loading using hydraulic ram feeder
    - Burners and fuel system
    - Fans
    - Pumps
    - Controls and Instrumentation
    - Chimney and flue connections
    - Incinerator loader for loading hoppers or carts
    - Ash handling equipment
- 1 year spare parts
- Waste weighing equipment
- Fuel Tank
- Wheeled 2.0m^3 waste storage hoppers (number to be decided by hospital managers)
- Incinerator loader
- Incinerator building, including fire safety equipment
- Platform and portholes designed to USEPA standards to facilitate stack testing

The incinerator consists of two chambers. The primary (ignition) chamber is operated at less than stoichiometric air requirement to produce a temperature of between 650°C and 980°C. Solid waste can only be burned in the primary chamber. The secondary (combustion) chamber is operated at excess air condition and is designed for gaseous combustion to maintain a temperature not less than 1000°C. Outlet temperature of the gas will not exceed 1200^{o}C.

i. Burners will be fitted in the primary and secondary chambers to ensure controlled incineration.

[4] Information obtained from design of incinerator system done by George Harty, October 2002

ii. The system will operate such that both combustion chamber areas are at subatmospheric pressure, even when the loading door is open. Combustion zones will at all times be subject to depression naturally caused by chimney, whether the plant is operating or not.

iii. The gas temperature in the primary chamber will be controlled by modulating the air at sub-stoichiometric conditions (starved air). The temperature in the secondary chamber will be achieved by air modulation and the firing rate of the secondary burners. The incinerator will be selected for two -second gas residence time. The fuel gas temperature will not exceed 150°C at the tip of the burner.

iv. Viewing ports will be provided that will facilitate an adequate view of the whole furnace at any time during operation. All the necessary safety measures will be incorporated in the design of viewing ports.

v. The projected area of the burning surfaces in the primary chamber will be typically a single hearth. If the unit is of a stepped-hearth configuration then multiple internal ash rams will be required. The chamber will be complete with the required structural supports, support channels and inspection doors. It will be lined with insulating and hard-faced refractory materials suitably supported with long life stainless steel anchors.

vi. Provisions will be made to prevent conditions where plastics would puddle on the hearth and return in a burning state on the ram face to cause fire in the loader / hopper.

vii. The secondary chamber will be complete with the required structural supports, support channels and inspection doors. It will be lined with insulating and hard faced refractory materials suitably supported with long life stainless steel anchors.

viii. Waste is collected from collection points using the specified wheeled carts then transported to the incinerator plant waste storage area with capacity for at least one day waste.

Transfer of the waste from the storage area will be by wheeled cart to the automatic loader. An automatic waste feed system including feed hopper and hydraulic charging rams, will be provided. The feed hopper size must be consistent with the volume of waste to be incinerated per day. The hydraulic ram will be designed with means of manually operated withdrawal of any machine part which passes into the furnace, but is designed to be normally outside the furnace. This will enable the part to be withdrawn and the furnace door closed, in the event of automatic feed mechanism breakdowns.

The system will be designed to prevent the operator being exposed to radiation from the furnace. Feed system will be interlocked with temperature monitors to prevent the addition of fresh materials if the temperature in the secondary combustion chamber falls below a preset minimum.

ix. The supplier will recommend and include in his pricing the equipment for loading the hopper.

x. A smoke hood will be provided between the furnace doorway and the loader hopper to provide ventilated cooled space to prevent loader hopper fires, and to prevent any furnace gas entering the plant room.

xi. All fans with motors will be mounted on a welded steel frame. Each frame will be one piece and will be rigid enough to hold all parts of the machine and its driving motor in correct alignment

xii. All rotating machinery will be mounted on suitable vibration isolators, selected with proper consideration of the prevailing machine frequencies and guaranteed by the supplier / contractor to prevent transmission of objectionable noise or vibration to the building structure. Separate vibration isolators will not be required under factory assembled units, in which all moving parts are adequately isolated within the unit.

Table 3.2 Other Incinerator Components

Component	Description
Charging Door	Cast iron construction is not necessary for this door. The framing around the charging door opening will be of cast iron air-cooled blocks designed to permit over fire air to enter the furnace section and also to protect the edges of the refractory walls from mechanical abuse.
Burners	Power burners using 30 second gas oil (No.2 diesel) will be provided for the ignition in primary chamber and maintaining combustion temperature in combustion chamber. Pilot ignition for the primary chamber should be LP-gas.
Grates	Grates will be of heavy cast iron construction. Grate support members will be such that grates are supported independently of the refractory walls. The free air opening of the grate will be at least 40 %.
Hearth	The system will include for a hot hearth system, with individual ash rams if multiple hearth is implemented. The hearth will be constructed of a dense high heat duty refractory and have minimum thickness of 150 mm
Clean Out Doors	A minimum of two clean-out doors with frames of heavy cast iron will be provided. Refractory lined doors, each having an adequate free opening to permit easy access will be used, one for cleaning out the furnace and one for settling the chamber. The ash pit section will have at least one clean-out door with insulated handles to facilitate removal of ash below the grates and will be adjustable to control combustion air through the grates. It is possible to have a mechanical ash removal system however this option would need to be specially requested and detailed by the supplier / contractor.
Stack	The incinerator will be suitable for top outlet stack. The refractory lined stack will be designed to provide natural draft evacuation of all combustion gases to atmosphere in case of electrical power failure. It will maintain a negative pressure in the ignition chamber. A self-supporting stack above the grate line with an inside diameter suitable for the combustion rate will be provided. The enclosure steel work adjacent to the incinerator may be suitably braced to support the discharge stack if necessary.

Component	Description
	The stack will terminate at least 10 meters from the ground and must terminate above the level of the plant room building roof. It will be designed, erected and commissioned in accordance with good practice. A suitable spark screen will be provided on top of the incinerator stack. The minimum spark screen height will be 1.5 times the outside diameter of the stack. This is required in the event of an emergency bypass of gases to the chimney. The incinerator and stack will be finished with two coats of high heat resistant silver paint having been sandblasted, brushed, cleaned and primed with a suitable primer.

Table 3.3 Electrical Requirements

Component	Description
General	The electrical installation will be in accordance with JS21 -local electrical installation code and the IEE wiring regulations (6th edition). An electrical supply will be provided up to a main isolator adjacent to the incinerator from the main electrical supply. Available supply is 415 V, 3-phase, 50 Hz. The supplier / contractor will, in his pricing, allow for making all final connections to the electrical equipment forming part of the incinerator works.
Motors	All motors will have sufficient capacity to start and operate the machine it drives without exceeding the motor name plate rating at the speed specified. Motors will be rated for continuous duty at 100% of rated capacity and temperature of 40°C. All motors with capacities greater than 0.75 hp, except as otherwise specified, will be suitable for 3 phase, 50 Hz, 415 V. All other motors below 0.75 hp will be single phase, 240 V, 50 Hz. Single phase motors will be open capacitor-start type. Three phase motors may be of the split phase type. All motors for V -belt drives will have adjustable motor slide bases. All motors will be in accordance with NEMA motor frame standards. All motors will be of the totally enclosed, drip proof type. Fuel pump motors will be explosion proof. Motors are expected to be exposed to severe duty and should be designed for such conditions. Each motor will be provided with a motor starter of proper design to meet the requirements of the motor and drive. All starters will be arranged for wall, floor or panel mounting and will be complete with necessary frames and support.
Control Panel	The control panel will be permanently and legibly marked, with the manufacturer's name and address, any special instructions for the safe and proper operation of the incinerator, maximum throughput capacity, date of installation and contract numbers.

Component	Description
	The incinerator will include a chart recorder for recording incinerator cycle temperatures. The control panel will be fully automatic and foolproof, preventing any user override of the safety systems. The panel will be equipped with monitors to detect single phasing conditions on three phase systems. The panel door will be interlocked so that the electrical supply will be isolated before opening. The panel will incorporate an emergency stop button. Indicator lamps will show when, the panel is live, individual pumps, fans, burners are running, the burn period is in progress, when the charging door is unlocked and can be opened for charging. Green indicator lamps on the panel door will indicate "run" and red indicator lamps will indicate "tripped" or "stopped" on every motor installed. **Emergency stop**: A stop button will be fixed near the door of the incinerator plant room for use in an emergency, when the incinerator appears to be going out of control. Operation of this will effectively shut down the plant, exclude any forced draft air input to the incinerator to reduce the burning rate, whilst maintaining a free passage of the flue gases to the chimney and ensure the plant is brought into safe condition.
Automatic Ash Removal	The ash will drop out of the primary chamber once the proper burn time has elapsed. This ash will be removed by a collection container or ash conveyor to feed a container.
Air Pollution Control System	The system will include a baghouse filter system. The baghouse assembly will be constructed of welded steel suitably reinforced to form a rigid structure and mounted on suitable steel frame. It will assure compliance with the applicable air pollution emission codes. The baghouse should be self cleaning and will include safety systems in the case of over temperature conditions in the secondary chamber. A scrubber assembly will also be included and should be constructed of type 316L stainless steel to include quenching section, venturi, circulation pump, filler valve, level sensor, liquid storage, packed tower and demister pad. All components will be skid-mounted for ease of assembly.
Spare Parts	The supplier / contractor will be required to include a list of spare parts and consumable items considered essential for the two years following the initial one year maintenance, see clause 15 below. This list will state, for each item, the estimated life in running hours, the number to be stored on the site, availability for those items not stored at the site, the estimated cost of each item of the spares to be carried.
Recommendations for storage and transfer of wastes from collection points to	Waste is bagged at the source and transferred to wheeled closed trolleys from predetermined holding or collection points to the storage area in the incinerator plant room. Containers will be puncture proof and ideally sited at a central disposal point

Component	Description
incineration site	for ease use by the departments concerned and subsequent removal by waste management operative but should not be accessible to the public. The transportation of waste through the hospital should be ideally routed to avoid casual contact with the public and at no time be left unattended. The transportation vehicles need to be in the form of rigid leak proof containers fitted with covers. Waste must be incinerated as soon as possible after transfer to the incinerator room, and not held for extended periods of time. Medical wastes should be incinerated within 24 hours of reaching the incinerator room.

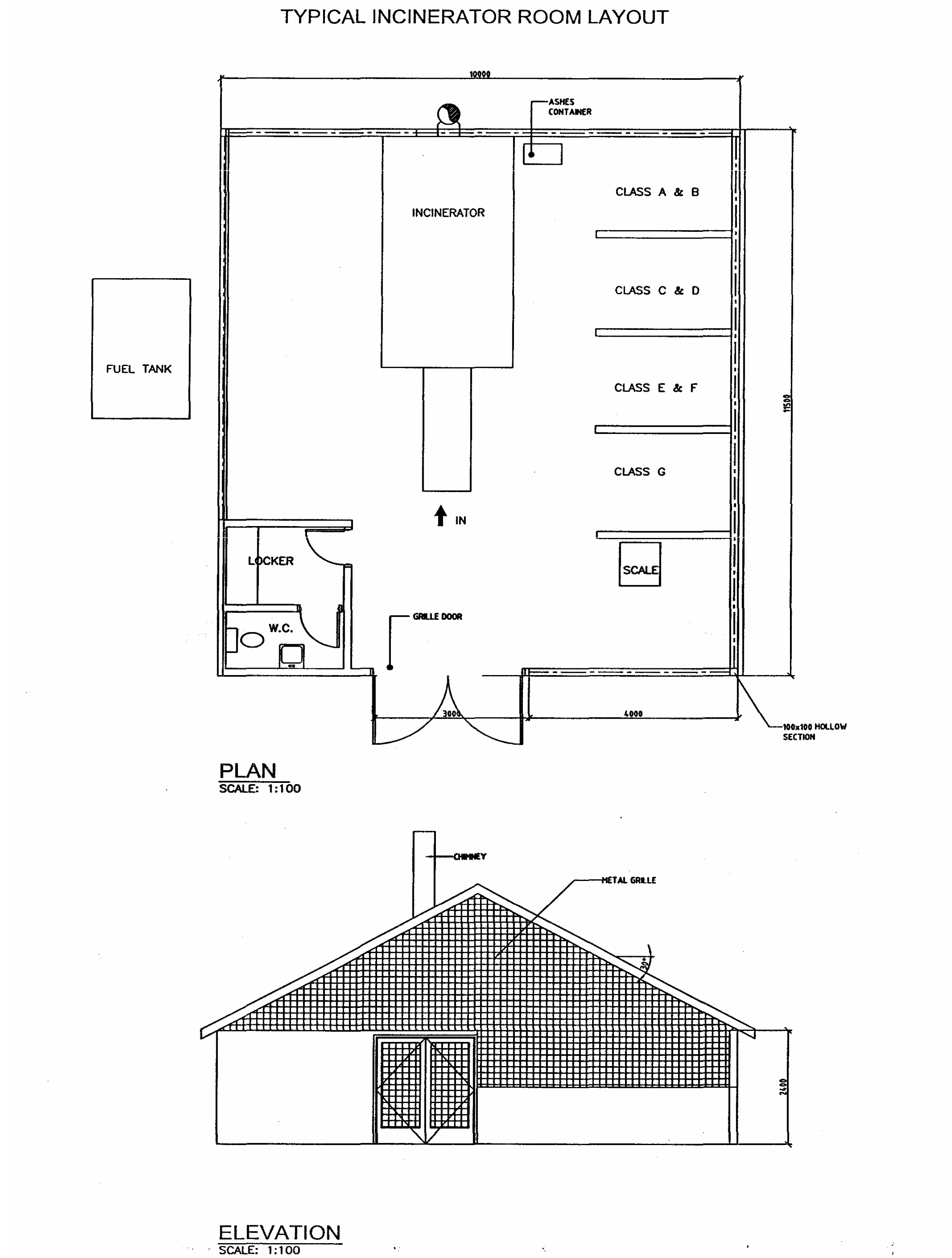
Table 3.4 Incinerator Building Design

Component	Description
General	The incinerator should be installed in a plant room designed for housing the entire operation, as the unit must be able to be operated in all weather conditions. It will be necessary to select the incinerator prior to final dimensioning of incinerator plant room so as to make design as economical as possible. The entire building will be constructed in accordance with the local hurricane and earthquake codes. The building to house the incinerator will have dimensions of 18m (60ft.) by 9m (30ft) and an approximate area of 162 m^2 (200 sq. ft.). The scrubbing system will supported by a steel frame. A typical layout of the incinerator room is shown at Figure 3.6. A typical plant of this size weighs in excess of 15 tonnes and the dimensions of the plant are typically, 7.0m (L) x2.0m (W) x2.8m (H). The plant room will have to accommodate this in addition to ensuring good working space.
Plant room Components	• Incinerator Unit • Storage and incinerator loading • Additional enclosed storage area for separation of hazardous waste to be disposed of by incineration or otherwise. • Additional enclosed storage area for temporary storage of bagged incinerator waste, (ash and other non-combustibles) each with floor area of $6m^2$. • Staff facilities - Unless otherwise provided elsewhere on the compound and in close proximity to the incinerator plant, there will be a room for staff accommodation including toilet facilities and equipment stores. Area for equipment storage, staff change room facilities is estimated at $10m^2$ • The entire floor should be designed for wash-down. The area will be run to falls with an open channel trapped drain. The drain will be carried to a sump for transfer to treatment facility by pumping. • Entrance way should be shuttered with electro-mechanical winch for opening and closing shutter. Roofing generally can be heavy gauge Aluminum sheeting on steel trusses appropriately protected from marine

Component	Description
	elements. • There will be a wash-down point complete with fixed 30-metre, high pressure industrial hose for washing down of compound, hence the necessary grading of the plant room floor. All wash-down waste and sewage from toilet should be routed to the hospital sewerage system. • The building will be equipped with electrical power supply as follows: o For Power - Three-phase, 415 V AC, 50 Hz with capacity estimated at 250 Amps to be revised when the incinerator has been selected. o For lighting and light loads - Single phase, 240 V AC, 50 Hz, 100 Amps • Lighting will be sufficient to provide standard service illuminance of 200 Ix at operating surfaces. All luminaries should be corrosion resistant and adaptable to high moisture high heat environment. Where trunking is used for electrical distribution circuits they will be of corrosion resistant material as well. • All un-insulated piping and metal work will be thoroughly cleaned and primed with one coat of metal primer and finished with appropriate corrosion resistant paint finish. • The wastewater system will consist of a wet well with a pump, if necessary, set for transferring wash-down to the stormwater system.
Fuel Storage	A new cylindrical fuel storage tank will be erected complete with pipe work, valves, sight level glass, dead weight fire valves etc. to serve the incinerator burners. The tank capacity will be determined by the maximum firing rate of both burners allowing for 10 days operation at eight hours per day initially. This would require a tank approximately 2000 liters. The tank will be external to the building and will be enclosed by a bund wall giving 910 mm clearance all round and height of 1200 mm. The tank will be able to contain spills up to 1.5 times its contents.
Emergency Facilities	***Fire fighting:*** Minimum of one 20 kg dry chemical fire extinguisher units will be installed in the plant room. The extinguisher will provide fast and effective protection against Class A:B:C or B:C fires. The fire protection and fire fighting system will be in accordance with local factory codes and practices and will be subject to approval of the fire department of the Ministry of Local Government. This will be in addition to the provision of water hydrants with fire hose reels. ***Isolation of fuel supply:*** The fuel valve serving the incinerator will be in a prominent position. The fuel supply line will be fitted with a suitable dead weight operating valve actuated by a fusible link mounted over each burner and also a red coloured panic button mounted near the front doors of the room. This will cut off the fuel supply where it enters the plant room, in the event of fusing of the links or manual pushing of the button. ***Standby Electrical Power:*** The incinerator facility should be connected to the

Component	Description
	hospital emergency supply so as to ensure continued processing of waste. The load will be determined on the selection of the incinerator. It is not expected to exceed 120kVA.

Figure 3.6 – Typical Layout of the Incinerator Room[5]



Not to scale

[5] Information obtained from design of incinerator system done by George Harty, October 2002

3.7.1 Sizing of Incinerator

3.7.1.1 Quantity and types of waste to be incinerated

There are two principal types of solid waste generated by a hospital, garbage which is generally non-hazardous in nature and medical wastes. Medical wastes are defined as wastes arising from medical, nursing, dental, veterinary, pharmaceutical or similar practices, and wastes generated in hospitals during investigations or treatment of patients or in research projects. Not all medical wastes are hazardous but some can be potentially hazardous to staff involved in their disposal and to the public if not safely managed.

Specific types of medical waste generated and incinerated at UHWI include:

- Sharps
- Infectious Waste
- Human Tissue
- Cytotoxic Waste
- Pharmaceutical Waste
- Chemical Waste
- Radioactive Waste
- Plastic Waste
- Hazardous (e.g. mercury)

A waste audit was conducted at the UHWI in September 2003 which resulted in the quantification of the medical waste stream, regular garbage and bulky waste. It was not possible to quantify the waste streams comprising medical waste as all the components were commingled. It was noted from the audit that hazardous and radioactive wastes were being combined with other infectious waste for incineration.

Based on recommendations from the audit to improve segregation, the UHWI has started to review their waste management practices with the aim of implementing new procedures to ensure that hazardous and radioactive waste are managed separately. Another benefit of segregation will be better estimation of the waste streams comprising medical waste.

Table 3.5 Medical Waste Streams at UHWI

WASTE STREAM	SOURCES	PACKAGING	STORAGE	LOCATION OF FINAL DISPOSAL
Infectious waste	Operating Theatre & Wards Clinics (including radioactive and hazardous waste such as mercury)	***Current and Proposed practice:*** Red Plastic bags	***Current and Proposed practice:*** Pre incineration, wastes will be stored at a designated location inside the Incineration room for not longer than 24 hours.	***Current and Proposed practice:*** On-site incinerator
	Sharps	***Current and Proposed practice:*** Double layered and waxed cardboard boxes (See picture below)	***Current and Proposed practice:*** Pre incineration, wastes will be stored at a designated location inside the Incineration room for not longer than 24 hours.	
Ash	Residue from incinerated infectious waste & sharps	***Current practice:*** Half drums or boxes ***Proposed practice:*** Puncture proof containers with covers that can be sealed	***Current and Proposed practice:*** Bottom and fly ash will be stored in a designated area inside the Incinerator room until container is full.	***Current practice:*** Taken to Riverton Landfill along with the general garbage by Garbage Disposal and Sanitation Systems ***Proposed practice:*** Special arrangement with a service provider to collect the ash and special arrangement with the NSWMA for the receipt and disposal of the waste at Riverton.

Figure 3.7: Sharps box

Based on the waste audit conducted in September 2003, preliminary data estimated the quantity of infectious medical waste generated by the hospital for incineration at approximately 670 kg/day. This compared well to an earlier estimate that the hospital had of 567 kg/day. It is the desire of the hospital to include the waste generated by Pathology (which is currently managed by the University Campus) in the waste to be incinerated at the hospital. The estimated quantity of waste generated by Pathology was calculated to be 10 kg/day.

The current total waste generated for incineration is therefore 680 kg/day, however for the purposes of this EIA 700 kg/day will be used as the current rate of waste generation. Expected expansion of the hospital is not expected to exceed 20%, therefore if allowance is made for this, the incinerator can be designed for waste generation at a rate of 840 kg/day. Refer to Appendix 4 for calculations regarding waste generation at the hospital.

If the incinerator has a throughput of 200kg/hour, it will only operate for 4 hours each day. There are two options that can be considered.

- A smaller incinerator could be considered with a throughput of near to 100 kg/hour so that it operates for an eight hour period or
- The hospital can accommodate waste from external sources so that its additional capacity is utilised.

It is strongly recommended that the latter option be pursued as fees could be charged that would help to offset the operating cost of the incinerator and it would assist other public hospitals and health care facilities, particularly those within close proximity that do not have an acceptable means of disposing of infectious waste or do not have incinerators that are functioning properly. It is also in keeping with recommendations to the Ministry of Health by consultant Scott Crossett to reduce incinerator operating costs within the public sector by having regional incinerators rather than an incinerator at each hospital or healthcare facility.

Table 3.6 – Condition of Incinerators at Hospitals within the South Eastern Region[6]

Health Facility/Lab (within the South Eastern Region)	Condition of the incinerator(s)
Bustamante Hospital for Children	The hospital also has two incinerators one which is an old single chamber diesel fuelled type and the other a more modern Italian design. The latter is not functioning properly and the waste is being burned at the older of the two units.
Kingston Public Hospital	The incinerator is in operation 7 days per week. The unit is a large single chamber unit. At the present time the incinerator receives wastes from the KPH and Victoria Jubilee Maternity Hospital both of which share the same compound. The incinerator burns about 100lb of medical wastes per day, which is carried out in two lots of about 50lb. The burn time is about 3hrs per 50lb load. The incinerator produces a grey smoke plume and has no gas scrubbing system and no temperature control device. Any body parts are brought to the incinerator and are burned immediately; the above weights do not include this figure. It was obvious from the composition of the ash that the burn was not sufficient to render some of the elements in the waste unrecognisable and sharps were still visible in the ash as were glass vials etc.
National Chest Hospital	The incinerator at the hospital is an old single chamber model with no identifying marks. The unit had no gas scrubbing system and no temperature control. The unit burned about 20 sharps boxes at a time. It required being manually loaded. The fuel/ air mix is provided to the incinerator automatically. The stack height for the unit was not higher than the surrounding buildings. The smoke was clearly visible from the stack.

3.7.2 Installation & Commissioning

The equipment supplier will be responsible for setting up and commissioning the incinerator. These activities include:

- On-site testing
- Recording installation details on "as built' drawings
- Instructions and training to users and maintenance technicians

[6] Scott Crossett MBE, BSc, Waste Management Consultant, Crown Agents, London

- Providing detailed shop drawings of incinerator pre-installation requirements for foundations, structures, elevations, layout etc.

The supplier / contractor will provide all shop drawings for builders work showing details of the following:
- Details for loading and charging, incinerator feed hopper.
- Incinerator ash removal area.
- Details of incinerator layout and chimney including roof breaching details if any, (shop drawings).
- Details of any plinth requirements.
- General arrangements for all equipment in the plant room together with installation pre-requirements.

In order to facilitate stack testing the incinerator will have portholes and a platform designed to USEPA standards.
Commissioning of the incinerator system will be carried out by a manufacturer's representative and the results recorded on prescribed Commissioning Record Sheets to be included in the contract document. Tests will be done to demonstrate that the plant meets the requirements as may be summarized in the supply contract. Two copies of the report of tests will be submitted to the University Hospital of the West Indies' commissioning advisor within 21 days of completion of tests. The hospital must then submit the report to the National Environment and Planning Agency (NEPA) and the Environmental Health Unit (EHU) in the Ministry of Health for their review. This report will be accompanied by record sheets and will contain:
- Detailed description of plant
- Details of instruments used and methods of use with reference to relevant standards within this specification and the ranges of individual instruments.
- Detailed report of readings taken
- Detailed results alongside legal limits to show comparison.
- Details of emission tests results
- Conclusions
- Recommendations

3.7.3 Cost Issues

Cost is another key factor in the consideration of medical waste disposal. In evaluating the costs of incineration, decision-makers should take into account, among others, capital and operating costs of the incinerator plus scrubber and other pollution control devices; the cost of secondary chamber retrofits for old incinerators; the costs of periodic stack testing, continuous monitoring, operator training; and the costs of maintenance and repair especially in relation to refractory wear or failure. The capital cost and operating and maintenance costs of the proposed incinerator are outlined below in Tables 3.7 and 3.8. After the first year, when the manufacturers warranty is up, operating and maintenance costs may increase.

Table 3.7 Capital cost of proposed incinerator

Item	Cost (US$)
Incinerator (200 kg/day throughput) with accessories • Closed transport carts • 1 year spare parts • Incinerator loaders • Fire extinguisher system • Emission Compliance testing • Installation and Commissioning • Compliance testing • Waste weighing equipment • Training	320,000
Pollution Abatement Equipment	185,000
Building Construction	120,000
Subtotal	625,000
10% Contingency	62,500
Total	**680,000**

Source: George Harty, January 2004

Table 3.8 Incinerator Operating and Maintenance Costs

Item	Unit Cost	Cost (J$)
Licencing fee to NEPA		10,000 (every 5 years)
Annual Stack testing (consultant)		1,300,000 annually
Discharge fees (assuming compliant operations)		2,000 annually
Operation & Maintenance		260,000 annually
Fuel [#2 Diesel](6000 L/week)	$25.07/L[7]	8,000,000 annually
Electricity (7000 kWh/week)	$0.642/kWh[8]	250,000 annually
Total		**9,812,000 annually[9]**

[7] This is the unit cost of #2 diesel from Petrojam at January 2004
[8] This is the unit cost for a JPSCo. Rate 40 customer (low voltage) at January 2004
[9] This total annual cost does not include the Licencing Fee to NEPA

By comparison, in jurisdictions within the USA, operating costs have been estimated at between US$0.07-$0.50 per pound of medical waste. If it is assumed that US$0.30/pound (the average of US$0.07/pound & $0.50/pound) is applicable to the incinerator proposed for the hospital and the quantity of waste is initially 700 kg/day then the estimated annual operating and maintenance cost would be J$10.1M which is close to the J$9.8M in Table 3.8.

Quantity of waste	= 700 kg/day
	= (700kg/day X 2.205) lbs/day
	= 1543.5 lbs /day
	= (1543.5 lbs /day X 365) lbs /yr
	= 563377.5 lbs /yr
Operating cost	= US$0.3/ lbs = J$18/ lbs
	= 563377.5 lbs /yr X J$18/ lbs
	= J$ 10.1M

4.0 ALTERNATIVES TO PROJECT

The management of medical waste is an evolving area of waste management with improvements being sought to reduce the toxicity and risk associated with the handling of medical waste. In this section, alternatives to the proposed project of installing an incinerator are discussed including the "do nothing" alternative.

4.1 The "Do Nothing" Alternative

The "do nothing" alternative would mean that the incinerator which currently exists at the hospital would remain. This also means that the operation of the incinerator would have to be limited to nights in an effort to reduce the soot blowing that is associated with its operation. The existing incinerator which is believed to be almost 50 years old does not have emission controls to prevent particulates, PM_{10}, dioxins, furans, hydrochloric acid and other pollutants from being released into the environment.

The paediatric ward is the building most severely affected by the emissions from the incinerator as the building is taller than the incinerator and traps the emissions. Patients and staff at the hospital complain that their health is being adversely affected as a result of the inefficient functioning of the incinerator.

This option is unacceptable when one considers the costs associated with operating this old and inefficient incinerator and the associated health effects. Additionally, the current method of medical waste management is not consistent with the hospital's mission statement. (See Section 3.3)

4.2 Alternative (Non-incineration) Treatment Methods

The increased awareness of the adverse environmental and health impacts of incineration and increasing availability of alternative non-incineration technologies have led to a concerned move by the industrialised nations towards eco-friendly non-incineration technologies.

Non-incineration treatment technologies can be categorised based on the fundamental processes used to decontaminate waste. The four basic processes are:

1. Thermal processes
2. Chemical processes
3. Irradiative processes
4. Biological processes

The majority of non-incineration technologies employ the first two processes listed above and are supplemented by mechanical processes.

4.2.1 Thermal Processes

Thermal processes rely on heat (thermal energy) to destroy pathogens in the waste. This category can be subdivided into low-heat, medium-heat, and high-heat thermal processes. This further sub-classification is necessary because physical and chemical mechanisms that take place in thermal processes are significantly different at medium and high temperatures.

4.2.1.1 Low-Heat Thermal Processes

Low-heat thermal processes are those that use thermal energy to decontaminate the waste at temperatures insufficient to cause chemical breakdown or to support combustion or pyrolysis. In general, low-heat thermal technologies operate between 200°F to about 350°F (93°C -177°C). The two basic categories of low-heat thermal processes are wet heat (steam) and dry heat (hot air) disinfection.

Wet heat treatment involves the use of steam to disinfect waste and is commonly done in an autoclave. Microwave treatment is essentially a steam disinfection process since water is added to the waste and disinfection occurs through the action of moist heat and steam generated by microwave energy.

In dry heat processes, no water or steam is added; instead, the waste is heated by conduction, natural or forced convection, and/or thermal radiation using infrared heaters.

These technologies have one thing in common - steam. As heat is applied to water, its temperature rises until it reaches its boiling point or saturation temperature at which point water is turned into steam. At atmospheric pressure (100 kPa [kilopascals] or 14.7 psia [pounds per square inch absolute]), the saturation temperature of water is 100°C or 212°F. At higher pressures, the saturation temperature is higher.

4.2.1.2 Wet Heat Treatment Systems

Autoclaves and Retorts

An **autoclave** consists of a metal chamber sealed by a charging door and surrounded by a steam jacket. Steam is introduced into both the outside jacket and the inside chamber which is designed to withstand elevated pressures.

Heating the outside jacket reduces condensation in the inside chamber wall and allows the use of steam at lower temperatures. Because air is an effective insulator, the removal of air from the chamber is essential to ensure penetration of heat into the waste. This is done in two general ways: gravity displacement or pre-vacuuming.

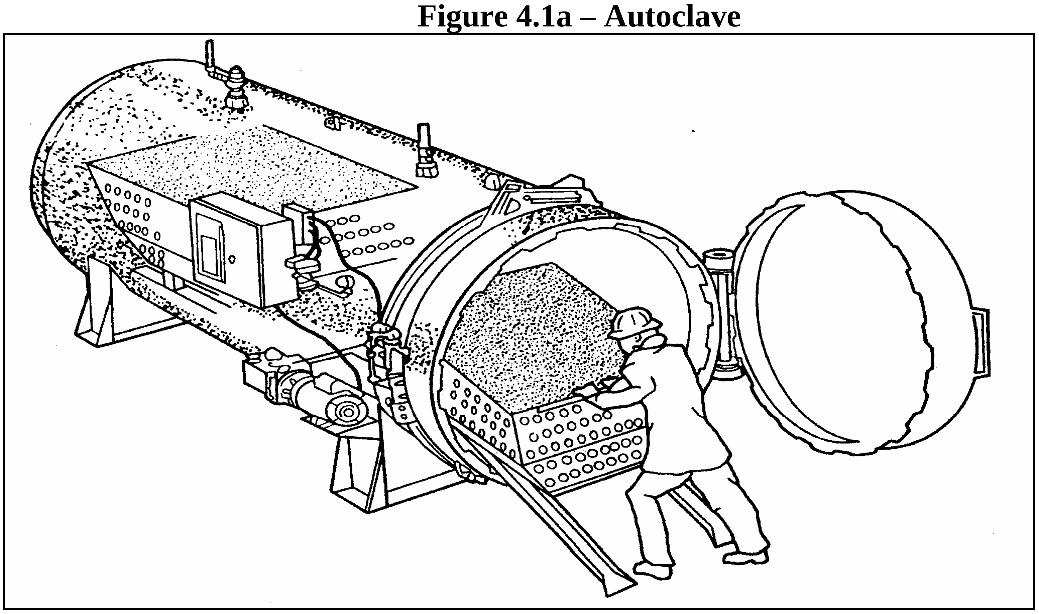
A *gravity-displacement (or downward-displacement) autoclave* takes advantage of the fact that steam is lighter than air; steam is introduced under pressure into the chamber, forcing the air downward into an outlet port or drain line in the lower part of the chamber.

A more effective method is the use of a vacuum pump to evacuate air before introducing steam, as is done in pre-vacuum autoclaves*. Pre-vacuum (or high-vacuum) autoclaves* need less time for disinfection due to their greater efficiency in taking out air.

Some autoclaves may use pressure pulsing with or without gravity displacement to evacuate air.

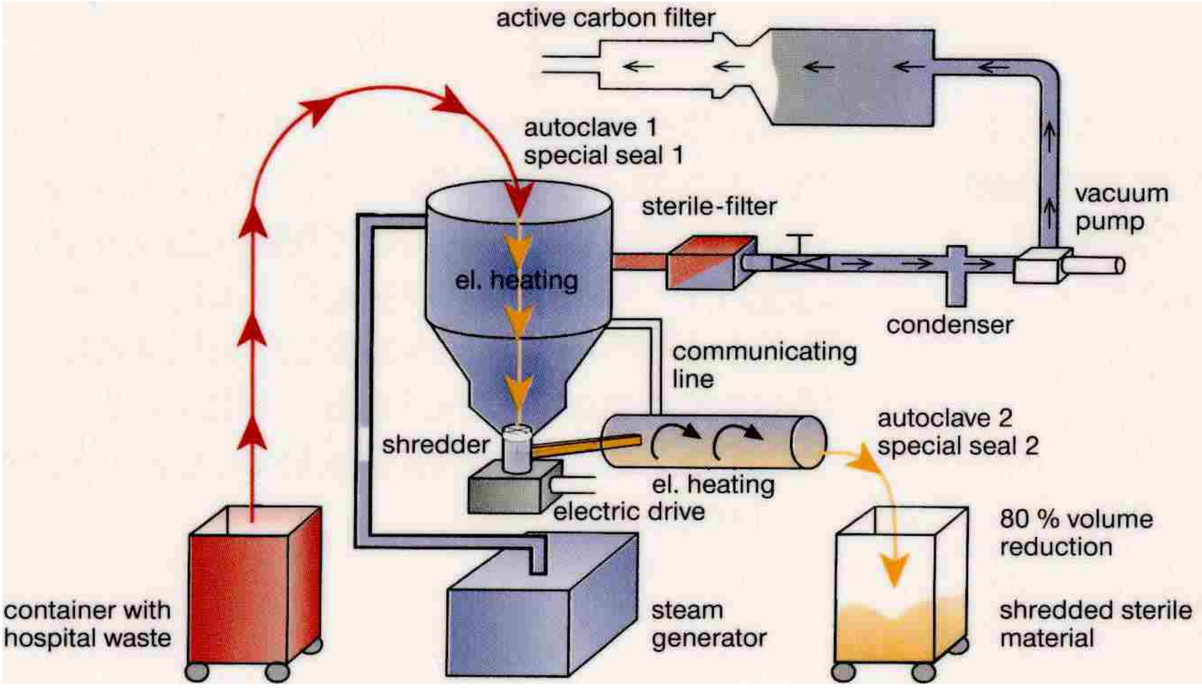
A **retort** is similar to an autoclave except that a retort has no steam jacket. It is cheaper to construct but requires a higher steam temperature than an autoclave. Retort-type designs are found in large-scale applications. The expected equipment lifetime is 10 to 15 years.

Figure 4.1a – Autoclave



Source: Finding the Rx for Managing Medical Wastes, Office of Technology Assessments, USA, September 1990

Figure 4.1b: Autoclave and shredder



Source: www.okay.co.uk/products.htm

The Shredding and Sterilization Technology - The Product and Process

Contaminated bagged waste is loaded into the SAS (shredder – autoclave-sterilization) unit and the lid is hermetically sealed. The material is then minutely shredded and then simultaneously heated, repeatedly turned over and steamed. Inside the autoclave, the waste is subjected to steam heated to 280°F and pressurized to 55 pounds per square inch for 10 minutes, which sterilizes the waste. A vacuum is then created and the air is drawn off in the process is passed through a sterile filter before it is run through an activated carbon filter and then released 'clean' back into the air. The remaining material is dried to form an inert waste which can be disposed of easily and safely.
Some benefits include:

- Complete sterilization
- Efficient shredding system
- Volume reduction the system reduces material by 80%
- Very environmentally friendly – no toxic air or water emission, no harmful substances used.
- Mobile or stationery models available - The entire Sanitec disinfection system (USA Case Study) for example is enclosed in all-weather steel housing, and is connected to the hospital's electrical and water systems. Hospital workers bring collected waste in carts to the automated lift and load system, which raises the cart and empties it into the in feed hopper. The hopper is sealed and the shredder is activated. Shredding reduces the waste's volume by 80 percent and, just as important, creates a more even waste stream that can be effectively treated at lower temperatures, minimizing the system's

overall energy consumption as well as the potential for releasing potentially harmful air emissions.

- Clean sterile waste product which is safe to transport and landfill
- Proven technology
- Low maintenance
- Low energy

System features include the following:

- Quality Assurance
    - All components are made of steel. The process control produces a continuous printed record of every batch processed.
    - The system has been thoroughly tested and certified by extremely demanding French authorities.
    - The fully automatic process has a cycle time of 40-60 min, depending upon the size of plant and the amount of waste.
    - Sterile fragments after 80% weight and volume reduction are discharged from the bottom of the autoclave and disposed off in a conventional land fill site.
- The Shredding Technique
    - The special design of shredder claws and counter rotating Shredder wheels, which change direction every 2 minutes, achieve shredding of all types of waste
- Capacities
    - 30 kg/h for T.300, approximately 300 litres of waste per hour
    - 80 kg/h for T.1000, approximately 1000 litres of waste per hour and
    - 195 kg/h for T.2000, approximately 2000 litres of waste per hour
- Supplier
    - The French Ministries of Health and the Environment have approved several non-incineration processes to treat potentially infectious wastes, including a steam system developed by Ecodas, headquartered in Roubaix. Ecodas drew upon its 20 years of experience manufacturing steam pressure autoclaves for the textile industry to design a medical waste treatment system. Jaafar Squali, managing director of Ecodas says that the innovation lies in combining a high-strength grinder with a particularly powerful sterilizer.

Table 4.1 Comparative Research about the Different Treatment Processes of Clinical Waste

TECHNOLOGY	Microbiology efficiency Niv.IV *	SHREDDING built in	CAPACITY Kg/h	INVESTMENT K Euro	COST Euro[10]/Kg
Ecodas	Yes	Yes	20 to 200	145 to 400	0.05 to 0.09
Autoclave and Shredding	No	No	400 to 500	200 to 500	0.10 to 0.14
Radiation	No	Yes	200 to 300	350 to 500	0.14 to 0.18
Microwave	No	Yes	100 to 400	435 to 600	0.12 to 0.22
Pyrolyse/Plasma	No	No	300 to 500	500 to 2000	0.14 to 0.34
Chemical	Yes	Yes	100 to 500	300 to 500	0.24 to 0.52
Incineration	Yes	No	Off Site	Off Site	0.64 to 1.04

Bacillus Stearothermophilus 8 log 10 reduction ***Source: Ecodas 2001***

The estimated cost of an Ecodas T 1000 (195 kg/hr) autoclave with shredding features incorporated is approximately US$15,500 which is approximately J$1M.

A typical operating cycle for an autoclave or retort is shown in **Figure 4.2**.

Types of Wastes Treated

The types of waste commonly treated in autoclaves and retorts are: cultures and stocks, sharps, materials contaminated with blood and limited amounts of fluids, isolation and surgery wastes, laboratory wastes (excluding chemical waste), and soft wastes (gauze, bandages, drapes, gowns, bedding, etc.) from patient care.

With sufficient time and temperature as well as mechanical systems to achieve unrecognisability, it is technically possible to treat human anatomical wastes but ethical, legal, cultural, and other considerations may preclude their treatment.

The following wastes should not be treated using this method:
- volatile and semi-volatile organic compounds
- bulk chemotherapeutic wastes
- mercury
- other hazardous chemical wastes
- radiological wastes

Emissions and Waste Residues

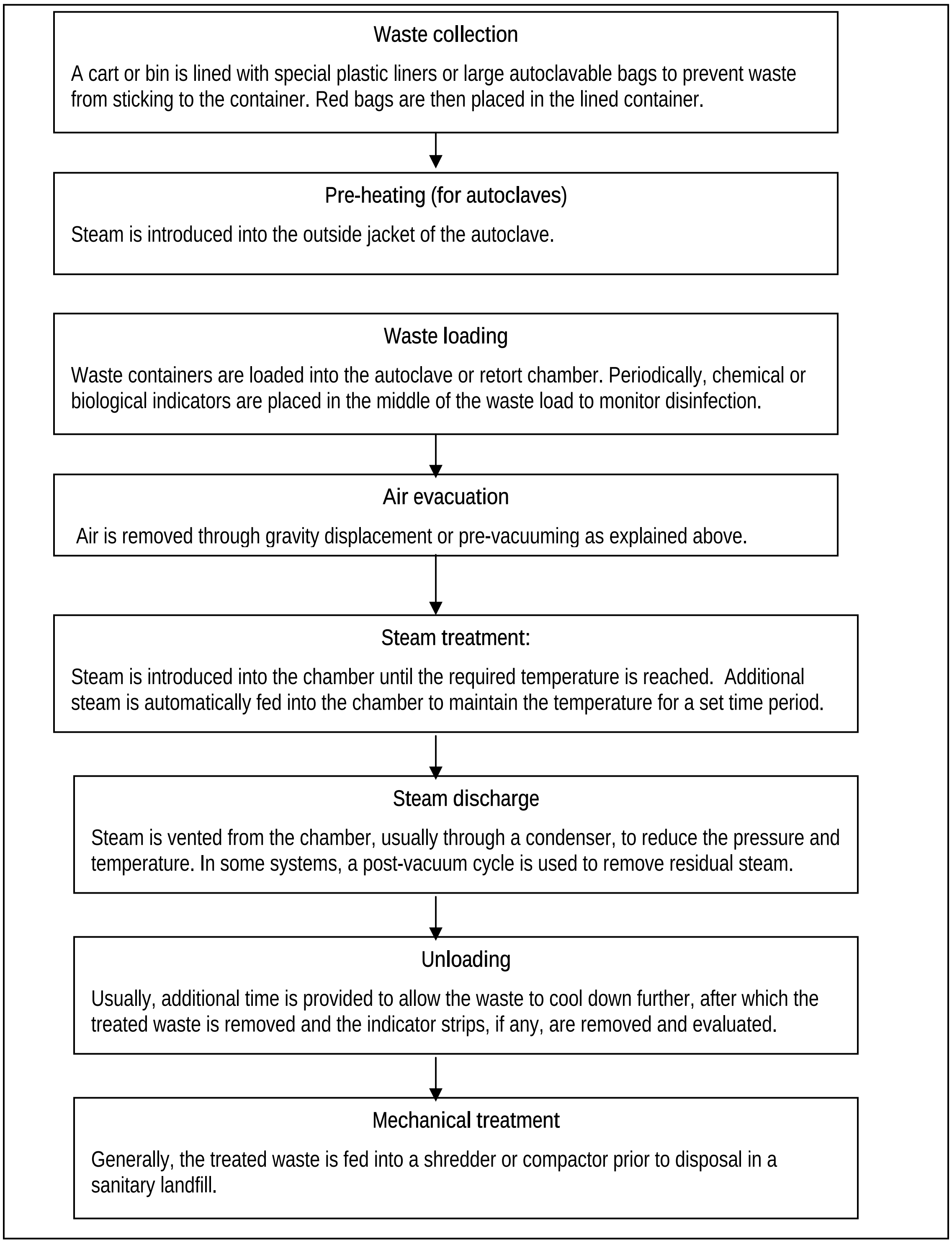
Odours can be a problem around autoclaves and retorts if there is insufficient ventilation. If waste streams are not properly segregated to prevent hazardous chemicals from being fed into the treatment chamber, toxic contaminants will be released into the air, condensate, or in the treated waste. This is the case when waste loads contaminated with antineoplastic drugs or heavy metals such as mercury are put in the autoclave. Thus,

[10] 1.2853 US$=1Euro

poorly segregated waste may emit low levels of alcohols, phenols, aldehydes, and other organic compounds in the air. Sufficient data is still not available to assess accurately the types and quantities of emissions associated with autoclaves. More independent emission tests of autoclaves operating under typical conditions are required.

Figure 4.2 - Flowchart showing the operation of an autoclave

Source: Non-Incineration Medical Waste Treatment Technologies, August 2001



Decontaminated waste from an autoclave or retort retains its physical appearance. Some landfill operators may refuse to accept treated waste that is recognisable. Since steam does not physically alter the waste in any significant way, a mechanical process such as a shredding or grinding is needed to render the waste unrecognisable. Shredding reduces the volume of the treated waste by 60 to 80 percent.

Table 4.2 – Advantages and Disadvantages of Autoclaving

ADVANTAGES	DISADVANTAGES
Steam treatment is a proven technology with a long and successful track record. The technology is easily understood and readily accepted by hospital staff and communities.	The technology does not render waste unrecognisable and does not reduce the volume of treated waste unless a shredder or grinder is added.
The time-temperature parameters needed to achieve high levels of disinfection are well-established.	Any large, hard metal object in the waste can damage any shredder or grinder.
Autoclaves are available in a wide range of sizes, capable of treating from a few pounds to several tons per hour.	Offensive odours can be generated but are minimised by proper air handling equipment.
If proper precautions are taken to exclude hazardous materials, the emissions from autoclaves and retorts are minimal.	If hazardous chemicals such as formaldehyde, phenol, cytotoxic agents, or mercury are in the waste, these toxic contaminants are released into the air, wastewater, or remain in the waste to contaminate the landfill.
Capital costs are relatively low compared to other non-incineration technologies.	If the technology does not include a way of drying the waste, the resulting treated waste will be heavier that when it was first put in because of condensed steam.
Many autoclave manufacturers offer many features and options such as programmable computer control, tracks and lifts for carts, permanent recording of treatment parameters, autoclavable carts and cartwashers, and shredders.	Barriers to direct steam exposure or heat transfer may compromise the effectiveness of the system to decontaminate waste.

Source: Non-Incineration Medical Waste Treatment Technologies, August 2001

Costs

Table 4.3 highlights a range of costs associated with the use of this technology.

Table 4.3 – Capital and Recurrent costs associated with Autoclaving

ITEM	COSTS (US$)
Cost of autoclave	26,000 – 200,000
Shredder	50,000 – 135,000
Self-contained compactor	19,000
Hydraulic bin dumper	14,500-16,500
Autoclave carts	1,100-1,500
Autoclavable bags	18-163 per 100 bags
Annual operational costs	0.05 – 0.07 per lb

Source: Non-Incineration Medical Waste Treatment Technologies, August 2001

Landfill costs must also be taken into account, but overall this treatment option is less expensive than incineration and the associated management of its ash residue. Information from the United Kingdom on the cost of incineration is approximately £450/tonne whereas heat treatment costs about £280/tonne indicating that cost savings can be achieved by autoclaving waste which is suited for that kind of treatment[11]. Further consultation is required with the Ministry of Health regarding the implementation of this option.

Microwave Systems

Microwave disinfection is essentially a steam-based process, since disinfection occurs through the action of moist heat and steam generated by microwave energy. Microwaves are very short waves in the electromagnetic spectrum. They fall in the range of the radio frequency band, above ultra-high frequency (UHF) used for television and below the infrared range. A *magnetron* is used to convert high voltage electrical energy into microwave energy, which is then transmitted into a metal channel called a *waveguide* that directs the energy into a specific area (such as the cooking area of a microwave oven or the treatment section of a disinfection unit).

What makes microwave technology an effective quick cooking device also makes it useful as a disinfection system. The waves of microwave energy cycle rapidly between positive and negative at very high frequency, around 2.45 billion times per second. This causes water and other molecules in the waste (or in food) to vibrate swiftly as they try to align themselves (like microscopic magnets) to the rapidly shifting electromagnetic field. The intense vibration creates friction, which, in turn, generates heat, turning water into steam. The heat denatures proteins within microbial cells, thereby inactivating pathogens.

Studies have shown that without water, the lethal effects of microwaves on dry microbial samples are significantly reduced. Studies have also concluded that microbial inactivation was not due to the microwave field as such but because of heat. Thus, microwave

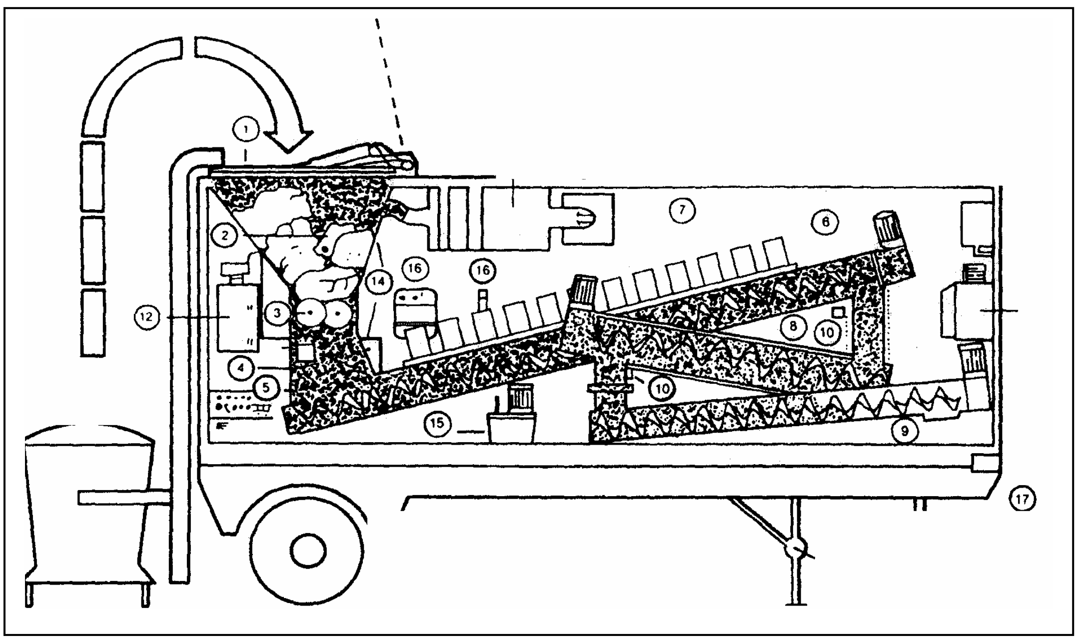
[11] Scott Crossett MBE, BSc, Waste Management Consultant, Crown Agents, London

treatment systems generally add water or steam into the waste as part of the treatment process.

Microwave units routinely treat sharps waste such as needles and wastes containing pieces of metal. It is a misconception that metals cannot be treated in the microwave disinfection system. Metals that are too large or too hard to go through the shredder, such as steel plates or prosthetic pieces, cannot be treated in the unit, but only because they would damage the shredder.

In general, microwave disinfection systems consist of a disinfection area or chamber into which microwave energy is directed from a microwave generator (magnetron). Typically, 2 to 6 magnetrons are used with an output of about 1.2 kW each. Some systems are designed as batch processes and others are semi-continuous.

Figure 4.3 Process scheme of a mobile microwave-disinfection unit



1. Feeding hopper
2. Feeding crank
3. Shredder
4. Connecting hopper with inspection window
5. Level sensors
6. Main conveyor auger
7. Microwave generators
8. Temperature holding section
9. Discharge conveyor auger
10. Temperature sensors
11. Filter system
12. Water tank with pump and spraying connection
13. Steam generator
14. Steam connection
15. Hydraulic aggregate
16. Room heater
17. Container

Source: Finding the Rx for Managing Medical Wastes, Office of Technology Assessments, USA, September 1990

The flowchart showing the operation of a microwave system is shown in Figure 4.4.

Types of Wastes Treated

The types of waste commonly treated in microwave systems are identical to those treated in autoclaves and retorts: cultures and stocks, sharps, materials contaminated with blood and body fluids, isolation and surgery wastes, laboratory wastes (excluding chemical waste), and soft wastes (gauze, bandages, drapes, gowns, bedding, etc.) from patient care. With sufficient time and temperature as well as mechanical systems to achieve unrecognisability, it is technically possible to treat human anatomical wastes but ethical, legal, cultural, and other considerations may preclude their treatment.

The following wastes should not be treated in microwave systems:
- volatile and semi-volatile organic compounds
- bulk chemotherapeutic wastes
- mercury
- other hazardous chemical wastes
- radiological wastes

Emissions and Waste Residues

If waste streams are not properly segregated to prevent hazardous chemicals from being fed into the treatment chamber, toxic contaminants will be released into the air, condensate, or in the treated waste. An independent study by the National Institute for Occupational Safety and Health (NIOSH), USA found no volatile organic compounds (VOCs) in a worker's personal air space and work area at a microwave facility that exceeded permissible exposure limits set by the Occupational Safety and Health Administration.

Figure 4.4 – Flowchart showing the operation of a microwave system

Waste Loading

Red bags are loaded into carts that attach to the feed assembly. High-temperature steam is then injected into the feed hopper. While air is extracted through a HEPA filter, the top flap of the hopper is opened and the container with medical waste is lifted and tipped into the hopper.

↓

Internal Shredding

After the hopper flap is closed, the waste is first broken down in the hopper by a rotating feed arm and ground into smaller pieces by a shredder.

↓

Microwave Treatment

The shredded particles are conveyed through a rotating conveyor screw where they are exposed to steam then heated to between 95° and 100°C by four or six microwave generators.

↓

Holding time

A holding section ensures that the waste is treated for a minimum total of 30 minutes.

↓

Optional Secondary Shredder

The treated waste may be passed through a second shredder that breaks it into even smaller pieces. This is used when sharps waste is treated in the microwave unit. The optional secondary shredder can be attached prior to operation in about 20 minutes.

↓

Discharge

The treated waste is conveyed using a second conveyor screw or auger, taking waste from the holding section and discharging it directly into a bin or roll-off container. The bin can be sent to a compactor or taken directly to a landfill.

Source: Non-Incineration Medical Waste Treatment Technologies, August 2001

The highest VOC level in the autoclave facility was 2-propanol, measured at 2318 mg/m^3. Another study of 11 VOCs (including benzene, carbon tetrachloride, chloroform, and other halogenated hydrocarbons) measured around six microwave treatment facilities showed that maximum and 8-hour concentrations were either below detection limits or well below permissible exposure limits.

Shredding of waste in the microwave unit not only enhances heat transfer but also reduces the volume of waste by as much as 80 percent. Initially, there may be a slight increase in mass due to some condensed steam. The treated waste is unrecognisable and can be disposed of in a regular sanitary landfill.

Microbial Inactivation

A microbiological study on treated waste from a microwave unit showed no growth of microorganisms (corresponding to a 7 $\log_{10}$ kill or better) for the following test organisms:

- Bacillus subtilis,
- Pseudomonas aeruginosa,
- Staphlococcus aureus,
- Enterococcus faecalis,
- Nocardia asteroides,
- Candida albicans,
- Aspergillus fumigatus,
- Mycobacterium bovis,
- Mycobacterium fortuitum, and
- Duck hepatitis.

No growth was also shown (greater than 3 $\log_{10}$ kill) for Giardia miura. Other studies show the efficacy of microwave disinfection for other microorganisms under moist conditions.

Table 4.4 – Advantages and Disadvantages of Microwave Systems

ADVANTAGES	DISADVANTAGES
Because many people have microwave ovens, it is easy for hospital staff and communities to understand and accept the technology.	If hazardous chemicals are in the waste, these toxic contaminants are released into the air or remain in the waste to contaminate the landfill.
If proper precautions are taken to exclude hazardous material, the emissions from microwave units are minimal.	There may be some offensive odours around the microwave unit.
There are no liquid effluents from some microwave units.	The secondary shredder used for sharps is noisy.
The internal shredder reduces waste volume up to 80 percent.	Any large, hard metal object in the waste could damage the shredder.
The technology is automated and easy to use. It requires one operator.	The capital cost is relatively high.

Costs[12]

Operating and maintenance costs associated with the use of microwave systems are reported to be approximately US$0.10 or US$0.07 per hour, depending on whether the system is operated 8 hours or 10 hours a day, respectively. Capital costs vary per unit and can range from US$45,000.00 to US$600,000. The use of electricity averages about US$0.02 per pound. Energy use is reportedly lower than that of an incinerator.

Dielectric Heating

Stericycle's patented proprietary Electro-Thermal Deactivation (ETD) treatment process uses an oscillating energy field of low-frequency radio waves to heat regulated medical waste to temperatures that destroy pathogens such as viruses, vegetative bacteria, fungi and yeast, without melting the plastic content of the waste which can be recycled to create new products. ETD is most effective on materials with low electrical conductivity that contain polar molecules, including all human pathogens.

Polar molecules are molecules that have an asymmetric electronic structure and tend to align themselves with an imposed electric field. When the polarity of the applied field changes rapidly, the molecules try to keep pace with the alternating field direction, thus vibrating and in the process dissipating energy as heat.

The electric field created by ETD produces high molecular agitation and thus rapidly creates high temperatures. All of the molecules exposed to the field are agitated simultaneously, and accordingly, heat is produced evenly throughout the waste instead of being imposed from the surface as in conventional heating.

This phenomenon, called volumetric heating, transfers energy directly to the waste, resulting in uniform heating throughout the entire waste material and eliminating the inherent inefficiency of transferring heat first from an external source to the surface of the waste and then from the surface to the interior of the waste material.

ETD employs low-frequency radio waves because they can penetrate deeper than high-frequency waves, such as microwaves, which can penetrate regulated medical waste of a typical density only to a depth of approximately five inches.

ETD uses specific frequencies that match the physical properties of regulated medical wastes generally, enabling the ETD treatment process to kill pathogens while maintaining the temperature of the non-pathogenic waste at temperatures as low as 90 degrees Celsius.

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[12] ***Source: Non-Incineration Medical Waste Treatment Technologies, August 2001***

Table 4.5 – Advantages and Disadvantages of Electro-Thermal Deactivation (ETD) treatment

ADVANTAGES	DISADVANTAGES
No regulated emissions or hazardous liquids or chemicals.	ETD cannot be used for destruction of radioactive medical waste, which must be destroyed by incineration.
Lower costs	
Reduces medical waste volume by 80%-85% and renders it safe and unrecognisable.	
Facilitates reuse and recycling (of plastics in particular) into new products.	
Potential to be located near to densely populated areas.	
Does not need grinding or shredding components.	
Potential for treated waste to be used as a fossil fuel substitute in cement kilns.	

Source: Non-Incineration Medical Waste Treatment Technologies, August 2001

Costs

Stericycle believes that it is less expensive to construct and operate an ETD treatment facility than to construct and operate either a like-capacity incinerator or a like-capacity autoclave with shredding capability, which may enable Stericycle to price its treatment services more competitively. They believe that the advantage of the ability to locate treatment facilities near dense population centres may provide transportation and operating efficiencies.

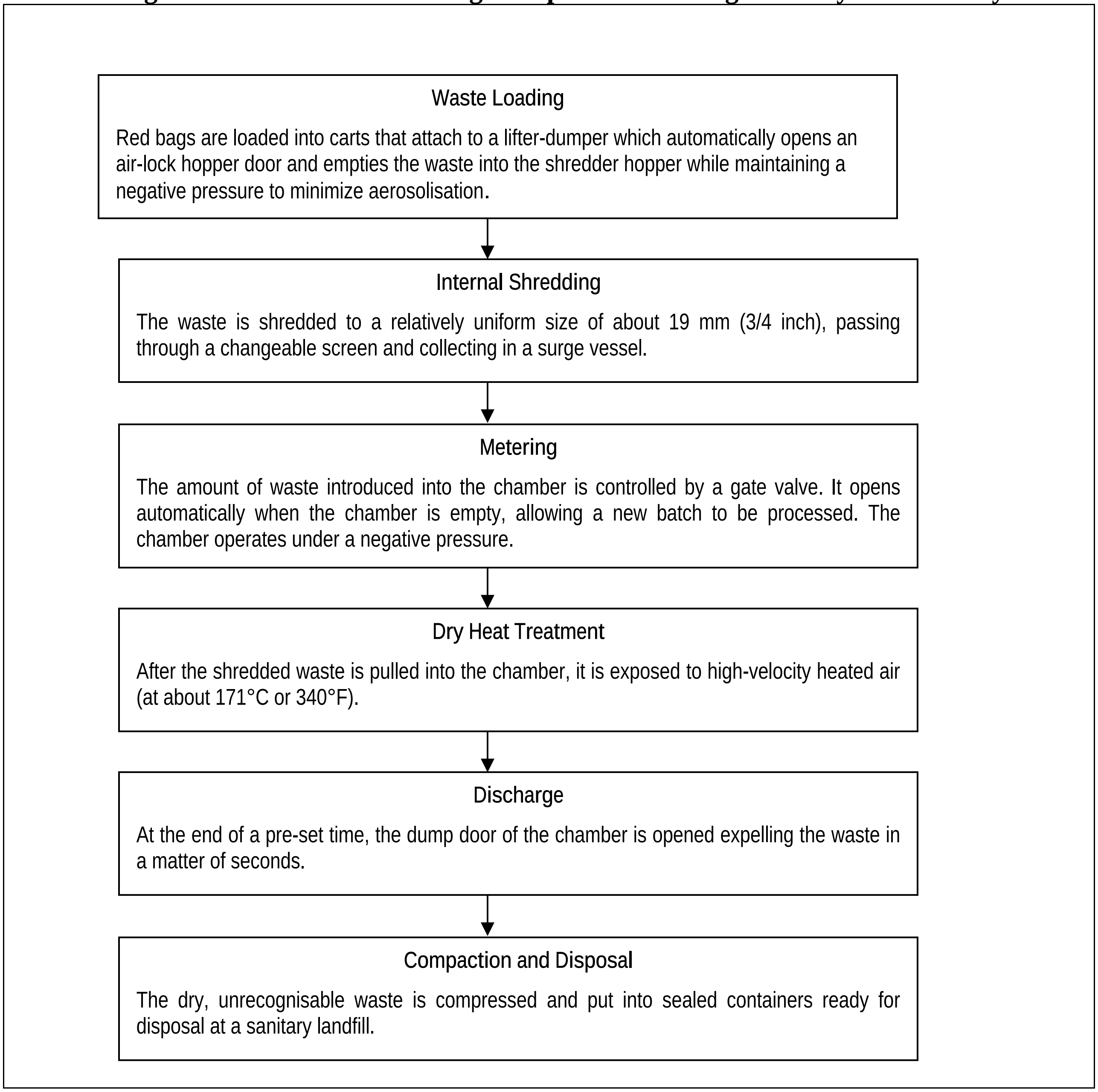
4.2.1.3 Dry Heat Treatment Systems

High Velocity Heated Air

The KC MediWaste System evolved out of efforts by Cox Sterile Products, Inc. to develop a rapid dry-heat sterilizer coupled with their adaptation of the Torbed technology by Torftech (UK), a dry-heat technology used in the processing of minerals, foods, and wastes.

The heart of the system is an air-tight stainless steel chamber into which shredded medical waste is introduced and exposed to high velocity heated air pumped into the bottom of the chamber through a ring of vanes or slots similar in design to turbine blades. The hot air is directed in a way that causes the waste particles to rotate turbulently around a vertical axis in a toroidal mixing action. Under these conditions, high rates of heat transfer take place. Within four to six minutes, dry unrecognizable waste is ejected. The waste can then be disposed of at a regular landfill.

Figure 4.5 - Flowchart showing the operation of a high velocity heated air system



Source: Non-Incineration Medical Waste Treatment Technologies, August 2001

Types of Waste Treated

The types of waste treated in the KC MediWaste System are somewhat similar to those treated in autoclaves or microwaves: cultures and stocks, sharps, materials contaminated with blood and body fluids, isolation and surgery wastes, laboratory wastes (excluding chemical waste), and soft wastes (gauze, bandages, drapes, gowns, bedding, etc.) from patient care. In addition, liquids such as blood and body fluids can also be treated in the unit. It is technically possible to treat human anatomical wastes but ethical, legal, cultural, and other considerations may preclude their treatment in this technology.

The following wastes should not be treated in the dry-heat sterilizer system:

- volatile and semi-volatile organic compounds
- chemotherapeutic wastes
- mercury
- other hazardous chemical wastes
- radiological wastes

Emissions and Waste Residues

Exhaust gases from the air pulled from the shredder hopper are filtered through a high-efficiency particulate air (HEPA) filter and a carbon filter to remove aerosolized pathogens and odours prior to discharge. The hot air from the chamber is cooled in a venturi scrubber which also removes particulates. There are some odours in the vicinity of the unit.

The conditions in the chamber do not support combustion. Therefore, the air emissions are minimal as long as waste streams are properly segregated to prevent hazardous chemicals from being fed into the chamber. There is also no liquid effluent from the chamber.

The waste residue is dry and unrecognisable. With shredding and compaction, the waste volume is reduced by about 80% and has been accepted for disposal at solid waste landfills. The mass of the dry treated waste is also reduced, depending on the amount of moisture it contained.

Microbial Inactivation

Microbiological tests using ***B. subtilis var. niger*** strips (the variety traditionally used to test for dry-heat resistance) introduced into the chamber showed a 6 log10 kill in about three minutes.

Heated air technology has the following advantages and disadvantages:

Table 4.6 – Advantages and Disadvantages of high velocity heated air systems

ADVANTAGES	DISADVANTAGES
The basic design of the treatment chamber is simple (it has been described as a popcorn popper).	If hazardous chemicals are in the waste, these toxic contaminants are released into the air or remain in the waste to contaminate the landfill.
If proper precautions are taken to exclude hazardous material, the emissions from the dry heat system are minimal.	Some slight odours may be generated near the compactor.
The technology can treat waste with varying moisture content, including blood and body fluids.	Any large, hard metal objects may interfere with the shredder.
There are no liquid effluents.	The KC MediWaste Processor is a relatively new technology.
The internal shredder and post-treatment compactor reduce waste volume by about 80 percent.	
The technology is automated and easy to use. It requires one operator.	
A combination of HEPA and carbon filters, and a venturi scrubber keep odours to a minimum.	
The treated waste is dry, unrecognisable, and compact.	

Source: Non-Incineration Medical Waste Treatment Technologies, August 2001

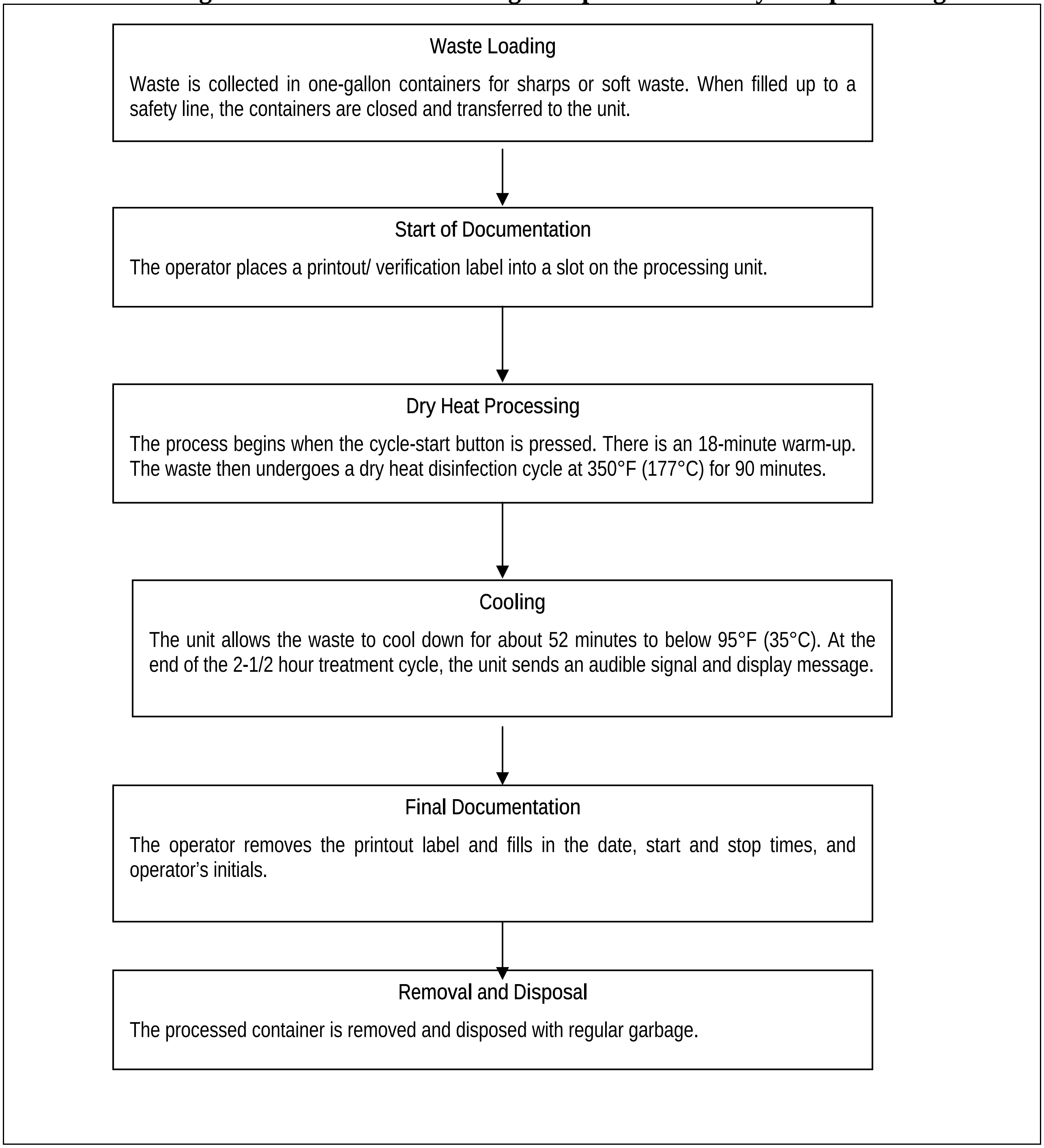
Costs

Approximate cost per unit is US$385,000.

Dry Heating

The Demolizer (Thermal Waste Technologies, Inc., formerly DOCC) is a desktop system for treating small amounts of sharps and soft “red bag” wastes at or near the point of generation. It is used in clinics, physicians’ offices, dental offices, veterinary clinics, and medical departments.

Figure 4.6 - Flowchart showing the operation of a dry heat processing



Source: Non-Incineration Medical Waste Treatment Technologies, August 2001

Types of Wastes Treated

The types of waste treated in the Demolizer include sharps and soft wastes (gauze, bandages, gloves, etc.) from patient care. Small amounts of liquid waste such as dressings soaked with blood or body fluids may also be processed, but not liquids in bulk quantities.

The following wastes should not be treated in the Demolizer system:
- volatile and semi-volatile organic compounds,
- chemotherapeutic wastes,
- mercury,
- other hazardous chemical wastes,
- radiological wastes, and
- human or animal body parts should not be treated.

The manufacturer also prohibits the treatment of:
- cultures and stocks,
- isolation waste, and
- bulk liquids

Emissions and Waste Residues

The conditions in the Demolizer treatment chamber do not produce any combustion byproducts. Emissions from the chamber are passed through a dual filtration system comprised of an activated carbon filter and a high-efficiency particulate air (HEPA) filter to remove odours and bacteria.

Exhaust from the Demolizer was tested by Valley Medical Laboratory (Springfield, MD) for microbial spores. Results using *B. stearothermophilus* showed no detectable releases of bio-aerosols from the Demolizer to the surroundings. The treated waste is dry. Although the waste retains much of its physical appearance, the waste is sealed and disposed in the processed container. The sharps waste generally melts down into a disk-shape solid plastic with metal portions embedded inside.

Microbial Inactivation

Microbiological tests were conducted to show an 8 log10 kill of *B. subtilis*. Tests also showed no growth of *Staphylococcus aureus*, *Candida albians*, *Mycobacterium fortuitum*, *Mycobacterium bovis*, and *Giardia sp*. Another test showed inactivation of duck hepatitis B virus by the Demolizer.

This technology has the following advantages and disadvantages:

Table 4.7 – Advantages and Disadvantages of Dry Heat Processing

ADVANTAGES	DISADVANTAGES
The small device—weighing about 35 pounds—is somewhat portable although designed for operation in one location. As a countertop unit, it is used at or near the point of generation and eliminates the need for on-site storage or transport of infectious waste.	If hazardous chemicals are in the waste, these toxic contaminants may concentrate in the filter, escape into the air, or remain in the solid waste to contaminate the landfill.

ADVANTAGES	DISADVANTAGES
If proper precautions are taken to exclude hazardous material, the emissions from the Demolizer are insignificant. There are no liquid effluents.	Since the unit is designed for small-volume generators, it cannot handle the waste for all of a hospital or large health care facility.
The technology is automated, easy to use, and requires a minute or so of labour time per cycle to operate. It employs microprocessor controls that have failsafe features.	The facility must purchase a single-use collection container for processing in the Demolizer. This consumable item accounts for a significant portion of the operating cost.
Odours are eliminated by a dual filtration system. The operation is virtually noiseless.	Even though sharps waste is reduced in volume by about 75 percent, the container in which the waste is disposed of does not change size and there is an insignificant loss of weight of the treated material.
The waste containers have a heat-sensitive colour changing strip to identify treated and untreated containers. They remain sealed when disposed in the trash. The device includes a print-out for labeling and documentation.	
The system has a low capital cost and requires no major installation except for a standard 110v grounded outlet.	

Source: Non-Incineration Medical Waste Treatment Technologies, August 2001

Costs

Each unit is estimated to cost US$4000.

4.2.1.4 Medium Heat Thermal Processes

Medium-heat thermal processes take place above 350°F and below 700°F. Two systems operating in this range have been referred to as reverse polymerization or thermal depolymerization.

"Polymerization" is the process of repeatedly combining a group of molecules to form a giant molecule called a polymer; rubber and plastics are examples of polymers. However, as applied to medium heat processes, the term "depolymerization" is used loosely to mean the breakdown of complex molecules into smaller ones.

Depolymerization

For the purpose of describing this technology, the **Environmental Waste International (EWI)** ***MD-1000*** will be used as an example. The technology is relatively new. The *MD-1000* directly applies high-energy microwaves to medical waste in a nitrogen atmosphere to break down the organic material. Unlike other microwave systems that heat the waste to near the boiling temperature of water, the *MD-1000* operates at temperatures high enough to cause chemical changes.

As intense microwave energy is absorbed by the waste, the internal energy of the organic material increases to a point where chemical decomposition on the molecular level happens. Since heating with microwaves occurs primarily from the inside out, the inside of the waste material reaches high temperatures but the temperature of the chamber itself remains between 150 to 350°C (300 to 662°F).

Burning can take place at the higher range of those temperatures but the nitrogen blanket forms an oxygen-depleting environment that inhibits combustion. At these temperatures, metals, ceramics, and glass are not chemically affected. The off-gases may contain hydrogen chloride which is neutralised in a scrubber, and simple hydrocarbons that are oxidized in a flare or low-flow combustor.

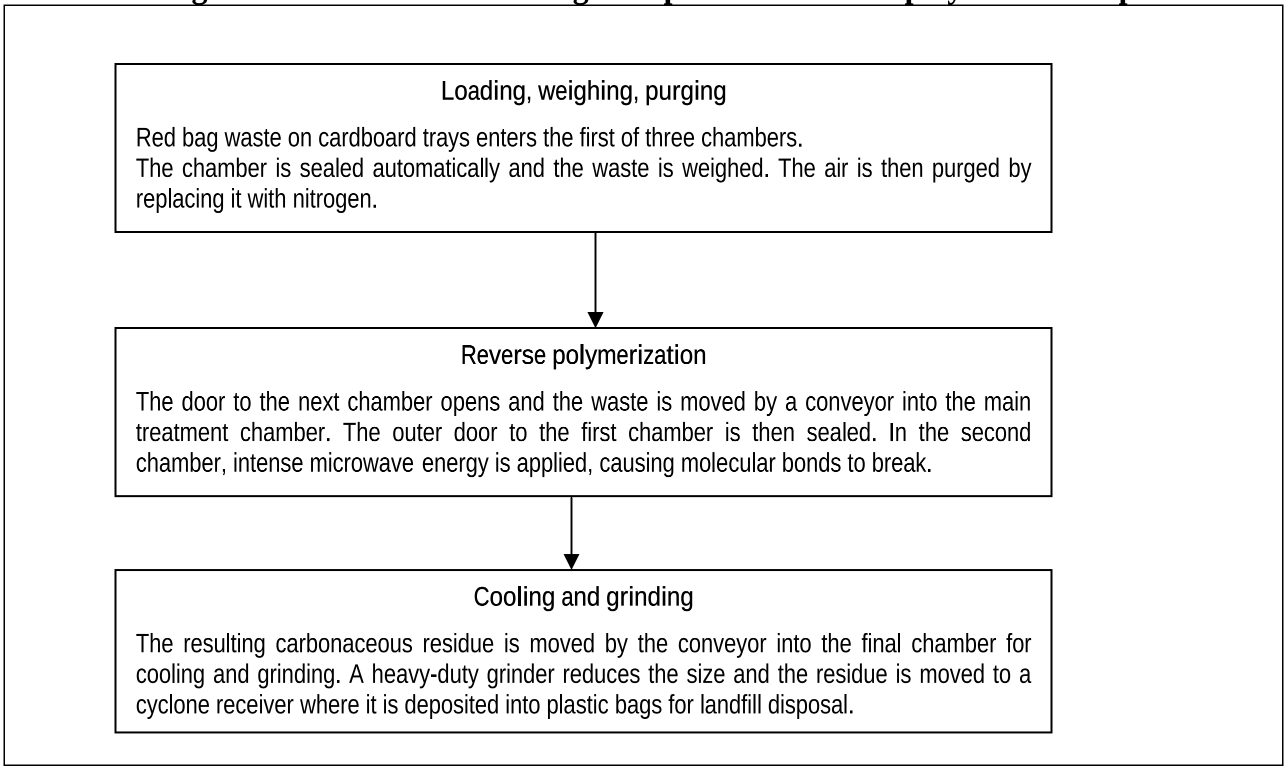
Grinding takes place after the waste has been treated. The grinder is equipped with auto reverse and overload detection.

The EWI operation is a three-stage operation involving:

1. loading, weighing, and purging;
2. reverse polymerization using microwave energy; and
3. cooling and grinding.

The complete cycle time is 50 to 80 minutes per load, depending on its mass. This corresponds to 2,700 lbs or 1,225 kg per day.

Figure 4.7 - Flowchart showing the operation of the depolymerization process



Source: Non-Incineration Medical Waste Treatment Technologies, August 2001

Types of Waste Treated

EWI reports that the *MD-1000* can treat a wide range of infectious waste including biological and anatomical waste, needles, sharps, plastics, and glass.

Emissions and Waste Residues

EWI conducted air emissions tests in 1994 from which they have computed estimates of maximum ground-level concentrations for various pollutants including simple hydrocarbons like butane, aromatic compounds like benzene and toluene, and criteria pollutants such as sulfur dioxide. The estimated concentrations were between one to six orders of magnitude below OSHA Threshold Limit Values.

In addition to air emissions, there is also wastewater from the scrubber. The solid waste residue is reportedly reduced up to about 80 percent in mass and volume.

Microbial Inactivation

Tests conducted for the manufacturer in 1997 by P. L. Seyfried of the University Of Toronto Department Of Microbiology showed a 6 $\log_{10}$ reduction for *B. stearothermophilus* spores.

4.2.1.5 High Heat Thermal Processes

High-heat thermal processes operate at temperatures above 700°F, generally ranging from around 1,000°F (540°C) to 15,000°F (8,300°C) or higher. High heat processes involve chemical and physical changes resulting in total destruction of the waste. A significant reduction in the mass and volume of the waste also occurs (90-95%). Incineration is an example of a high-heat thermal process.

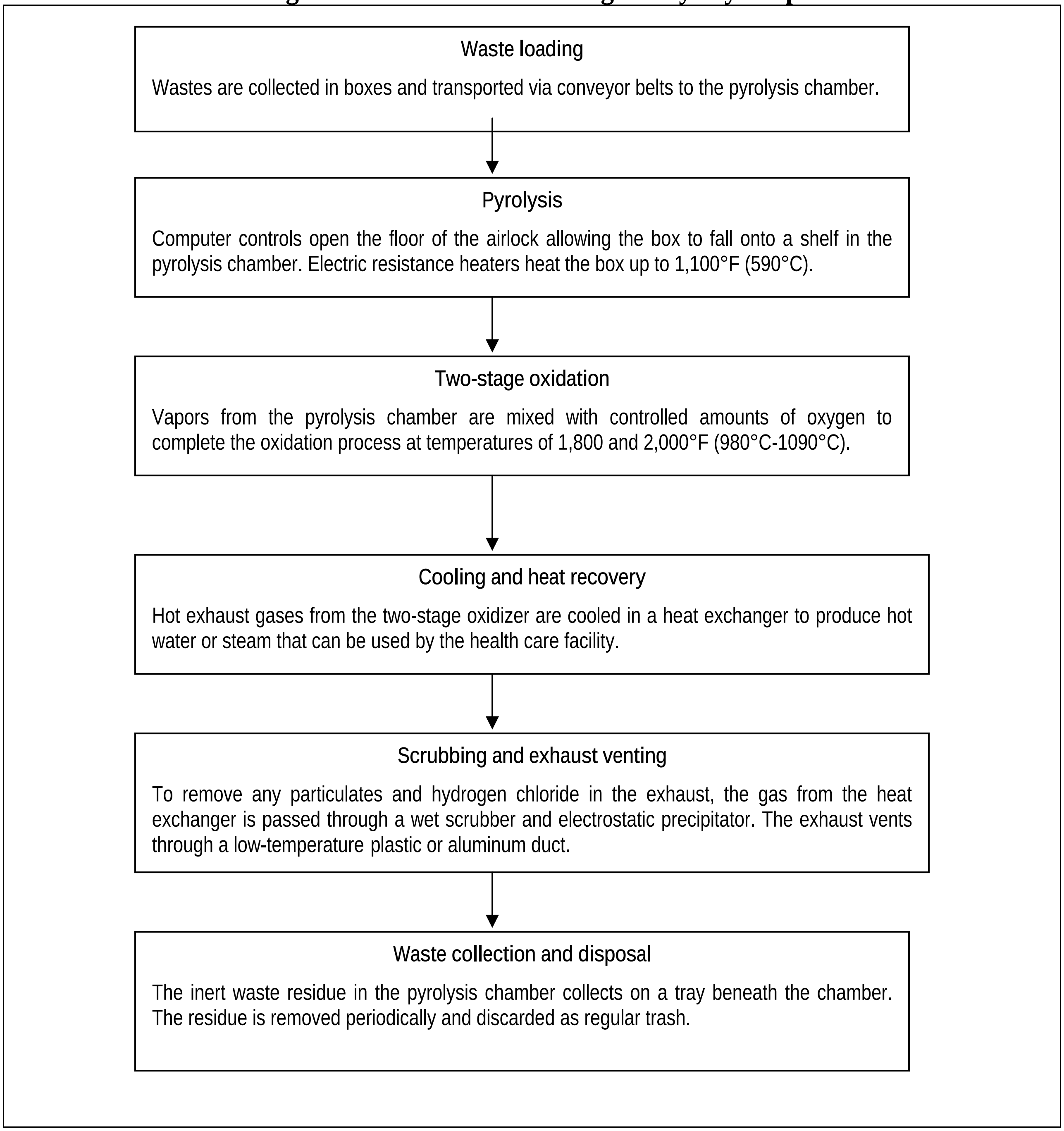
Pyrolysis – Oxidation

This treatment system involves a two step process:

A. Firstly, the waste enters a pyrolysis chamber where it is heated from 200°F to 1,100°F (93°C- 590°C). This causes organic solids and liquids to vaporise, leaving behind an inert ash including inorganic material such as glass and metal fragments.

B. In the second step, the vapours are drawn by an induced draft fan from the pyrolysis chamber into a two-stage oxidation chamber operating at 1,800°F and 2,000°F (980°C-1090°C). Controlled amounts of oxygen are added in the oxidation chamber to complete the combustion process. With the addition of pollution control devices, the result is a relatively clean exhaust stream (primarily water and carbon dioxide).

Figure 4.8 - Flowchart showing the Pyrolysis operation



Source: Non-Incineration Medical Waste Treatment Technologies, August 2001

Types of Wastes Treated

Because of its high temperatures, all wastes normally treated in an incinerator can be handled by this method. These include cultures and stocks, sharps, materials contaminated with blood and body fluids, isolation and surgery wastes, laboratory wastes, and soft wastes (gauze, bandages, drapes, gowns, bedding, etc.) from patient care. In addition, the technology can handle plastics, blood and body fluids, pathological waste, animal waste, and dialysis waste.

Technically, this technology is capable of destroying bulk chemotherapeutic waste, pharmaceutical waste, hazardous waste, and controlled substances but treating these waste streams in a health care facility may be prohibited by regulations or require special permits.

Radiological wastes and waste contaminated with mercury should **not** be treated using this method.

Emissions and Waste Residues

There are virtually no perceptible odours associated with the system, in part because of the negative pressure in the unit and the pollution control devices cleaning the exhaust stream.

There is no liquid effluent from the process. Water used in the wet scrubber is re-circulated. To reduce buildup of salt and suspended solids, some water is periodically sent to an evaporator tank where the water is vaporized and the solids are mixed with the residue from the pyrolysis chamber.

The treated waste is dry, inert, and essentially sterile. Mass reduction can be as high as 95 percent, and volume reduction may even be higher.

Microbial Inactivation

Because of the very high temperatures, the waste residue is expected to be inert and practically sterile.

Table 4.8 – Advantages and Disadvantages of Pyrolysis

ADVANTAGES	DISADVANTAGES
The process results in total destruction of medical waste with very low emission levels compared to those of incinerators. It does not require a stack; the exhaust gas vents through a low-temperature duct.	Despite lower emissions than conventional medical waste incinerators, the unit may still emits dioxin, which has been linked to serious health problems including cancer.
It can treat the wide range of medical waste (except for radiological waste and mercury).	The installed capital cost of the unit is very high in relation to its throughput capacity. The technology may not be cost-effective for small hospitals and health care facilities.
There are no liquid effluents. The waste residue is inert, unrecognisable, and	The required space and footprint of the system is large compared to other

ADVANTAGES	DISADVANTAGES
essentially sterile and can be disposed in a regular landfill. Mass and volume reductions of 95 percent or greater are achieved.	technologies of the same capacity.
The process recovers up to 80 percent of the heat in the form of hot water or steam.	The facility has to purchase boxes of the correct dimensions to fit the waste entry section.
There are almost no odours and very little noise during operation. Despite high temperatures in the pyrolysis chamber and oxidizer, the surfaces of the unit are at about room temperature.	
A bar code system provides documentation that can be stored electronically or printed out by the computer.	
The system is fully automated, requiring only a few minutes of operator time per hour. The loader automatically loads boxes as needed.	
The conveyor system is ergonomically designed to minimise lifting.	

Source: Non-Incineration Medical Waste Treatment Technologies, August 2001

Advanced Thermal Oxidation

Unlike the other high heat technologies mentioned above, which operate under pyrolytic conditions, advanced thermal oxidation is a combustion process (it has been called an "advanced incinerator"). However, unlike traditional dual-chamber incineration where waste is burned inside a primary chamber in a "starved air" mode, this technology uses an oxygen-rich fast-burn process.

Advanced oxidation technology differs from traditional incineration in at least three basic ways:

1. The waste is shredded internally into small particles before being burned;
2. The shredded particles are injected at high speed into the primary chamber where they are carried by a rapidly swirling, oxygen-rich hot vortex generated by multiple gas burner jets located strategically inside the chamber; and
3. Combustion gases are rapidly quenched using liquid mist injectors. In addition, the residence times are longer in the primary and secondary chambers—up to 3.5 seconds in each chamber, compared to a 1-second residence time in the secondary chamber of many traditional incinerators.

Moreover, the secondary chamber of the advanced oxidation technology operates at higher temperatures than in traditional incinerators. The entire process is computer controlled. These design differences are significant in that they allow a more efficient and complete combustion than traditional incinerators and minimise the temperature range at which dioxins and furans are formed.

The Process

NCE Corporation's **TurboClean** is an advanced thermal oxidation system for medical waste using a patented "flash-burn," oxygen-rich, high-temperature combustion process. Medical waste is shredded using a four-shaft shredder assembly with an auger and sizing screen to provide good feed control.

Shredded particles of about half a pound or less are injected one at a time with air into a high-speed vortex in a primary chamber operating between 1850° to 2,000°F (1,010° to 1,093°C). Thermal oxidation is rapid and efficient under these conditions.

Ash is removed at the bottom, while the combustion gases flow into a secondary chamber at 2,000 to 2,150°F (1,093° to 1,177°C) to complete the combustion process. To withstand the high temperatures, the chambers use a lightweight, space-age product used for space shuttle reentry. The hot combustion gases are quenched rapidly to 325°F in a cooling chamber and liquid mist injectors. The gas is cleaned in packed bed absorbers and a venturi section to remove particulates before exiting the exhaust duct at a temperature of about 150°F.

The TurboClean is composed of loader, shredder, material injection system, primary and secondary chambers, cooling chamber, a 30 HP turbo fan, liquid mist injectors, and liquid filtration system. Volume and mass reductions as much as 97 percent or more may be achieved. The standard throughput rate is 200 lbs/hr, but higher capacity units could be designed. It is highly automated. A data acquisition system monitors sensors throughout the process. No special skills are required to operate the equipment.

Wastes to be treated

The TurboClean can handle all wastes normally treated in an incinerator including cultures and stocks, sharps, materials contaminated with blood and body fluids, isolation and surgery wastes, laboratory wastes, soft wastes, blood and body fluids, pathological waste, animal waste, chemotherapeutic wastes, and dialysis waste.

The technology is also being tested for destruction of illegal drugs, contraband, and coded material.

The following wastes should not be treated using this technology:
- aerosol cans,
- machine oils,
- batteries,
- large metal objects,
- radioactive material,
- x-ray film,

- lead containers,
- mercury, and
- other materials containing toxic metals

Costs

The 200-lb/hr unit costs about $776,000 and is in the very initial stage of commercialization.

4.2.2 Chemical Based Technologies

Hospitals and other health care facilities have used chemical agents routinely for decades, in applications ranging from disinfecting reusable instruments to general cleaning of work surfaces. When applied to medical waste treatment, the main problem is how to ensure contact between the chemical and infectious waste with a high enough concentration and sufficient exposure time to achieve proper levels of disinfection. Chemical-based disinfection technologies generally incorporate internal shredding and mixing to resolve the problem of contact and exposure. To maintain the proper concentration, chemical technologies must be able to replenish chemicals lost through volatilization, decomposition, adsorption on waste surfaces, and interaction with microorganisms. Other factors such as pH, temperature, and the presence of other chemicals that may interfere with the disinfection process should also be considered.

Depending on the nature of the chemicals, occupational exposures of workers to concentrations in the air and through skin contact may be a concern. Since many chemical-based technologies release substantial quantities of liquid effluent or wastewater into the sewer, the releases must comply with limits set in effluent discharge permits/licences. In addition, it is important to determine what the long-term environmental consequences of those releases might be.

In the past, the most common chemical disinfectants for treating medical waste were chlorine-based because of the ability of chlorine and hypochlorite to inactivate a broad range of microorganisms. Solutions of sodium hypochlorite (bleach) were regularly used. Recently, non-chlorine chemical disinfectants have been introduced into the market, such as peroxyacetic acid (also known as peracetic acid), glutaraldehyde, sodium hydroxide, ozone gas, and calcium oxide. Some of these are commonly used in disinfecting medical instruments.

The use of chemical disinfectants can be divided into two categories: chlorine and non-chlorine treatment systems.

Types of Wastes Treated

The types of waste commonly treated in chemical-based technologies are:

- cultures and stocks,
- sharps,
- liquid human and animal wastes including blood and body fluids (in some technologies, this may be limited to a certain percentage of the waste),
- isolation and surgery wastes,

- laboratory waste (excluding chemical waste), and
- soft wastes (gauze, bandages, drapes, gowns, bedding, etc.) from patient care.

Ethical, legal, cultural, and other considerations may preclude treatment of human anatomical wastes in chemical treatment systems.

The following wastes should not be treated using this method:

- Volatile and semi-volatile organic compounds,
- chemotherapeutic wastes,
- mercury,
- other hazardous chemical wastes, and
- radiological wastes

Large metal objects may damage internal shredders.

Emissions and Waste Residues

Since chemical processes usually require shredding, the release of pathogens through aerosol formation may be a concern. Chemical-based technologies commonly operate as closed systems or under negative pressure passing their air exhaust through HEPA and other filters. These safeguards should not be compromised.

Another issue relates to occupational exposures to the chemical disinfectant itself through fugitive emissions, accidental leaks or spills from storage containers, discharges from the treatment unit, volatilized chemicals from treated waste or liquid effluent, etc. Chemical disinfectants are sometimes stored in concentrated form, thus increasing the hazards.

The study by the National Institute for Occupational Safety and Health (NIOSH) found no volatile organic compounds (VOCs) in a worker's personal air space and work area at a mechanical/chemical treatment facility that exceeded permissible exposure limits set by the Occupational Safety and Health Administration. The highest VOC level in the facility was ethanol, measured at 4732 mg/m3.

Microbial Inactivation

Microorganisms vary in their resistance to chemical treatment. The least resistant are vegetative bacteria, vegetative fungi, fungal spores, and lipophilic viruses; the more resistant organisms are hydrophilic viruses, mycobacteria, and bacterial spores such as *B. stearothermophilus.*

Tests of microbial inactivation efficacy should be conducted to show that a 10_4 kill or greater of at least *B. stearothermophilus* spores is achieved at the chemical concentrations and treatment conditions of normal operation of the technology.

Table 4.9 – Advantages and Disadvantages of Chemical Treatment

ADVANTAGES	DISADVANTAGES
The technologies using sodium hypochlorite have been used since the early 1980s and have a long track record. The process is well-understood.	There are concerns of possible toxic byproducts in the wastewater from large-scale chlorine and hypochlorite systems.
The technologies are well-automated and easy to use.	Chemical hazards are a potential problem with chemical-based systems.
Liquid effluents generally can be discharged into the sanitary sewer.	If hazardous chemicals are in the waste, these toxic contaminants are released into the air and wastewater, remain in the waste to contaminate the landfill, or they may react with the chemical disinfectant forming other compounds which may or may not be hazardous.
No combustion byproducts are produced.	Noise levels, such as from a hammermill process or a shredder, can be very high.
If the technology incorporates shredding, the waste is rendered unrecognisable.	There may be some offensive odours around some chemical treatment units.
	Any large, hard metal object in the waste can damage mechanical devices such as shredders.

Source: Non-Incineration Medical Waste Treatment Technologies, August 2001

4.2.3 Irradiation Technologies

When electromagnetic radiation has high enough energy to knock out electrons from their atomic orbits, it is referred to as ***ionizing radiation***; examples are x-rays and gamma rays. ***Non-ionizing radiation***, such as microwaves and visible light, do not have sufficient energy to remove electrons. If ionizing radiation interacts with a cell, its main target is the DNA in the nucleus. At sufficiently high doses of ionizing radiation, extensive damage is done to DNA leading to cell death. The ionizing radiation also creates so-called free radicals that cause further damage by reacting with macromolecules in the cell (e.g., proteins, enzymes, etc.).

Ionizing radiation can be obtained using radioactive materials, such as **Cobalt-60**, that emit high-speed gamma rays. **UV-C** or ultraviolet radiation in the C range (253.7 nm), also known as germicidal or shortwave UV, is another kind of ionizing radiation and can destroy cells under the proper conditions. UV-C can be generated using special lamps and had been employed as a supplement to alternative treatment technologies to inactivate aerosolized pathogens from shredders and other mechanical devices.

Another technique for producing ionizing radiation is to use an “electron gun” from which a beam of high-energy electrons is propelled at high speed to strike against a target. When energy is applied to a material (called a *cathode*) with loosely bound electrons, a stream of electrons is released.

The **electron beam** can be focused using electric and magnetic fields to cause it to bombard a target (called the *anode*). The energy of the electrons measured in *electron-volts* (eV) is determined by the voltage difference between the cathode and anode, and by the current.

If infectious waste is in the path of the beam, the electron shower destroys microorganisms by chemical dissociation, the rupture of cell walls, and destruction of DNA and other macromolecules. As e-beams strike metals in the waste, x-rays may also be produced. These x-rays also interact with molecules causing chemical bonds to break. The e-beam converts some oxygen in air into ozone, which itself has disinfecting and deodorizing properties. The high-energy electrons, together with x-rays, free radicals, and ozone, destroy viruses, fungi, bacteria, parasites, spores, and other microorganisms, as well as odours in the waste.

Electron beam technologies are highly automated and computer controlled. In general, e-beam systems consist of:

- a power supply;
- a beam accelerator where the electrons are generated, accelerated, and directed towards the target;
- a scanning system which delivers the required dose; a cooling system to cool the accelerator and other assemblies;
- a vacuum system to maintain a vacuum in the accelerator; a shield to protect workers;
- a conveyor system to transport the waste; and sensors and controls.

The shielding system could be in the form of a concrete vault, an underground cavity, or an integral shield around the treatment area. E-beams do not alter the physical characteristics of the waste except perhaps to raise the temperature a few degrees. As such, e-beam technologies require shredders or other mechanical device in the post-processing stage to render the waste unrecognisable and reduce waste volume.

Types of Wastes Treated

The types of waste commonly treated in an e-beam technology equipped with a mechanical destruction process are:

- cultures and stocks,
- sharps,
- materials contaminated with blood and body fluids,
- isolation and surgery wastes,
- laboratory waste (excluding chemical waste), and
- soft wastes (gauze, bandages, drapes, gowns, bedding, etc.) from patient care.

Ethical, legal, cultural, and other considerations may preclude treatment of human anatomical wastes.

The following wastes should not be treated in e-beam units:

- volatile and semi-volatile organic compounds,
- chemotherapeutic wastes,
- mercury,

- other hazardous chemical wastes, and
- radiological wastes

Emissions and Waste Residues

E-beam systems do not create any pollutant emissions except possibly for small amounts of ozone which breaks down to diatomic oxygen (O_2). The residual ozone helps remove odours and contributes to the disinfection process in the treatment chamber, but it should be converted back to diatomic oxygen before being released into the environment or workspace.

The waste residue looks exactly as it did before treatment, since e-beam irradiation does not change the physical characteristics of the waste. Therefore, a mechanical process is needed to render the treated waste unrecognizable and reduce volume. E-beam systems may contain lead in the shielding; the lead should be recycled or treated as hazardous waste after the e-beam unit is decommissioned.

Microbial Inactivation

Bacteria exhibit varying degrees of resistance to radiation, depending, in large part, on their ability to repair damage to their DNA from irradiation. Depending on the dose, bacterial cells may not be killed outright but their ability to reproduce is impaired. *B. stearothermophilus* and *B. subtilis* spores have been recommended for demonstrating microbial inactivation by irradiation. However, *B. pumilus* spores are more resistant to irradiation and have been used as a standard biological indicator in the sterilization of medical products by irradiation. Other biological indicators even more resistant to radiation, such as *Deinococcus radiodurans*, can provide a very stringent measure and add a margin of safety, if needed.

Table 4.10 – Advantages and Disadvantages of E-beam systems

ADVANTAGES	DISADVANTAGES
The basic technology has been used in other applications for about two decades and is familiar to hospital staff involved in cancer therapy.	Personnel must be protected from radiation exposure.
E-beam technology does not produce any toxic emissions (except for small amounts of ozone) and there are no liquid effluents.	If an integral shield is not part of the design, the e-beam system requires a concrete shield several feet thick or an underground structure, either of which adds significantly to the installed capital cost.
Unlike cobalt-60, there is no ionizing radiation after the machine is turned off.	Ozone off-gas needs to be removed before the exhaust is released to the atmosphere.
It is a room-temperature process and nothing is added to the waste – no steam, water, chemicals, heated air, etc.	In relation to food irradiation, some groups have raised the possibility that low-levels of radioactivity may be induced. This is an area that needs more investigation.
The technology is well-automated and requires little operator time.	The basic technology does not reduce waste volume or make the waste

ADVANTAGES	DISADVANTAGES
	unrecognisable unless a shredder or other mechanical device is added as a post-treatment step.
The e-beam technology itself (i.e., excluding shredders or compactors) is noiseless.	Any large, hard metal object in the waste can damage any shredder or grinder.
It has a low operating cost.	

Source: Non-Incineration Medical Waste Treatment Technologies, August 2001

Costs

Because of their relatively high capital investment (US$350,000 per unit) and low staffing requirements, sterilization systems are normally operated around the clock on a two or three-shift basis. Most E-beam systems will maximize their effective performance at usage levels above 7000 operating hours per year. The cost of operating an E-beam system can range from as low as $50/hr for a smaller in-line system to $150/hr for a large-volume stand-alone sys-tem. Normal operating expenses include the cost of staffing, electrical power, maintenance, and supplies.

Depending on the size of the system, operation will require from one to four material or box handlers. A trained electronics technician should be on call during system operation, and would also perform routine preventative maintenance and equipment-calibration tasks.

Power consumption is directly related to the accelerator's kilowatt power, with smaller in-line systems running at approximately $4/hr and larger ones at $15-$20/hr.

The cost of replacement parts for spent electronic components makes up the majority of maintenance expense, with most components having fairly well-known service lives ranging from 10,000 to 25,000 hours (mean time before failure).

E-beam systems require regular purchase of dosimetry supplies, with the cost of radiochromic films averaging $3 per hour of system operation.

4.2.4 Biological Processes

Biological processes employ enzyme mixtures to decontaminate medical waste. The resulting sludge is put through an extruder used to remove water for sewage disposal. The technology is suited for large applications (10 tons/day) and is also being developed for use in the agricultural sector to break down animal waste.

An emerging biological treatment technology was developed after six years of research and development work involving resources from Virginia Tech, The University of Virginia, and The Medical College of Virginia. The system has a delivery hopper, grinder with HEPA filter, reaction chamber tank where waste is exposed to a solution of enzymes and a separator where the slurry is separated into liquid and solid waste streams. The liquid is sent to the sewer and solid waste is send to a landfill (the solids from animal waste may be recycled as compost). The technology requires regulation of temperature, pH, enzyme level, and other variables. The unit is being designed for a regional medical waste treatment centre.

4.2.5 Mechanical Processes

Mechanical processes such as shredding, grinding, hammermill processing, mixing, agitation, liquid-solid separation, conveying (using augers, rams, or conveyor belts), and compaction, supplement other treatment processes. Mechanical destruction can render the waste unrecognisable and is used to destroy needles and syringes so as to minimise injuries or to render them unusable. In the case of thermal- or chemical-based processes, mechanical devices such as shredders and mixers can also improve the rate of heat transfer or expose more surfaces to chemical disinfectants. Mechanical processes can add significantly to the level of maintenance required.

A mechanical process is supplementary and cannot be considered a treatment process on its own. Unless shredders, hammermills, and other mechanical destruction processes are an integral part of a closed treatment system, they are usually not used before the waste is decontaminated as workers would be exposed to pathogens released to the environment by mechanical destruction. If mechanical processes are part of a system, the technology is designed in such a way that the air in and from the mechanical process is disinfected before being released to the surroundings. It is especially important for air to be drawn into the mechanical process (away from the inlet) when waste is being fed. This is often done using a draft fan which maintains a negative pressure in the mechanical processing chamber; air taken from the mechanical process passes through the disinfection chamber or through a high efficiency particulate air (HEPA) filter before being released to the environment.

Shredders, grinders, and hammermills are commonly used size reduction equipment. Other terms, such as granulators, particlizers, and cutters, are also used. In general, size reduction is accomplished by shearing the material between two surfaces (as in shredders) or by impact against a solid surface (as in hammermills). A screen is usually added to control the size of particles that exit the device. Sometimes, a ram is used to push the waste through the shredder or grinder.

Shredders are designed with hardened steel cutting knives, hooks, disks, or blades mounted on rotating shafts. These knives cut against stationary knives on the casing (single-shaft shredders) or against other knives mounted on one or more counter-rotating shafts (multiple-shaft shredders). Because waste material can get lodged between the blades, many shredders used for medical waste are equipped with reverse action, e.g., when an overload occurs, the normal rotating motion is stopped and a reverse rotating motion is used to clear the obstruction. This action maybe repeated several times automatically. If the blockage is still not removed, the shredder shuts off and the operator is sent an audio-visual or electronic alert. Removing the blockage then requires manual operation. Shredders generally operate at low speed and high rotation force.

Grinders refer to size-reduction equipment using a series of rollers that operate at high speed. Terms like crusher and pulverizer are also used. When the rollers are equipped with teeth or knives, they operate much like multiple-shaft shredders, which is why the terms shredder and grinder are sometimes used interchangeably. A hammermill has a rotating shaft with swinging T-shaped steel hammers or beaters mounted on it. As the hammermill rotates at high speed, waste is crushed by the hammers against a plate. Hammermills tend to be noisier and use more energy.

All these devices are maintenance-intensive. Hammers need periodic resurfacing, dull cutting knives need sharpening, and worn or broken shredder blades need to be replaced. Some shredders and grinders have a breakaway pin to protect the shaft during those rare but inevitable times when a prosthetic steel joint ends up in the shredder. When that happens, it is safer and easier to replace the breakaway pin than to replace the entire shaft. However, hard metal objects would likely cause shredder blades to break or chip especially if the device has automatic reverse action. Mechanical devices should have an alternative way of disinfecting the waste in the event that the equipment needs to be opened for repair; otherwise service personnel could be exposed to pathogens. In addition to metal parts that can dull or chip shredder blades, soft waste such as cloth, gauze, or moist paper can also cause problems by wrapping around shredder blades and shafts.

Some hot (molten or softened) plastics can flow around shredder parts and harden upon cooling. Some equipment can handle these problems better than others. When considering a technology that has a grinder or shredder, facilities should evaluate the size-reduction equipment based on real-world experiences of other facilities dealing specifically with medical waste. They should also inquire about: safety; overload protection; how the equipment handles temporary obstructions; alternative disinfection procedures during repairs; average life span of blades, cutting knives, hammers, and other items that wear out; cost of sharpening and of their replacement; and preventive maintenance procedures, among others. The amount of wear depends on the types of waste treated. For example, treating sharps may result in more frequent replacement than treating soft wastes. Access to repair and maintenance records of facilities that have installed the specific device could be valuable in evaluating the reliability of different size-reduction equipment.

Unrecognisability

Mechanical destruction processes can render the waste unrecognisable. Even where there is no “unrecognisability” requirement, municipal landfill operators may refuse to accept the waste even if it is treated (disinfected) but still remains recognisable. “Unrecognisability” is beneficial from an aesthetic perspective, as an indication that the waste has been treated and because rendering the waste unrecognizable usually entails a reduction in waste volume—an obvious benefit in areas where landfill space is limited.

Table 4.11 Summary of the Significant Environmental Impacts associated with the Proposed Alternatives to the Project

TECHNOLOGY	SIGNIFICANT ENVIRONMENTAL IMPACTS	ADVANTAGES/DISADVANTAGES OF TECHNOLOGY
THERMAL PROCESSES **(a) Low Heat**		
Wet Heat • Autoclaves and Retorts • Microwaves	• Odours related to process • Potential release of toxic chemicals • Potential release of toxic chemicals • Offensive odours	Waste must be shredded for unrecognisability. It is technically possible to treat human anatomical wastes but ethical, legal, cultural, and other considerations may preclude their treatment in this technology. The following wastes should not be treated using this method: • volatile and semi-volatile organic compounds • bulk chemotherapeutic wastes • mercury • other hazardous chemical wastes • radiological wastes
Dry Heat • High Velocity Treated Air	• Potential release of toxic contaminants to the atmosphere and the landfill • Slight odours	It is technically possible to treat human anatomical wastes but ethical, legal, cultural, and other considerations may preclude their treatment in this technology. The following wastes should not be treated in the dry-heat sterilizer system: • volatile and semi-volatile organic compounds • chemotherapeutic wastes • mercury • other hazardous chemical wastes • radiological wastes
(b) Medium Heat Depolymerization	Emissions and wastewater from scrubbers	Grinding required to make waste unrecognisable. Relatively new technology
(c) High Heat Pyrolysis-Oxidation	May emit dioxins Disposal of ash from processing	Technically, this technology is capable of destroying bulk chemotherapeutic waste, pharmaceutical waste, hazardous waste, and controlled substances but treating these waste streams in a health care facility may be prohibited by regulations or require special permits. Radiological wastes and waste contaminated with

TECHNOLOGY	SIGNIFICANT ENVIRONMENTAL IMPACTS	ADVANTAGES/DISADVANTAGES OF TECHNOLOGY
		mercury should **not** be treated using pyrolysis – oxidation. Also the capital cost is very high in relation to its throughput capacity. Space requirements are large.
Advanced Thermal Oxidation	May emit dioxins Disposal of ash from processing	This technology can handle all wastes normally treated in an incinerator including cultures and stocks, sharps, materials contaminated with blood and body fluids, isolation and surgery wastes, laboratory wastes, soft wastes, blood and body fluids, pathological waste, animal waste, chemotherapeutic wastes, and dialysis waste. The following wastes should not be treated using this technology: • aerosol cans, • machine oils, • batteries, • large metal objects, • radioactive material, • x-ray film, • lead containers, • mercury, and • other materials containing toxic metals It is in the very initial stage of commercialization.
CHEMICAL PROCESSES Chlorine and Non-chlorine Based Systems	• Worker exposure to effects of chemicals • Release of pathogens through aerosol formation • Spills and leakage of chemicals • Toxic by-products released in wastewater • Noise levels from any mechanical equipment used • Offensive odours	Grinding required to make waste unrecognisable. Large metal objects may damage internal shredders. Ethical, legal, cultural, and other considerations may preclude treatment of human anatomical wastes in chemical treatment systems. The following wastes should not be treated using this method: • volatile and semi-volatile organic compounds, • chemotherapeutic wastes, • mercury, • other hazardous chemical wastes, and • radiological wastes

TECHNOLOGY	SIGNIFICANT ENVIRONMENTAL IMPACTS	ADVANTAGES/DISADVANTAGES OF TECHNOLOGY
IRRADIATION PROCESSES	• Potential worker exposure to radiation • Potential release of ozone gas	E-beam technologies require shredders or other mechanical device in the post-processing stage to render the waste unrecognisable and reduce waste volume. Ethical, legal, cultural, and other considerations may preclude treatment of human anatomical wastes. The following wastes should not be treated in e-beam units: • volatile and semi-volatile organic compounds, • chemotherapeutic wastes, • mercury, • other hazardous chemical wastes, and • radiological wastes This technology is highly automated and computer controlled.
BIOLOGICAL PROCESSES	Disposal of liquid and solid wastes	The technology is suited for large applications (10 tons/day)
MECHANICAL PROCESSES	• Worker exposure to pathogens • Exposure to elevated noise levels • Offensive odours • Not aesthetically pleasing	Mechanical processes such as shredding, grinding, hammermill processing, mixing, agitation, liquid-solid separation, conveying (using augers, rams, or conveyor belts), and compaction, supplement other treatment processes. Mechanical processes can add significantly to the level of maintenance required.
"DO NOTHING" ALTERNATIVE	Emissions from inefficient incinerator	Existing incinerator at the UHWI is not operating properly.

Most of the alternative methods to incineration presented above have one or two disadvantages when compared to incineration.

- They are significantly more expensive
- They require additional mechanical equipment such as shredders to render the waste unrecognisable and reduce volume
- They have limitations in the type of waste that can be burned e.g. cytotoxic, pathological and chemotherapeutic waste
- The technologies are relatively new

Autoclaving with shredding and compaction however is a technologically and financially feasible alternative to incineration. The technology is proven as it has been in use for decades and the effectiveness of the technology has been improved by having the shredding function integral to the process. It will achieve the same volume reduction and sterilisation as incineration without the adverse impacts of hazardous emissions. The capital cost of the autoclave/shredder system is significantly less than the cost of an incinerator with the same waste throughput and the operating cost is about 1/5 of the cost of operating an incinerator.

4.2.6 Third Party Services

At this time it is not feasible for the University Hospital to depend on a third party for incineration services as most of the hospitals within reasonable proximity do not have properly functioning incinerators. Additonally there is no other known medical waste treatment facility offering service in Jamaica.

However if the UHWI was to install a new medical waste treatment system they could offer third party services to other healthcare facilities for a fee for use of either an autoclave or an incinerator.

Figure 4.9
Functional Ministry of Health Incinerators

- St. Ann's Bay Hospital
- May Pen Hospital
- Mandeville Hospital

Source: Scott Crossett MBE, BSc, Waste Management Consultant, Crown Agents, London

5.0 DESCRIPTION OF BASELINE/AFFECTED AREA

The University Hospital of the West Indies is located in the northeastern section of the parish of Kingston and St. Andrew (See Location Map at Figure 5.1). Adjacent to the hospital is the University of the West Indies, Mona Campus, a regional tertiary education institution. Geographically it is nestled between the Long Mountain to the southwest and the Dallas Mountains to the northeast. It is near to a small commercial community called Papine. This community has a wide range of shops and eating establishments and is also home to another tertiary education institution, University of Technology (UTECH). The community off August Town is situated to the south consisting of residences and light commercial establishments such as shops, eating establishments and bars.

Northwest of the hospital is the residential community of Mona Heights. This area is also home to a number of schools namely:

- Mona Primary
- Mona High
- Mona Preparatory

Situated to the east of the hospital is the Mona Reservoir which is a major source of potable water for the parish of Kingston and St. Andrew. Directly east of the Hospital are the residential community of Mona Commons and a squatter community which has been the source of concern for the hospital and other residents in the area.

5.1 Rainfall

It is located in the rain shadow of the Blue Mountains and therefore like the rest of Kingston does not benefit from significant rainfall. The average annual rainfall for Kingston is less than 1500 mm. Like most parts of Jamaica, Kingston experiences two wet seasons, May to June and September to November. The driest periods are from December to March.

5.2 Temperature

Apart from rapid temperature fluctuations associated with afternoon showers and or the passage of frontal systems, Kingston's temperatures like the rest of the island are fairly constant all year round under the moderating influence of the warm waters of the Caribbean Sea. For Kingston the average daily temperature is 26.2 degrees Celsius, with an average maximum of 30.3 degrees Celsius and an average minimum of 22 degrees Celsius. The coolest months are December to February and the warmest are from June to August.

5.3 Wind

For most of the year, the daily wind pattern is dominated by the northeast trades. During the day, along the south coast, the sea breeze combines with the trades to give an east-southeasterly wind at an average speed of 34 km/h. From December to March, however, the trades are weakest and the local wind regime is a combination of trades, sea breeze and a northerly or north-westerly component associated with cold fronts and high pressure areas from the United States of America.

During the night, the trades combine with land breezes which blow offshore down the slopes of the hills near the coasts. As a result, on the south coast, night-time winds generally have a northerly component with a mean speed of 13 km/h. By day, from June to July mean onshore winds often reach a maximum of up to 48 km/h along the south coast during the mid-afternoon.

5.4 Sunshine

Variations in sunshine form month to month in any are usually small, approximately 1 hour. Differences, however, are much greater between coastal and inland stations.

Maximum day length occurs in June when 13.2 hours of sunshine are possible and the minimum day-length occurs in December when 11.0 hours of sunshine are possible. However, the mean sunshine in mountainous areas is less than 6 hours per day, while in coastal areas it is near 8 hours per day. The shorter duration in hilly areas is due mainly to the persistence of clouds.

5.5 Relative Humidity

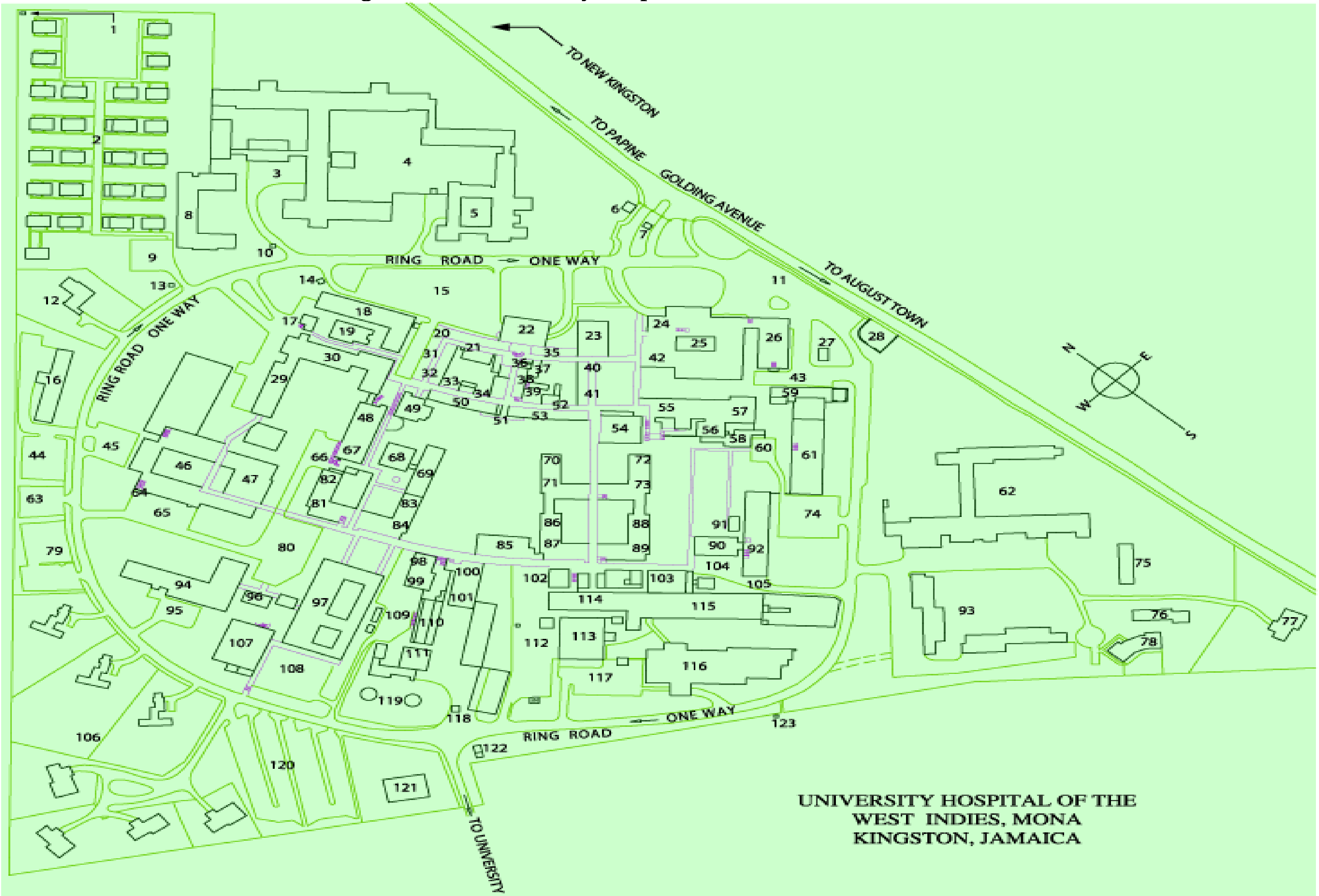
Afternoon showers are the major cause of most daily variations in relative humidity. Highest values are recorded during the cooler morning hours near dawn, followed by as decrease until early afternoon when temperatures are highest. Relative humidity values in the plains will average about 77% reflecting the effects of afternoon showers in nearby hills.

5.6 The Construction Site

The site for construction is adjacent to the existing power generating unit and across the road from the incinerator currently in use. Figures 5.1, 5.2 and 5.3 show various views of the location of the site for the new incinerator and the stack from the existing incinerator in the background.

Figure 5.1 – Location Map

Figure 5.2 University Hospital of the West Indies Site Plan



UHWI MONA

1	Security Post	31	Medical Out Patient	61	Psychiatry Ward	91	Occupation Therapy
2	Nurses Quarters	32	Ecg, Emg	62	Junior Doctors Accommodation	92	Specialist wards: Orthopaedics, ophthalmology, Otolaryngology & Dermatology
3	Car Park	33	Staff Clinic	63	Car Park	93	Registrars Townhouses
4	Nurses Homes	34	Bank, Tam.	64	Mona Institute of Medical Science Polyclinic	94	Tropical Metabolism Research Unit
5	Schools of Nursing	35	Pulmonary	65	Car Park	95	Car Park
6	Security Post	36	Cashier Collections	66	Car Park	96	C.H.A.R.E.S.
7	Main Gate	37	Registrations, Admissions	67	Obstetrics	97	Paediatrics Wards 14, 15, &16
8	Sisters Quarters	38	Health Insurance, Social Work	68	Diagnostic Unit	98	Upper Floor Sewing Room & Paediatrics Doctors Lounge
9	Car Park	39	Medical Records Assessments	69	Family Planning	99	Lower Floor Linen
10	Security	40	Surgical Outpatients	70	Lower Floor, Ward 1 Surgical	100	Upper Floor Cafeteria
11	Car Park	41	Ent & Psychiatric Clinics	71	Upper Floor Ward 3 Medical	101	Lower Floor Kitchen
12	Residence	42	Pharmacy	72	Lower Floor Ward 2 Surgical	102	Upper Floor Dietary Department Director of Nursing
13	Security Post	43	Car Park	73	Upper Floor Ward 4 Medical	103	Lower Floor Depart of Anaesthetics
14	Security Post	44	Car Park	74	Car Park	104	Car Park
15	Car Park	45	Car Park	75	Store	105	Security
16	Post Graduate	46	Faculty of Medical Science	76	Store	106	Residences
17	Mortuary	47	School of Medical Science	77	Residence	107	Medical Library
18	Rippel Building	48	Top Floor, Delivery, Mid Floor, Nursery	78	Children's Daycare	108	Car Park
19	Laboratory	49	cardiology	79	Car Park	109	Car Park
20	Haematology	50	Gynaecology Clinic	80	Car Park	110	Maintenance Workshops
21	Child Clinic	51	Chief of Security	81	Lower Floor Ward 10	111	Boilers
22	Administration & Medical Files	52	Chemotherapy	82	Upper Floor Ward 12	112	Car Park
23	Orthopaedics	53	Physiotherapy	83	Upper Floor Ward 11	113	Intensive Care Unit
24	Ambulatory Care	54	Nuclear Medical & School of Radiography	84	Ground Floor Ward 9	114	Central Sterilising Department
25	Minor Operation	55	Mammography & Ray Department	85	Kidney Dialysis Unit	115	Operating Theatres
26	Accident & Emergency	56	Cat Scan & Ultrasound	86	Lower Floor Ward 5 Burns Unit	116	Tony Thwaites Wing
27	Volatile Store	57	Catheterisation	87	Upper Floor Ward 7 Medical	117	Car Park
28	Electric Substation	58	Mir	88	Lower Floor Ward 6 Surgical	118	Security
29	Microbiology	59	Min Mart Cafeteria	89	Upper Floor Ward 8 Medical	119	Fuel Tanks
30	Pathology	60	Car Park	90	Eye Clinic & Operating Theatre	120	Car Park
						121	Main Generator
						122	Electricity Substation

Making reference to the site plan for the hospital at Figure 5.2, the existing incinerator is located adjacent to location 111 (the boilers) and the proposed incinerator will be located adjacent to the standby power generation plant at location 121.

Figure 5.3- Picture taken from the site for the new incinerator showing the stack of the existing incinerator across the road

Figure 5.4 Site for new incinerator (in the foreground) adjacent to the standby power generating plant

Figure 5.5 Site for new incinerator adjacent to the standby power generating plant

6.0 SIGNIFICANT ENVIRONMENTAL IMPACTS OF CONSTRUCTION, OPERATION OF THE NEW INCINERATOR AND MITIGATION MEASURES

Most of the significant environmental impacts that can likely arise from the construction and operation of the new incinerator can be mitigated once appropriate precautions are in place. The following tables define the environmental impacts, their source and the recommended mitigation measures.

6.1 Construction of the new Incinerator

Table 6.1 Environmental Impacts and Mitigation Measures Associated with Construction

ENVIRONMENTAL ASPECT	ENVIRONMENTAL IMPACTS	MITIGATION MEASURES
Air Pollutants ***a. Dust*** Fugitive dust generated during the excavation of the site and the construction of the control room for the incinerator comprising total suspended particulates and PM_{10}, generated during the excavation of the site and the construction. Cement dust is likely to be a major source of TSP and PM_{10}.	Dusting at the paediatric wing which is situated across from the construction location will be an irritant to both workers and patients. May cause, contribute to and exacerbate respiratory illnesses. Affects flora adversely and impacts negatively on the aesthetics of surroundings	Ensure that there is regular wetting of the site during excavation. Erect fencing to keep dust within the confines of the site. Ensure that workers wear personal protective gear such as dusk masks or respirators to reduce their exposure to pollutants.
Air Pollutants ***b. Emissions*** Emissions from heavy equipment such as excavators, tractors and trucks will be generated more than usual during the construction period.	Local impacts from emissions would affect the health of workers at the construction site, staff at the hospital and possibly patients as well. May affect patient recovery. Emissions and their associated (global) impacts are: • carbon dioxide and monoxide, green house gases which contributes to global warming • low level ozone and particulates contribute to smog • particulates which contribute to respiratory discomfort and can aggravate conditions such as asthma • oxides of sulphur and nitrogen (SOx and NOx) which contributes to the generation of acids	Equipment to be used on site should be in optimal working condition and throughout the duration of the project should be regularly serviced to reduce pollution.

ENVIRONMENTAL ASPECT	ENVIRONMENTAL IMPACTS	MITIGATION MEASURES
	which can adversely affect flora and fauna as well as buildings. Increased emissions of these types are of concern within the hospital environment which seeks to treat illnesses and provide an environment that facilitates recovery from illnesses.	
Noise Noise associated with construction activities and the movement of heavy equipment such as excavators, backhoes and trucks delivering material and aggregate and carting away waste. Noise associated with hammering during erection of the control room and the new stack will also be generated.	Irritating to site workers with the potential of impairing hearing, nuisance to hospital staff and patients. May affect patient recovery. Increased noise is of particular concern within the hospital environment which seeks to treat illness and provide an environment that facilitates recovery from illnesses.	Equipment to be used on site should be in optimal working condition and throughout the duration of the project should be regularly serviced to reduce noise. Little can be done to reduce the impact of noise levels on the nearby patients except to schedule all activities that will create above normal noise levels to periods acceptable to the hospital administration and patients as far as possible. Will only persist for the duration of construction.
Solid Waste Solid waste comprised of the following: • soil and vegetation from excavation • packaging e.g. cement bags • wood and steel scraps • food waste e.g. plastic bottles, Styrofoam containers, plastic bags, food scraps	Improperly managed solid waste can lead to the harbouring of pests, rodents and vermin. It will affect the aesthetics of the hospital premises and increase sedimentation which may cause blockage of drains during rainfall events. Nails, scrap steel etc. may cause a safety hazard if not secured.	Arrangements must be made to minimise the quantity of waste generated in the first place. Where possible formwork should be reused to get the maximum usage out of the wood before disposal is required. There should be designated containers for the disposal of solid waste. Arrangements must be in place for the periodic disposal of this waste at the Riverton Disposal site depending on the rate of waste generation and the size of the storage containers to be used..

ENVIRONMENTAL ASPECT	ENVIRONMENTAL IMPACTS	MITIGATION MEASURES
		Where waste consists of stockpiles of earth or rubble, berms should be in place to prevent the washing away of the material during rainfall.
Wastewater Wastewater will be generated from construction activities such as mixing cement and washing down of work areas. There will also be wastewater generated from soil and aggregate stockpiles during rainfall. Sewage will be generated by workers at the construction site.	Stormwater with high sediment loading may cause gullies and drains to become filled with sediments and trash which reduce their effectiveness and eventually result in flooding. If proper arrangements are not made for sanitary conveniences for the workers, sewage disposal may become a serious sanitation problem causing odours, generation of pests and other potential health problems.	Where waste consists of stockpiles of earth or rubble, berms should be in place to prevent the washing away of the material during rainfall. Arrangements must be made for temporary sanitary conveniences for workers so that sewage disposal is not a problem.

6.2 *Operation*

Table 6.2 Environmental Impacts and Mitigation Measures Associated with Operations

ENVIRONMENTAL ASPECT	ENVIRONMENTAL IMPACT	MITIGATION MEASURES
Air pollutants A medical waste incinerator releases into the air a wide variety of pollutants including dioxins and furans, metals (such as lead, mercury, and cadmium), particulate matter, acid gases (hydrogen chloride and sulphur dioxide), carbon monoxide, and nitrogen oxides. The principal air pollutants that may be generated during the operation of the facility will be emissions from the operation of the incinerator. The expected pollutants include: • Particulate Matter (PM) • Carbon Monoxide (CO) • Sulphur Dioxide (SO_2) • Hydrogen Chloride (HCl) • Volatile Organic Carbons (VOCs) • Polychlorinated Biphenyls • Antimony • Arsenic • Cadmium • Chromium • Copper	Possible adverse impacts include: • Deterioration of air quality, with particulates in particular causing, contributing to and exacerbating respiratory illnesses • Deterioration of water quality, negative effects on flora and fauna and buildings due to the formation of acids from oxides of nitrogen and sulphur (NOx and SOx) • The effect of toxins (persistent organic pollutants) such as dioxins and PCBs which have the greatest long term health effects on animals at the top of the food chain (such as humans) causing adverse effects upon reproduction and development, suppression of the immune system, disruption of hormonal systems, and cancer • Negative health effects from the dispersion of mercury found in discarded and broken mercury-containing equipment such as mercury thermometers which are incinerated along with other infectious wastes. Mercury which is a toxin, bio-accumulates in the human body over time when inhaled and causes serious health and environmental effects. • Negative impacts on human health, flora and fauna and contamination of land and water from heavy metals	Segregate medical waste so that waste that does not have to be incinerated is excluded. This will reduce the loading on the incinerator. Further segregation of the infectious/hazardous waste is required to ensure that radioactive wastes and materials which contain heavy metals are excluded from the waste stream. Minimise or eliminate where possible the use of pvc containing materials at the hospital especially where alternatives are available. This will reduce the quantity of dioxins produced during incineration. Discarded or broken medical equipment such as mercury thermometers, sphygmomanometers, blood pressure devices, dilation and feeding tubes must not be incinerated. They should be placed in a sealed leak-proof package and arrangements should be made with the National Solid Waste Management Authority to see if they will take the waste and place it in a designated (hazardous) waste cell at the Riverton disposal site. It should be noted however that the Riverton disposal site was originally a dumpsite and it is not designed to take hazardous wastes so this special arrangement may not be available and if so it is likely to come at a cost. The hospital should:

ENVIRONMENTAL ASPECT	ENVIRONMENTAL IMPACT	MITIGATION MEASURES
• Mercury • Nickel • 2,3,7,8-tetrachlorodibenzo-p-dioxin • Chlorinated dibenzo-p-dioxins	Globally there is the contribution to global warming by the emission of greenhouse gases such as carbon monoxide and dioxide.	• identify all mercury containing equipment • implement a mercury free purchasing policy • implement a mercury reduction programme to phase out the use of mercury containing equipment over time Solid and liquid low-level radioactive wastes with short half-lives should be stored in a container at the hospital until they decay. (The actual storage time depends on the half-life of the radioactive materials present.) After the wastes are analyzed for radioactivity to confirm that they have decayed, they can be disposed of as ordinary trash. This method of handling low-level waste is called storage for decay. Employ the use of pollution abatement equipment on the incinerator. A combination of APC devices should be utilized as part of the mitigation measure to safeguard against non-compliant chlorinated dioxin concentrations. This combination should be a wet scrubber and a fabric filter. It must be noted that non-incineration technologies can also have toxic emissions (although research indicates that these occur in smaller amounts).
Noise Noise will be generated by the operation of the incinerator.	This noise may be irritating to those working in close proximity to the incinerator.	Unlikely to be significant or noticeable if the incinerator is kept in optimal working condition and is serviced according to the manufacturers

ENVIRONMENTAL ASPECT	ENVIRONMENTAL IMPACT	MITIGATION MEASURES
		maintenance requirements.
Spills of hazardous/infectious waste Based on the proposed location of the new incinerator, the infectious waste will need to be transported across the road which is the main thoroughfare used by patrons of the UHWI. Infectious /hazardous waste spills may occur.	Possible public health hazard if staff and the public come into contact with waste.	Have a designated crossing defined on the main road so that motorists are aware that they may need to stop to facilitate the movement of waste across the road. Designate times when traffic flow is low to move waste across the road if possible, to reduce the possibilities of accidents. If waste is likely to be moved when it is dark, the carts should have fluorescent markings for easy identification at night. They should also be marked with the internationally recognised symbol for hazardous/infectious waste. Use an enclosed leak and puncture proof cart to transport waste across the road. Carts must be regularly inspected to ensure there are no defects which can cause leakage of the contents or spills. The Emergency Response Plan will address potential spills and workers will be trained on the actions that are to be taken if such an event were to occur.
Oil/Fuel Spills Oil spills can occur within the building housing the incinerator as well as outside at the fuel tank	Oil/fuel can enter the drainage system and either contaminate the sewage treatment facility or if released to the environment, it can contaminate land and water	The fuel tank will be surrounded by a bund wall to contain up to 1.5 times the contents of the fuel tank in case of a spill. All washdown from inside the incinerator building will be directed to a sump equipped with an oil/water separator to trap and filter oil from wastewater before it is discharged to the drains.

ENVIRONMENTAL ASPECT	ENVIRONMENTAL IMPACT	MITIGATION MEASURES
		Arrangements for the proper disposal of the waste oil collected in the oil/water separator will be made. An emergency response plan will be developed with detailed procedures for preventing and handling spills Workers handling waste for incineration and operating the incinerator must be attired in protective gear to prevent contact with infectious waste or burns associated with incineration.
Ash disposal Ash generated as a result of incineration of medical waste has concentrated quantities of heavy metals and other hazardous substances. Dioxins and furans may be found in the bottom ash. In cases where low-level radioactive waste is incinerated, the ash residue may also contain traces of radioactive isotopes. Fly ash (ash that is carried by the air and exhaust gases up the incinerator stack) contains heavy metals, dioxins, furans,	If improperly contained, transported and disposed ash may pose a public health risk to those coming into contact with it as well as it may contaminate water and land resources.	Segregate waste to ensure that radioactive wastes and materials which contain heavy metals are excluded from the waste stream as far as possible. Workers removing ash from the incinerator must be attired in protective gear to prevent inhalation of the fine particles and skin contact. Bottom ash and fly ash must be containerized in a leak proof container and sent to Riverton disposal site for disposal. Special arrangement should be made with the National Solid Waste Management Authority for receiving this waste due to the special handling required.

ENVIRONMENTAL ASPECT	ENVIRONMENTAL IMPACT	MITIGATION MEASURES
and other toxic chemicals that condense on the surface of the ash. Even when the fly ash is removed from the exhaust stream by pollution control devices such as baghouse filters, the toxic materials remain concentrated on the filter cake and should be treated as hazardous waste.		

6.2.1 Potential Positive Impacts from New Incinerator

Potential positive impacts from the installation of a new incinerator at the UHWI include:

- Improved air quality as the incinerator will use 3% sulphur oil and will be fitted with pollution abatement equipment
- Potential for better segregation of medical wastes to exclude radioactive and hazardous (heavy metals) waste once new waste management practices are implemented
- Improved storage of infectious waste awaiting incineration
- Potential for better handling and disposal of ash from incinerator once new waste management practices are implemented
- Lower fuel costs as new incinerator would burn fuel more efficiently
- Potential to earn revenue from charging fees to other healthcare facilities for incinerating their waste which can be used to offset operational costs
- NEPA's Licence requirements will establish the framework for a good monitoring and maintenance programme which should seek to prevent problems rather than react to them

6.2.2 Cost Implications associated with Mitigation Measures

Construction

The mitigation measures for the construction phase should be included as line items in the Bills of Quantities in the tender document so that the bidders are sure to cost these items and can be held accountable for them during construction. It is not possible to estimate these costs as they will vary depending on the contractor, the number of construction workers, and condition of heavy equipment.

Operation

In many instances it is not possible to define the cost of the mitigation measures as further information on the quantity of each the waste stream that comprise medical waste at the hospital are known. However the activities and equipment that will have costs associated with them are listed below in Table 6.3.

Table 6.3 Cost Implications associated with Mitigation Measures

MITIGATION MEASURES	COST IMPLICATIONS
Segregate infectious/hazardous waste to ensure that radioactive wastes and materials which contain heavy metals such as mercury are excluded from the waste.	• Special containers for storage of radioactive wastes • Special location (room) equipped with shield for worker safety, for the storage of low-level radioactive waste with short half lives. Size of room and number of containers is dependent of the quantity of radioactive waste which has not yet been quantified. • An inventory system for radioactive wastes in storage and a labeling system with the name of the radioisotope, the date of storage and the half life must be developed.

MITIGATION MEASURES	COST IMPLICATIONS
	• Special containers for mercury contaminated wastes – the sharps box currently being used by the hospital could be utilised for this purpose but they would need to be labeled appropriately to distinguish them from the sharps container • Special arrangements with NSWMA for disposal of hazardous wastes will be at a cost. These costs are determined on a case by case basis by the NSWMA, if they choose to accept the waste • If NSWMA does not agree to accept hazardous waste they will have to be stored by the UHWI until a hazardous waste site is established
Use alternatives to pvc and mercury containing materials	Some alternatives may cost more, but most are about the same.
Pollution abatement equipment on the incinerator.	This cost is included in the cost of the incinerator (US$ 185,000)
Leak and puncture proof cart to transport waste across the road.	The cost of the carts is included in the cost of the incinerator and accessories.
Bund wall surrounding the fuel tank to contain up to 1.5 times the contents of the fuel tank in case of a spill.	Cost to be included as a line item in the Bills of Quantities for the construction of the incinerator room and installation of the incinerator.
Oil water separator to capture spills or oil contaminated wastewater from the Incinerator room	• Cost to be included as a line item in the Bills of Quantities for the construction of the incinerator room and installation of the incinerator. • Current arrangement for Shell to collect oily waste from another sump at the hospital can be extended to cover this area
Personal Protective Equipment (PPE) for the persons handling the medical waste	• The hospital already purchases PPE for medical personnel and for the persons who currently handle the medical waste that is incinerated. There should be no additional cost. • Contracts with waste management service providers must have provisions for personnel being attired with PPE

6.3 Screening Model of Stack Emissions

The incinerator being selected is a single hearth, controlled-air system. The facility will have two (2) chambers and will be capable of handling 1600 kg of waste per day, seven days per week, or a burning rate of 200 kg per hour, using an 8-hour workday. The facility will utilise No. 2 diesel oil, with a maximum input of 30 L/hr and 132 L/hr to the primary and secondary chambers respectively.

6.3.1. Assessment Methodology

The assessment methodology follows the guideline specified in the Natural Resources Conservation Authority Ambient Air Quality Guideline Document of 1999. The document recommended that a screening model be utilised as the first tier to determine the impact of the emissions from the proposed incinerator.

The Screen View model estimates the maximum ground-level concentrations and the distance from the base of the stack to where the maximum concentrations occur. It has the following features:

- Incorporation of the effects of building downwash on the maximum concentrations for both the near wake and far wake regions
- Estimation of concentrations in the cavity re-circulation zone
- Incorporation of the effects of simple elevated terrain on maximum concentrations
- Estimation of 24-hour average concentrations due to plume impaction in complex terrain using the VALLEY model 24-hour screening procedure
- Calculation of the maximum concentration at any number of user-specified distances in flat or elevated simple terrain
- Examination of a full range of meteorological conditions, including all stability classes and wind speeds to find maximum impacts
- Incorporation of the input of source parameters, including emission rate, stack height, stack inside diameter, stack gas exit temperature, stack gas exit velocity, ambient air temperature, incinerator building height, length and width
- With the exception of the 24-hour estimate for complex terrain impacts, the results from SCREEN are estimated maximum 1-hour concentrations.

For this particular project, since a number of buildings are nearby the proposed site location for the incinerator (including the proposed incinerator building), building downwash was applied. The site location is adjacent to elevated terrain and some complex terrain features, and hence both complex and elevated terrains were considered. The full range of meteorological conditions, including all stability classes and wind speeds were also considered for the modeling analysis. For all model runs, the urban dispersion coefficient was applied.

6.3.2 Emission Estimation

A significant step in conducting the air dispersion model was the use of emission rates from the proposed incinerator. These rates were estimated in accordance with the recommendation outlined in the Ambient Air Quality Guideline Document. According to Davis & Associates (1999), emission rates are estimated in the following order of preference:

- Stack Testing
- Manufacturer’s emission data
- Mass balance calculations
- Emission factors
- Engineering calculations

Now since a new unit is being proposed, stack testing data is not applicable. Also, there were no manufacturer's emission data available for the proposed unit. Therefore, certain mass balance calculations were conducted, but not for all the parameters since they were not applicable in all cases. Consequently, the safest estimates were the use of the emission factors from the United States Environmental Protection Agency (USEPA) AP-42 Listing. Care was taken to perform back-up checks using the mass balance methodology for certain parameters.

Table 6.4 shows the emission rates that were calculated using emission factors from the USEPA AP-42 List. The pollutants identified include all the criteria pollutants as well as those described in the Priority Air Pollutant list that can possibly be emitted from an incinerator. The emission rates were calculated by the following formula:

Emission Rate = Emission Factor x Waste Feed Rate

Table 6.4: Emission Rates for Proposed Incinerator

Pollutants	**Emission Factors, lb pollutant/ton waste**[13]	**Emission Rates, g/s**
Particulate Matter (PM)	4.67	0.118
Carbon Monoxide (CO)	2.95	0.0745
Sulphur Dioxide (SO_2)	2.17	0.0548/0.1848[14]
Volatile Organic Carbons (VOCs)	0.299	0.00755
Polychlorinated Biphenyls	4.65×10^{-5}	1.17×10^{-6}
Antimony	0.0128	0.000323
Arsenic	2.42×10^{-4}	6.11×10^{-6}
Cadmium	5.48×10^{-3}	0.000138
Chromium	7.75×10^{-4}	1.96×10^{-5}
Copper	0.0125	0.000316
Hydrogen Chloride	33.5	0.846
Mercury	0.107	0.002702
Nickel	5.9×10^{-4}	1.49×10^{-5}
2,3,7,8-tetrachlorodibenzo-p-dioxin	1×10^{-6}	2.53×10^{-8}
Chlorinated dibenzo-p-dioxins	2.13×10^{-5}	5.38×10^{-7}

Now since the fuel consumption is available, a mass balance calculation can be performed to check the generation of sulphur dioxide. It should be noted that both particulate matter and nitrogen oxides would be negligible pollutants from the burning of No. 2 diesel oil since the oil would have contained little or no nitrogen particulate content.

Maximum Fuel Input would be 162 L/hr for both chambers of the incinerator and the density of No. 2 oil is 845 kg/m^3 or 0.845 kg/L.

Therefore, total maximum fuel use = 162 L/hr x 0.845 kg/L = 137 kg/hr

[13] Obtained from USEPA AP-42 Emission Factors
[14] Corrected SO_2 Emission Rate

Now assuming a 365 days per year and a 8-hour per day operation and a maximum sulphur content in fuel of 0.5%,

$$SO_2 = 137 \text{ kg/hr x } 0.001 \text{ t/kg x } 8 \text{ hr/d x } 365 \text{ d/yr x } 0.5\%S \text{ x } 64 \text{ t}SO_2/32 \text{ tS}$$
$$= 4 \text{ t/yr} = 0.13 \text{ g/s}$$

Hence, the corrected SO_2 emission rate would be 0.0548 g/s plus 0.13 g/s, or 0.1848 g/s since the emission factor estimate only considered the waste feed rate.

6.3.3 Source Input Parameters

Source input parameters also represent an important aspect of the modeling analysis. Table 6.5 shows the source input parameters that were obtained from the project document prepared by Harty (2002). The document recommended that the stack height be at least 10 m above the ground. Hence 10.5 m was selected as the stack height even though Good Engineering Practice (GEP) stack height was calculated as 14.25 m. Any physical stack with a height less that GEP stack height must be evaluated for potential building downwash effects. Therefore, the building dimensions as listed in Table 6.2 were provided. It should also be noted that the stack inside diameter was selected as 20 inches (0.508 m), which is typical for an incinerator stack. Additionally, the stack gas exit temperature and the stack gas exit velocity were derived from the specifications of the incinerator for the St. Ann's Bay Hospital. The exit velocity was set at 4087 Actual Cubic Feet per Minute (ACFM), while the exhaust temperature was set at 900 ^{o}F (482 ^{o}C).

Table 6.5: Source Input Parameters

Source Inputs	Value	Units
Stack Height	10.5	M
Stack Inside Diameter	0.508	M
Stack Gas Exit Velocity	9.5166	m/s
Stack Gas Exit Temperature	482	^{o}C
Ambient Air Temperature	30	^{o}C
Incinerator Building Height	5.1	M
Incinerator Building Length	12.2	M
Incinerator Building Width	10.6	M

6.3.4 Receptor Locations

Receptor locations identify the area of predicted maximum concentrations. With the Screen View model, these locations can either be automated or discrete. The automated or discrete distances are associated with either the complex, simple flat or simple elevated terrains. Simple flat terrain is represented by heights that do not exceed stack base elevation, while simple elevated terrain is characterized by heights that exceed stack base elevation, but are below stack height. On the other hand, complex terrain includes those heights that exceed stack height.

For the automated distances option, the Screen model calculates the maximum concentration across a range of meteorological conditions for the minimum distance given. The Screen model then computes the concentration for each distance in the array larger than the minimum and less than or equal to the maximum. The Screen model also uses an iteration routine to determine the maximum value associated with that distance to the nearest meter.

With regards to the discrete distances option, the Screen model allows the user to find the maximum impact at specific locations of interest, such as nearby residences and playing areas.

Tables 6.6 and 6.7 show the receptor locations that were used for this project.

Table 6.6: Automated Distances

Terrain Height Above Stack Base, m	Minimum Distance, m	Maximum Distance, m
2.5	1	61
4	61	274
6	274	457
8	457	600
10	600	800
10	800	1000
10	1000	1200
10	1200	1400
10.5	1400	1500

Table 6.7: Discrete Distances

Terrain Feature	Terrain Height Above Stack Base, m	Distance from Source, m
UWI Playing Field	0	61
UHWI Main Entrance Gate	2	366
Paediatric Building	6	91
Main Parking Area	8	457
College Green	12	457
UTECH	20	548
Mona Heights	30	1524
August Town	70	1524
Hope Pastures	70	2286
Papine Square	110	1524
Long Mountain Country Club	1000	2286

6.3.5 Model Runs

With all the input parameters defined, the Screen View model was conducted using the following model runs:

- With a receptor height above ground of 0 m (ground-level receptors)
- With a receptor height of 5 m above ground (flagpole receptors)

6.3.6 Results And Discussion

This section documents the results of the entire project, including the proposed emissions from the incinerator and the predicted concentrations from the various model runs.

6.3.7 Emission Rates

Table 6.8 shows the uncontrolled emission rates that will be generated from the proposed incinerator (as a result of the use of emission factors) and their comparison with the Draft Air Emission Standards. From the table it is observed that all emission rates are in compliance with the emission standards. Therefore it can be concluded that once the manufacturer of the incinerator complies with the calculated uncontrolled emissions, then compliance with the emission standards is assured. It should be noted that the emission factor for carbon monoxide has an A-rating, while those for sulphur dioxide, particulate matter and volatile organic carbons have a B-rating. The emission factor ratings range from A through E, and therefore it can be concluded that the estimates of the emissions were accurate.

It should be observed that other emission sources identified include steam boilers and the existing incinerator that will be retired. The emissions from these sources were accounted for by assuming a background concentration for particulate matter and sulphur dioxide.

Table 6.8: Emission Rates

Parameters	Emission Rates, g/s	Emission Rates, mg/m^3	Emission Standards mg/m^3
Particulate Matter	0.118	61.115	200
Carbon Monoxide	0.0745	28.39819	100
Sulphur Dioxide	0.1848	38.60583	300
Volatile Organic Carbons	0.00755	3.91293	20

6.3.8 Model Results

Tables 6.9 and 6.10 provide the maximum predicted concentration values of all the modeling analysis performed. It should be observed that the results were compiled for all those averaging periods for which national ambient air quality standards (NAAQS) exist. Additionally, the Screen model generates 1-hour predicted concentrations for simple terrain and 24-hour concentrations for complex terrain. Where NAAQS exists for pollutants with long-term concentrations higher than 1-hour (for simple terrain) or 24-hour (for complex terrain), the conversion factors as provided in the NRCA Ambient Air Quality Guideline Document were used for such conversion.

Table 6.9: Summary of Model Predictions with 0 receptor height

Pollutants	**Averaging Period**	**NAAQS µg/m^3**	**Background µg/m^3**	**Simple Terrain**			**Complex Terrain**		
				Max. Conc. µg/m^3	**Distance m**	**Terrain Ht., m**	**Max. Conc. µg/m^3**	**Distance m**	**Terrain Ht., m**
PM	1-hour	N/A	N/A	25	61	4	N/A	N/A	N/A
	24-hour	150	60	10*	61	4	5	457	12
	Annual	60	15	2.5*	61	4	1*	457	12
CO	1-hour	40,000	0	16	61	4	N/A	N/A	N/A
	8-hour	10,000	0	11.2*	61	4	N/A	N/A	N/A
	24-hour	N/A	N/A	6.4*	61	4	3	457	12
SO_2	1-hour	700	0	39	61	4	N/A	457	12
	24-hour	280	0	15.6*	61	4	7	457	12
	Annual	60	0	3.9*	61	4	1.4*	457	12
HCl	1-hour	100	0	178.4	61	4	N/A	N/A	N/A
	24-hour	20	0	71.4*	61	4	33.45	457	12
PCBs	1-hour	0.375	0	$2.5x10^{-4}$	61	4	N/A	N/A	N/A
	24-hour	0.15	0	$1.0x10^{-4*}$	61	4	$4.6x10^{-5}$	457	12
Antimony	1-hour	62.5	0	$6.8x10^{-2}$	61	4	N/A	457	12
	24-hour	25	0	$2.7x10^{-2*}$	61	4	$1.3x10^{-2}$	457	12
Arsenic	1-hour	0.75	0	$1.3x10^{-3}$	61	4	N/A	N/A	N/A
	24-hour	0.3	0	$5.2x10^{-4*}$	61	4	$2.4x10^{-4}$	457	12
Cadmium	1-hour	5	0	$2.9x10^{-2}$	61	4	N/A	N/A	N/A
	24-hour	2	0	$1.2x10^{-2*}$	61	4	$5.5x10^{-3}$	457	12
Chromium	1-hour	3.75	0	$4.2x10^{-3}$	61	4	N/A	N/A	N/A
	24-hour	1.5	0	$1.7x10^{-3*}$	61	4	$7.9x10^{-4}$	457	12
Copper	1-hour	125	0	$6.7x10^{-2}$	61	4	N/A	457	12
	24-hour	50	0	$2.7x10^{-2*}$	61	4	$1.25x10^{-2}$	457	12
Mercury	1-hour	5	0	0.57	61	4	N/A	N/A	N/A
	24-hour	2	0	0.23*	61	4	0.11	457	12
Nickel	1-hour	5	0	$3.2x10^{-3}$	61	4	N/A	N/A	N/A
	24-hour	2	0	$1.3x10^{-3*}$	61	4	$5.9x10^{-4}$	457	12
2,3,7,8-TCDD	1-hour	N/A	N/A	$5.3x10^{-6}$	61	4	N/A	N/A	N/A
	24-hour	N/A	N/A	$2.1x10^{-6*}$	61	4	$1.0x10^{-6}$	457	12
	Annual	$2.3 x 10^{-7}$	0	$5.3x10^{-7*}$	61	4	$2.0x10^{-7*}$	457	12

Pollutants	Averaging Period	NAAQS µg/m^3	Background µg/m^3	Simple Terrain			Complex Terrain		
				Max. Conc. µg/m^3	Distance m	Terrain Ht., m	Max. Conc. µg/m^3	Distance m	Terrain Ht., m
CDD	1-hour	1.25×10^{-5}	0	$1.1x10^{-4}$	61	4	N/A	N/A	N/A
	24-hour	5×10^{-6}	0	$4.4x10^{-5*}$	61	4	$2.1x10^{-5}$	457	12

* Calculated Ambient long-term concentrations
N/A – Not Applicable

Table 6.10: Summary of Model Predictions with receptor height of 5m

Pollutants	Averaging Period	NAAQS µg/m^3	Background µg/m^3	Simple Terrain			Complex Terrain		
				Max. Conc. µg/m^3	Distance m	Terrain Ht., m	Max. Conc. µg/m^3	Distance m	Terrain Ht., m
PM	1-hour	N/A	N/A	36	61	4	N/A	N/A	N/A
	24-hour	150	60	14*	61	4	5	457	12
	Annual	60	15	3.6*	61	4	1*	457	12
CO	1-hour	40,000	0	23	61	4	N/A	N/A	N/A
	8-hour	10,000	0	16*	61	4	N/A	N/A	N/A
	24-hour	N/A	N/A	9.2*	61	4	3	457	12
SO_2	1-hour	700	0	56	61	4	N/A	457	12
	24-hour	280	0	22*	61	4	7	457	12
	Annual	60	0	5.6*	61	4	1.4*	457	12
HCl	1-hour	100	0	257.5	61	4	N/A	N/A	N/A
	24-hour	20	0	103*	61	4	33.45	457	12
PCBs	1-hour	0.375	0	$3.6x10^{-4}$	61	4	N/A	N/A	N/A
	24-hour	0.15	0	$1.4x10^{-4*}$	61	4	$4.6x10^{-5}$	457	12
Antimony	1-hour	62.5	0	$9.8x10^{-2}$	61	4	N/A	457	12
	24-hour	25	0	$3.9x10^{-2*}$	61	4	$1.3x10^{-2}$	457	12
Arsenic	1-hour	0.75	0	$1.9x10^{-3}$	61	4	N/A	N/A	N/A
	24-hour	0.3	0	$7.6x10^{-5*}$	61	4	$2.4x10^{-4}$	457	12
Cadmium	1-hour	5	0	$4.2x10^{-2}$	61	4	N/A	N/A	N/A

Pollutants	**Averaging Period**	**NAAQS μg/m³**	**Background μg/m³**	**Simple Terrain**			**Complex Terrain**		
				Max. Conc. μg/m³	**Distance m**	**Terrain Ht., m**	**Max. Conc. μg/m³**	**Distance m**	**Terrain Ht., m**
	24-hour	2	0	$1.7x10^{-2*}$	61	4	$5.5x10^{-3}$	457	12
Chromium	1-hour	3.75	0	$5.97x10^{-3}$	61	4	N/A	N/A	N/A
	24-hour	1.5	0	$2.4x10^{-3*}$	61	4	$7.8x10^{-4}$	457	12
Copper	1-hour	125	0	$9.6x10^{-2}$	61	4	N/A	457	12
	24-hour	50	0	$3.8x10^{-2*}$	61	4	$1.25x10^{-2}$	457	12
Mercury	1-hour	5	0	0.82	61	4	N/A	N/A	N/A
	24-hour	2	0	0.33*	61	4	0.11	457	12
Nickel	1-hour	5	0	$4.5x10^{-3}$	61	4	N/A	N/A	N/A
	24-hour	2	0	$1.8x10^{-3*}$	61	4	$5.9x10^{-4}$	457	12
2,3,7,8-TCDD	1-hour	N/A	N/A	$7.7x10^{-6}$	61	4	N/A	N/A	N/A
	24-hour	N/A	N/A	$3.1x10^{-6*}$	61	4	$1.0x10^{-6}$	457	12
	Annual	2.3×10^{-7}	0	$7.7x10^{-7*}$	61	4	$2.0x10^{-7*}$	457	12
CDD	1-hour	1.25×10^{-5}	0	$1.6x10^{-4}$	61	4	N/A	N/A	N/A
	24-hour	5×10^{-6}	0	$6.4x10^{-5*}$	61	4	$2.1x10^{-5}$	457	12

* Calculated Ambient long-term concentrations
N/A – Not Applicable

The results in Tables 6.9 and 6.10 revealed compliance with the NAAQS and the Priority Air Pollutants (PAPs) for all parameters, except hydrogen chloride, 2,3,7,8 tetra-chlorinated dibenzo-p-dioxin and total chlorinated dibenzo-p-dioxins. The results also showed that the flagpole receptors had a slightly higher predicted concentration values for the same receptor location for the simple terrain features, and similar values for the complex terrain calculations. It should be observed that for the complex terrain calculations, Screen View ignored the designated 5 m receptor height above ground, and used a receptor height of 0 m. Hence the similar results for the complex terrain calculations. The maximum predicted concentrations for the simple terrain occurred at a height of 4 m and a downwind distance of 61 m, and this corresponds to a the south western end of the Paediatrics Block. For the complex terrain, the worst case impact at a downwind distance of 457 m and a terrain height of 12 m. This corresponds to the discrete location of the Golden Circles community.

6.3.9 Trouble-Shooting

Since the predicted maximum concentration values for hydrogen chloride, 2,3,7,8 tetra-chlorinated dibenzo-p-dioxin and total chlorinated dibenzo-p-dioxins exceeded the NAAQS, an attempt was made to test certain source input parameters into the Screen View model. These parameters included stack height, stack gas exit velocity and stack gas exit temperature.

The GEP stack height was calculated as 14.25 m and since this height represents the maximum height allowed for the incinerator stack, this height was tested in the model. Additionally, the stack gas exit temperature ranged from 427 – 538 ^{o}C (800 – 1000 ^{o}F), with 482 ^{o}C (900 ^{o}F) being selected as the exit gas temperature. For the trouble-shooting activity, the maximum exit gas temperature of 538 ^{o}C was selected.

With regards to exit gas velocity, it was deduced that this can be calculated as 1.5 times the wind speed at the top of the stack. This wind speed value varies based on the prevailing stability class (see Table 6.11). Hence, if the average of the maximum wind speeds is taken, then a value of 11.75 m/s is obtained for the exit gas velocity. This value was also used as part of the trouble-shooting activities.

Table 6.11: Wind Speed versus Stability Class

Stability	**10-Meter Wind Speed [m/s]**	
Class	**Min**	**Max**
A	1.0 m/s	3.0 m/s
B	1.0 m/s	5.0 m/s
C	1.0 m/s	10 0 m/s
D	1.0 m/s	20 0 m/s
E	1.0 m/s	5.0 m/s
F	1.0 m/s	4.0 m/s

When the values for the stack height, exit gas velocity and exit gas temperature were applied singly, or in combination to the modeling scenario of the pollutants hydrogen chloride, 2,3,7,8 tetra-chlorinated dibenzo-p-dioxin and total chlorinated dibenzo-p-dioxins, the results revealed compliance with the NAAQS for 2,3,7,8 tetra-chlorinated dibenzo-p-dioxin, but non-compliance with NAAQS for total chlorinated dibenzo-p-dioxins. For hydrogen chloride, compliance was at times achieved for the 1-hour standard, while non-compliance always resulted for the 24-hour standard.

This situation led to the only alternative of including an air pollution control (APC) device as part of the modeling analysis. Since all the other pollutants, except the dioxins and hydrogen chloride were achieving compliance prior to the use of the APC device, the model runs with the APC device included were only applied to 2,3,7,8 tetra-chlorinated dibenzo-p-dioxin, hydrogen chloride and total chlorinated dibenzo-p-dioxins.

For hospital waste incineration applications, the most commonly employed APC device is the wet scrubber. For a wet scrubber, the USEPA AP-42 Emission Factors document recommends the following emission factors (Table 6.12) and the corresponding emission rates were calculated.

Table 6.12: Emission Rates (with an APC device)

Pollutants	**Emission Factors, lb pollutant/ton waste**	**Emission Rates, g/s**
Hydrogen Chloride (Low Energy Wet Scrubber only)	1.0	0.025
2,3,7,8-tetrachlorodibenzo-p-dioxin (Wet Scrubber only)	2.67×10^{-8}	6.74×10^{-10}
Chlorinated dibenzo-p-dioxins (Wet Scrubber only)	1.84×10^{-6}	4.65×10^{-8}
Hydrogen Chloride (Wet Scrubber/FF)	1.9	0.048
Chlorinated dibenzo-p-dioxins (Wet Scrubber/FF)	3.44×10^{-7}	8.69×10^{-9}

Now with the introduction of the APC device, stack gas exit velocity and stack exit temperature had to be reduced. Such reduction was determined to be 44.44% (Anderson 2000, Inc, 1999). This translated into the exit temperature being reduced from 482 ^{o}C to 260 ^{o}C, and the gas exit velocity being reduced from 9.5166 m/s to 5.287 m/s. Now when the new emission rates were applied to the modeling scenario with a flagpole receptor height above ground of 5 m, with all other source input parameters remaining constant, the results outlined in Table 6.13 were obtained. The results revealed that all NAAQS are achieved with the exception of the 1-hour standard for total CDD.

Table 6.13: Maximum Predicted Concentrations (with an APC device)

Pollutants	Averaging Period	NAAQS $\mu g/m^3$	Background $\mu g/m^3$	Simple Terrain			Complex Terrain		
				Max. Conc. $\mu g/m^3$	Distance m	Terrain Ht., m	Max. Conc. $\mu g/m^3$	Distance m	Terrain Ht., m
2,3,7,8-TCDD (Wet Scrubber only)	1-hour	N/A	N/A	$3.1x10^{-7}$	61	4	N/A	N/A	N/A
	24-hour	N/A	N/A	$1.2x10^{-7*}$	61	4	$3.9x10^{-8}$	457	12
	Annual	2.3×10^{-7}	0	$2.1x10^{-8*}$	61	4	$7.8x10^{-9*}$	457	12
CDD (Wet Scrubber only)	1-hour	1.25×10^{-5}	0	$2.2x10^{-5}$	61	4	N/A	N/A	N/A
	24-hour	5×10^{-6}	0	$8.8x10^{-6*}$	61	4	$2.7x10^{-6}$	457	12
CDD (Wet Scrubber/FF)	1-hour	1.25×10^{-5}	0	$4.0 x10^{-6}$	61	4	N/A	N/A	N/A
	24-hour	5×10^{-6}	0	$1.6 x10^{-6}$	61	4	$5.0x10^{-7}$	457	12

* Calculated Ambient long-term concentrations
N/A – Not Applicable

Since the project document by Harty (2002) recommended a combination of APC devices including a wet scrubber and a baghouse filter, the emission factor for the wet scrubber/fabric filter system was applied. Now the USEPA AP-42 document does not provide an emission factor for a combination of wet scrubber/bag filter, but it however provided one for Dry Sorbent Injection/Fabric Filter (DSI/FF). Now the CDD value for DSI/FF is 3.44 x 10^{-7} lb/ton. It should be noted that since DSI is comparable to the wet scrubber technology (since they both provide acid gas control in the flue gas stream), it can be assumed that a similar emission factor will prevail for the wet scrubber/FF system. The new model runs revealed results as shown in Table 6.13 that all NAAQS have now been achieved.

6.3.9.1 Conclusion & Recommendation

The following conclusions and recommendations can be made as result of the air quality assessment that was performed:

- The emission rates as calculated from the emission factors for particulate matter, sulphur dioxide, carbon monoxide and volatile organic carbons can safely be applied to the proposed incinerator, since these emission rates are less than the emission standards for a new incinerator.
- The height of the stack can safely be designed as 10.5 m. In any case, the design stack height should not exceed the GEP stack height of 14.25 m.
- A combination of APC devices should be utilized as part of the mitigation measures to safeguard against non-compliant chlorinated dioxin concentrations. As recommended by the project document by Harty (2002), this combination should be a wet scrubber and a fabric filter.
- The stack exit gas velocity can safely be set as 5.287 m/s with the air pollution control devices being applied.
- As much as possible, every attempt must be made to design the incinerator with emission rates that will avoid the inclusion of the APC device, in order to save costs.
- Since emission factors were used to estimate the emission rates, and this technique is fourth in order of priority, it should be observed that the NEPA may be approached with the notion of purchasing and installing the state-of-the-art incinerator, and then to conduct a stack emission testing exercise during its commissioning. A recommendation should then be made to utilise the stack testing data and re-run the modeling analyses so that a more representative prediction of ambient air quality concentrations can be made. This approach actually follows the decision tree as recommended in the NRCA Ambient Air Quality Guideline Document.

  Details of the screening model runs are at Appendix 5.

7.0 Environmental Management and Monitoring

Environmental monitoring will be required to monitor the effectiveness of the mitigation measures and to report to the regulatory agencies. Through sound environmental management, many avoidable adverse impacts from the construction and operation of the incinerator can be prevented.

7.1 Environmental Management and Monitoring – Construction

All mitigation measures outlined in the Section 6 will be adhered to by the contractor. The project coordinator/engineer will be responsible for ensuring that the mitigation measures are implemented and will prepare a monthly report to be submitted to NEPA on the effectiveness of the measures.

Report of tests done to demonstrate that the plant meets the requirements as summarized in the supply contract will be submitted to the University Hospital of the West Indies' commissioning advisor within 21 days of completion of tests and subsequently the hospital will submit the report to the National Environment and Planning Agency (NEPA) and the Environmental Health Unit (EHU) in the Ministry of Health for their review. This report will be accompanied by record sheets and will contain:

- Detailed description of plant
- Details of instruments used and methods of use with reference to relevant standards within this specification and the ranges of individual instruments.
- Detailed report of readings taken
- Detailed results alongside legal limits to show comparison.
- Details of emission tests results
- Conclusions
- Recommendations

7.2 Environmental Management and Monitoring – Operation

The following environmental management and monitoring measures will be implemented during operation of the incinerator:

- All mitigation measures outlined in the Section 6 will be adhered to by the Engineering and Public Health Departments at the Hospital.
- The Procurement Department of the hospital must adopt and implement a green procurement policy so that there is general reduction in the waste generated by the hospital and alternative materials to those which contain mercury, plastic and other hazards are utilised. These materials release hazardous substances/emissions when incinerated.
- The hospital will implement a rigorous segregation programme to ensure that materials containing hazardous substances such as mercury are not incinerated. Where plastic wastes are not considered to be infectious they should not be incinerated either. Written procedures will be developed on the subject of waste management.
- Waste disposal for ash, hazardous wastes, old incinerator and regular garbage should be in accordance with the requirements of the regulators; NSWMA and NEPA.

- Sulphur in oil must be monitored to ensure that the it meets the 2% requirements
- The incinerator must be maintained in accordance with the manufacturers requirements and records must be kept
- Regularly worn parts will be kept in stock as spare to reduce downtime of incinerator associated with a breakdown or malfunction. A service contract will be in place to facilitate quick repair in more severe cases. Records of malfunctions of the incinerator must be must be reported to the EHU and NEPA within 24 hours and must be retained.
- Emissions testing and reporting must be done in accordance with the requirements of NEPA
- Fire prevention precautions must be in place as required by the Fire Brigade. There will need to be regular inspections of the fire fighting equipment with records kept.
- Regular inspections will be conducted to verify the integrity of the fuel tanks and pipelines. Written procedures governing the operation of the fuel tank and precautions to be taken will be developed.

7.3 Emergency Response Plan

An emergency is any unplanned occurrence caused by either natural or man-made events which can lead to deaths, significant injuries, cessation of operations, physical or environmental damage and economic losses. Numerous events can lead to emergencies. These include:

- Hurricanes
- Earthquakes
- Fires
- Floods
- Communications failure
- Chemical spills
- Structural failure
- Civil disturbance

Emergency management is therefore critical to planning, mitigating, responding and recovering from the potential impacts of these events.

The emergency management process however is very site specific and varies according to type of operations, geographic location, proximity to neighbouring communities and the history of such occurrences. Therefore, one of the first stages in developing and Emergency Response Plan (ERP) would be the identification of the potential hazards or threats to the facility, organisation or operation based on the above mentioned factors.

The Emergency Response Plan must be documented and cover all the area mentioned above.

- The plan must identify the person(s) responsible for Emergencies and Safety. This person will keep the documentation updated (at least annually) and ensure that it is disseminated to all relevant persons.
- The plan must speak to the preparatory actions that must be taken in case of emergencies with forewarning such as hurricanes and responsibilities must be assigned.

- The plan should include actions that must be taken when an earthquake, spill, riot or fire occurs. A safe area must be designated for persons to congregate during an emergency.
- A system must be in place to account for all staff members in an emergency with the appropriate responsibilities assigned.
- Drills must be conducted on a specified frequency (for example 3 times for the year for fire). In a hospital setting there may be some restrictions on conducting actual drills but desktop drills can be done.
- The plan must include for fire fighting equipment to be checked on a specified frequency by a competent entity.
- The plan must speak to cleanup measures after the emergency.

The Emergency Response Plan must be developed in consultation with the Office of Disaster Preparedness to ensure that it meets their requirements. The Emergency Response Plan for the incinerator will form a part of the overall Emergency Response Plan for the hospital.

7.4 Recommendations to Improve Medical Waste Management

Based on the information gathered in the waste audit conducted at UHWI in September 2003 there are a number of opportunities for improvement and cost savings.

7.4.1 Waste generation data

There was a general absence of data to accurately estimate the amount of infectious waste and garbage generated by the hospital. This problem together with insufficient segregation of waste made it impossible to provide estimates on the specific categories of waste within the infectious and garbage waste streams. The hospital will have to institute systems to segregate and weigh the waste destined for incineration. A similar exercise will also be required for garbage as it is necessary to know the quantity of kitchen waste, yard waste and office waste generated. With this information targets for improvements can be established and the effectiveness of actions taken can be measured.

7.4.2 Improvements to UHWI's Waste Management Practices

Waste minimisation is one of the most effective ways of protecting people and the environment while saving facilities substantial amounts of money. Waste minimisation techniques which are applicable to a facility such as the UHWI and will generally improve waste management at the facility include segregation, source reduction and resource recovery and recycling. The application of these techniques will be discussed throughout this section along with other improvements which can be made to waste management practices at the hospital in the areas of storage, collection and disposal.

7.4.2.1 Source Reduction

Source reduction entails minimising or eliminating the generation of waste at the source through techniques such as product substitution, technology change and good operating practices. Through purchasing and product substitution, toxicity of waste can also be reduced. Information is usually obtained from Material Safety Data Sheets (MSDS) on the toxicity and hazardous components of materials and substances as well as the safety measures to be implemented when they are being used. Comparison of the MSDSs for products that have the same use can help to determine which one is less harmful to human health and the environment. This becomes one of the criteria for selection of the product.

The GOJ Environmental Guide Green Procurement has been made available to all public sector agencies including the University Hospital of the West Indies and it is aimed at providing information on how to reduce waste and costs in the public sector. To date, UHWI has not utilised this document to assist them with their procurement practices. In order to encourage the UHWI to use the document, it is recommended that training be provided to the relevant UHWI staff on its content and how to implement its recommendations. The personnel who should participate include:

- Persons in charge of procurement
- Persons who prepare contracts for goods and services
- Cost centre managers

7.4.2.2 Segregation

Segregation is the action of separating different types of waste at the point of generation and keeping them isolated from each other. Single stage segregation is preferred; that is, the waste stays in the same bag or container for storage, transportation and disposal. This helps to reduce risk of human exposure to hazardous wastes and reduces the probability of human error when compared to a system that employs segregation at the point of disposal. By doing this, appropriate resource recovery and recycling techniques can be applied to each separate waste stream. The amounts of infectious waste, hazardous waste and low-level radioactive waste that must be treated according to special (and usually costly) requirements are minimised

Additionally, standardising waste disposal bags and containers reduces human error in waste segregation which contributes to incidents of exposure of hospital or other personnel to medical waste that is toxic or infectious. It is important to make the relevant personnel aware of the segregation requirements as the success of this initiative depends on their acceptance of the requirements.

7.4.2.3 Waste Storage

Due to the hazardous nature of some medical wastes, appropriate methods of storing the waste will help to prevent infections and accidents. The following practices are generally recommended for medical wastes:

- Sharps containers must be rigid, leak proof, tamper-proof. The current practice of using waxed doubled lined cardboard boxes should continue as hazardous emissions are generated by incinerating plastic containers. This method of containment is also

approved of by WHO (1997) in cases where plastic containers are unavailable or too costly.
- All sharps boxes must be packaged within heavy duty, leak proof bags to facilitate their movement for the point of generation to the location for incineration.
- Heavy duty, leak proof bags should be used for infectious waste and they should be marked with the international infectious substance symbol.
- Cytotoxic waste should be collected in strong leak proof containers, labeled "Cytotoxic waste" and should be stored separately from other medical wastes in a designated secure location.
- Radioactive waste should be contained within a special container such as a lead shielded box labeled with the radioactive symbol; waste that is stored during radioactive decay should be labeled with the type of radionuclide, the date and details of the required storage conditions.
- Low-level radioactive infectious waste (e.g. swabs, syringes for diagnostic or therapeutic use) may be collected along with other infectious waste destined for incineration.
- Personnel handling bags to be incinerated **must** be appropriately attired in disposable safety gear which should also be incinerated after use.
- The new Incinerator Room should improve the method of storage of waste awaiting incineration.

Bin Rooms

Bin rooms need to be kept clean at all times. This means that the waste that is being stored there must be packaged in bags that are of a high quality to prevent spillage or leakage of their contents during handling, and should be non-reactive with the wastes that they will contain. Bags equivalent in thickness to domestic garbage bags are generally not strong enough. It is advisable to use bags described as heavy duty or stronger (thickness 2 mil and above) for general garbage and extra heavy duty or stronger for infectious waste (thickness 3 mil and above). Replacement bags should be readily available to repackage any bag that has burst.

Obsolete equipment must not be stored in the bin rooms. The normal procedure for condemning obsolete equipment should be adhered to in all cases.

Waste from clinics

It is inappropriate to have bagged waste (infectious and general) from the clinics left in corridors for collection. It is an unnecessary risk to expose both staff and patients to possible infection if the red bags should rupture. It would also be unsanitary to have the contents of the regular garbage exposed within the hospital environment if these bags were to rupture. A specific area must be designated similar to the concept of the bin room for bagged waste from the clinics to await collection.

7.4.2.4 Mercury

Discarded or broken medical equipment such as mercury thermometers, sphygmomanometers, blood pressure devices, dilation and feeding tubes must not be incinerated. They should be placed in a sealed leak-proof package and arrangements should be made with the National Solid Waste Management Authority to see if they will take the waste and place it in a designated (hazardous) waste cell at the Riverton disposal site. It should be noted however that the Riverton disposal site was originally a dumpsite and it is not designed to take hazardous wastes so this special arrangement may not be available and if so it is likely to come at a cost.

In light of this, it is advisable to use alternatives to mercury-containing equipment due to the health and environmental hazards associated with the disposal of mercury. The hospital should:

- identify all mercury containing equipment
- implement a mercury free purchasing policy
- implement a mercury reduction programme to phase out the use of mercury containing equipment over time

7.4.2.5 PVC and DEHP (di-2-ethylhexyl phthalate[15])

Some hospitals are reconsidering their use of polyvinyl chloride (PVC or vinyl) medical products, due to the associated health concerns when:

- these wastes are incinerated
- there is prolonged exposure to DEHP containing PVC products used for medical purposes.

PVC-free and DEHP-free alternatives are available for almost every use of PVC in the health care setting, including medical devices.

With the exception of the bags used for packed red blood cells, PVC-free intravenous and blood bags are available in Europe and the U.S. PVC-free bags are cost-effective and technically competitive with PVC bags. PVC-free or DEHP-free tubing is on the market for most medical applications. Additionally, alternatives for disposable PVC gloves are readily available.

Medical Products made from PVC which typically contain DEHP

- PVC blood bags
- PVC catheters
- PVC colostomy bags
- PVC dentures
- PVC enteral feeding bags
- PVC gloves
- PVC IV bags
- PVC mattress covers
- PVC oxygen tents
- PVC pillow case covers
- PVC syringes
- PVC tubing
- PVC urine bags

To move away from PVC devices containing DEHP, hospitals should:

- perform an audit to identify PVC and DEHP products;
- identify and evaluate alternatives;

[15] Di (2-ethylhexyl) phthalate (DEHP) is a manufactured chemical that is commonly added to plastics to make them flexible. DEHP is a colorless liquid with almost no odour.

- purchase PVC- or DEHP-free products of equivalent quality and performance.

The primary aim of UHWI should be to replace PVC products with PVC-free alternatives. In doing so, those PVC products which contain DEHP will also be covered. Where no alternatives exist for a PVC product, one that does not contain a DEHP plasticizer should be selected.

Purchase orders and requests for bids or proposals to supply medical products should specify that PVC alternatives or PVC products without DEHP are required.

7.4.2.6 Waste Management Responsibility and Monitoring

As the first step, the UHWI needs to develop and document their waste management policy so that all members of staff as well as external service providers are clear on what the hospital wants to achieve regarding the management of waste. It is only when all stakeholders have the same understandings of the objectives and accept them that there will be a commitment towards changing existing practices and developing new ones that are consistent with the intentions of the hospital.

Waste Management at the hospital is currently the responsibility of the Public Health Department. They will need to prioritise the solid waste recommendations from this audit and develop an action plan with goals, dates and resources (human and financial) to implement the recommendations.

It is advisable that the most important actions and those which give the highest return be implemented first.

This department will also have the responsibility of monitoring the implementation of the action plan as well as establishing systems to capture better data on the quantities and types of waste generated and disposed of by the hospital. They will need to track performance and report on whether goals are being achieved or not. They will need to recommend alternative actions if goals are not being achieved. This will not only mean changing the plan but it may require better cooperation from staff.

An internal audit programme should be established to periodically check on the effectiveness of the entire waste management system. This internal audit should be conducted at least once each year against established criteria for each area/department.

Results of the audit should be documented, kept for analysis and follow-up, and shared with designated members of the hospital management and pertinent unit managers.

Table 7.1 Action Plan to Develop Waste Management Plan

ACTION	RESPONSIBILITY
Define the waste management policy for UHWI.	CEO and senior management staff, Public Health Department, Purchasing Department
Define and formalise the group that will lead the implementation of the actions to improve the waste management practices of the hospital	CEO and senior management staff, Public Health Department, Purchasing Department
Prioritise the initiatives that will be pursued	CEO and senior management staff, Public Health Department, Purchasing Department
Identify persons who may require training in the area of waste management	Public Health Department, Administration and HRD
Conduct training	HRD, Third party contractor
Develop written procedures to institutionalize the requirements for the waste management system	Public Health Department

7.5 Training

7.5.1 Waste Management

Training of staff and contractor services in the waste management practices of the hospital is critical to its success. Training programmes should include:

- Basic training in waste handling procedures for all new staff
- In-service training to revise and update the knowledge of waste handling staff.
- Special training programmes should be available to address the problem of language barriers for those staff that have difficulty understanding or are illiterate.

Pamphlets, booklets and signs are all useful materials to complement the formal training activities and they act a reminder for staff.

7.5.2 Incinerator Operation

Training will also be provided by the manufacturer/supplier of the incinerator regarding its operations and maintenance requirements. Persons who should participate in this training include:

- The Manager in charge of Engineering (Operations and Maintenance)
- The Public Health Officer
- The personnel that will operate the incinerator

7.5.3 Regulatory Requirements

The Permit and Licence obtained from NEPA will have reporting requirements and other obligations which will need to be fulfilled. Other regulators such as the Ministry of Health, the

National Solid Waste Management Authority and the Office of Disaster Preparedness and Emergency Management will also have requirements. Persons who have to ensure that the obligations are fulfilled will need to be trained in the regulatory requirements, the stack testing and the completion of forms.

The persons who should be included in this training include:

- The Public Health Officer
- The Manager in charge of Engineering (Operations and Maintenance)

The UHWI may wish to consider hiring someone with the specialist skills in stack testing. This person would analyse the data and prepare the reports to NEPA. Alternatively, the UHWI may contract these services. The person with responsibility for this area must be very familiar with the NEPA's requirements as there will be serious cost implications if air emission standards are not met.

8.0 Decommissioning of medical waste incinerator[16]

The following programme for decommissioning the existing medical waste incinerator at UHWI, based on guidelines developed by the United States Environmental Protection Agency (US EPA) is recommended.

A company with specialist skills for decommissioning incinerators or one with experience in the removal of asbestos is recommended.

Table 8.1 Decommissioning Schedule

PROCEDURES ESTIMATED DURATION	TIME REQUIRED
Site Preparation and Containment	1 day
Preliminary site decontamination	0.5 days
Construction of containment	5 days
Smoke Test	0.5 days
Removal and decontamination of top vertical section of incinerator flue	4 days
Removal and decontamination of incinerator	1 day
Disposal	Within 1 day of obtaining permit/ permission for disposal

[16] Decommissioning and Disposal of a Clinical Waste Incinerator at Tong Shin Kin Hospital, December 2002 Ref# R1641.02

8.1 Possible Contaminated Waste, Impact on the Environment & Environmental Mitigation Measures

8.1.1 Site Inspection & Sampling

Ash generated from the incinerator could be hazardous waste and as such must be sampled based on the size of the incinerator chamber. For example, if an incinerator chamber is 2 square metres, three samples are sufficiently representative of the quality of the residual ash.

At least two samples of ash residuals in the flue should be taken at the middle and at the far end from the incinerator furnace to provide a good spatial coverage. Parameters to be tested include PCB levels, dioxins and heavy metals.

A sample test sheet for the ash residue from a furnace is shown below in Table 8.2:

Table 8.2 Sample Test Sheet for the Ash Residue from a Furnace

Parameters for analysis*	Assessment Criteria **	Sampling Result		Compliance
		Average	Range	
PCB	1	N. A.	<0.1	Yes
Dioxin	1 ppb	0.011478 ppb	0.007287 – 0.016453 ppb	Yes
PAH				
Naphthalene	5	25.7	16.3 – 39.7	**No**
Other PAH	5	Below Assessment Criteria	Below Assessment Criteria	Yes
Heavy metals				
Chromium	250	31.0	24.9 – 35.9	Yes
Cobalt	50	4.00	2.37 – 5.37	Yes
Nickel	100	35.0	28.8 – 39.7	Yes
Copper	100	639	75 – 1630	**No**
Zinc	500	251	134 – 409	Yes
Arsenic	30	2.9	2.1 – 3.4	Yes
Molybdenum	40	13.6	4.97 – 18.7	Yes
Cadmium	5	0.32	0.14 – 0.50	Yes
Tin	50	3.11	2.57 – 3.63	Yes
Barium	400	258	217 – 283	Yes
Mercury	2	0.6	0.46 – 0.70	Yes
Lead	150	16.7	14.1 – 19.3	Yes

* All values are in the unit of mg/kg dry wt. unless otherwise stated.
** 1. The assessment criteria are referenced to Dutch B standard for land contamination except for dioxin.
** 2. The assessment criterion for dioxin is referenced to the USEPA standard of 1 ppb (equivalent to 1000 pg/g)

If the residues sampled from the incinerator flue and chamber contain levels above those recommended, decommissioning of the structures should therefore be carried out with special care and protection to ensure that any incineration residues that may contain the contaminants dioxin, copper and naphthalene as revealed through sampling are handled, transported and disposed of properly.

8.2 Decommissioning Method – Containment Approach

Decommissioning of the incinerator should be conducted under containment as a prudent approach to avoid the release of any incinerator ash to the environment, which could be generated during the exercise.

8.2.1 Site Preparation and Containment Construction

Preliminary site decontamination of all debris should be carried out using HEPA vacuum cleaner. Except the incinerator, all other existing items should be removed from the incinerator room as far as practicable to avoid obstructing the subsequent work activities. The walls, floor and ceiling of the incinerator room, boiler room, and mechanical/electrical room where the vertical chimney duct is located, must be lined with 3 layers of fire retardant polythene sheets.

The top portion of the chimney above the roof must also be enclosed with three layers of polythene sheets. At the entrance to each level, a 3-chamber decontamination unit should be constructed for entry and exit from the work area. The 3-chamber decontamination unit will comprise a dirty room, a shower room and a clean room of at least 1m x 1m base each with 3 layers of fire retardant polythene sheet where all workers must carry out decontamination procedures before leaving the work area.

An air mover should be provided at the incinerator room, boiler room, and at the bottom of the stack to exhaust air from the work area. A stand-by air mover should also be installed with each of the air movers. Sufficient air movement should be maintained to give a minimum of 6 air changes per hour to the work area, and maintain a negative pressure of 0.05-0.15 inches of water within the work area throughout the entire course of the decommissioning works. A pressure monitor with printout records and audible alarm should be installed at an easily accessible location to demonstrate that negative pressure is maintained. New pre-filters and HEPA filters should be used at the air movers.

A copy of the maintenance records of the air movers should be kept on site for inspection upon request. The appointed contractor should also check the differential pressure of the air mover to make sure the filter is not blocked. A differential pressure above 0.2 inches of water indicates that the filters would need to be changed. All items remaining inside the containment should be covered with at least 2 layers of fire retardant polythene sheets before the decommissioning works proceed.

8.2.2 Smoke Test

Before commencement of the decommissioning work, a smoke test with non-toxic smoke must be carried out to ensure the air-tightness of the containment. A determination of whether there are stagnant air pockets indicated by an aggregate of smoke that cannot effectively be extracted should be made.

After a successful test, the air mover should be switched on to exhaust smoke from the containment and to give a minimum of 6 air changes per hour, and check visually to see that the absolute filters screen out the smoke effectively and if the pressure gauges read normal. If not, the air mover should be sealed up and returned to the supplier workshop for necessary servicing, and replaced by a tested air mover. The normal reading pressure range for maintaining 6 air changes per hour should be 1.5-4 mm/0.05-0.15 inches of water or equivalent (negative pressure). The audible alarm's integrity should also be checked and the trigger should be at <1.5 mm/0.05 inches of water (negative pressure). Otherwise securely seal up all openings before switching off the air mover.

8.2.3 Treatment and Disposal of Waste

All workers must wear full protective equipment, disposable protective coverall (with hood and shoe covers), nitrile gloves, rubber boots (or boot covers), and full-face positive pressure respirators equipped with a combination cartridge that filters particulates and removes organic vapour. The organic vapour protection is an added level of protection against the unlikely exposure to any vapour. The incinerator flue should be removed from top down starting from the roof area. The chimney flue should be taken down in sections by loosening the flanges. Any ash or incineration residues attached to the incinerator and flue section should be removed by HEPA vacuuming.

The detached sections of the flue should be wrapped with 2 layers of fire retardant polythene sheets. A third layer should then be wrapped and secured with duct tape. Decontamination of the outer layer of the wrapped flue sections by wet wiping should then take place.

Upon removal, the entire incinerator should be wrapped with 3 layers of fire retardant polythene sheets. The outermost layer secured with duct tape. Wastes generated from the containment or decontamination unit including the fire retardant polythene sheets, protective clothing of the workers such as the coverall, nitrile glove, rubber boots and materials used for wet wiping should be disposed of at landfill site. Wastewater generated from the decontaminated process will be very small and the contractor should take precautionary measures as to minimise the quantity of contaminated water arising.

After completion of removal, all surfaces must be decontaminated, including the wrapped incinerator furnace and flue sections left within the containment, by wet wiping and HEPA vacuum. Spraying of the innermost layer of the fire retardant polythene sheet covering the wall, ceiling and floor must be done.

Upon drying, the innermost layer of the polythene sheet covering the containment must be peeled off and disposed at a landfill site. The above decontamination procedures are to be repeated for the second innermost layer of fire retardant polythene sheet, including the wrapped incinerator furnace and flue sections left within the containment by wet wiping and HEPA vacuuming. After spraying this second innermost layer of the polythene sheet covering the wall, ceiling and floor must be peeled off and also disposed at a landfill site.

Finally, the last layer of polythene sheet should then be taken down after spaying and disposed as contaminated wastes.

8.2.4 Type of Waste and Disposal Method

Presently, there are no disposal facilities for the treatment of contaminated ash from incinerators.

Other wastes including the combustion furnace and its associated panels, the entire flue section, as well as wastes generated from this decommissioning works are also considered as contaminated waste and can be disposed of at a designated landfill. Wastes generated from this decommissioning works refer to the polythene wrapping sheets for the incinerator furnace and flue sections, waste generated from the dismantling of the containment and decontamination units, and cloth used in wet wiping wrapping, etc. as previously described in this section. They should be placed into appropriate containers such as drums or heavy duty and leak-proof plastic as a prudent approach.

Permits have to be obtained from the National Environment and Planning Agency (NEPA) and the National Solid Waste Management Authority (NSWMA) prior to the decommissioning exercise. Care must also be exercised when selecting contractors that have the requisite skills and experience, for the decommissioning exercise.

Table 8.3 outlines the significant impacts that are associated with the decommissioning of a medical waste incinerator, their sources and the mitigation measures to address the adverse impacts.

Table 8.3 Environmental Impacts and Mitigation Measures Associated with Decommissioning the Existing Incinerator

ENVIRONMENTAL ASPECT	ENVIRONMENTAL IMPACTS	MITIGATION MEASURES
Air Pollutants Residues retained on the inner surface of the stack/flue of the incinerator and the combustion chambers may pose a health risk to the persons dismantling the incinerator. This risk could spread to the wider hospital community if particulates and PM_{10} in the residues are allowed to become airborne through a failure to contain the contaminated parts. Pollutants of particular concern in the residues include PCBs, dioxins and heavy metals.	May cause, contribute to and exacerbate respiratory illnesses. Possible adverse impacts include: • Deterioration of air quality, with particulates in particular causing, contributing to and exacerbating respiratory illnesses • The effect of toxins (persistent organic pollutants) such as dioxins and PCBs which have the greatest long term health effects on animals at the top of the food chain (such as humans) causing adverse effects upon reproduction and development, suppression of the immune system, disruption of hormonal systems, and cancer • Negative impacts on human health, flora and fauna and contamination of land and water from heavy metals	Follow decommissioning procedures described earlier in this section.
Noise The demolition of the incinerator will generate minimal noise.	The demolition activities are not expected to give rise to any significant noise impact and any associated noise would be for a temporary period.	Ensure good preparation according to the decommissioning procedures described above to ensure that schedule is adhered to. Use only hand-held tools.
Wastewater Though quantities of wastewater may be small, this needs to be appropriately contained to prevent release into any nearby waterways or leaching into soil.	Contamination of land and water	Use water only if absolutely required. Convey wastewater to a sewage/wastewater treatment facility.

ENVIRONMENTAL ASPECT	ENVIRONMENTAL IMPACTS	MITIGATION MEASURES
Solid Waste The incinerator may be contaminated with residues of PCBs, dioxins and heavy metals.	Improper disposal of the scrap material obtained from the dismantling of the incinerator may cause: • Public health concerns for those that handle the waste or casually come into contact with it as a result of improper disposal • Aesthetic problems • Contamination of flora, fauna, land and water resources which in turn can cause bioaccumulation in the food chain.	Follow decommissioning procedures described above in this section, particularly the recommendations for disposal.

9.0 Interagency/Non-Governmental Organisations/Public Consultation

Since the proposed incinerator is to be located on the compound of the hospital near to the location of the existing incinerator, public consultations were conducted with persons at the following locations in and around the hospital.

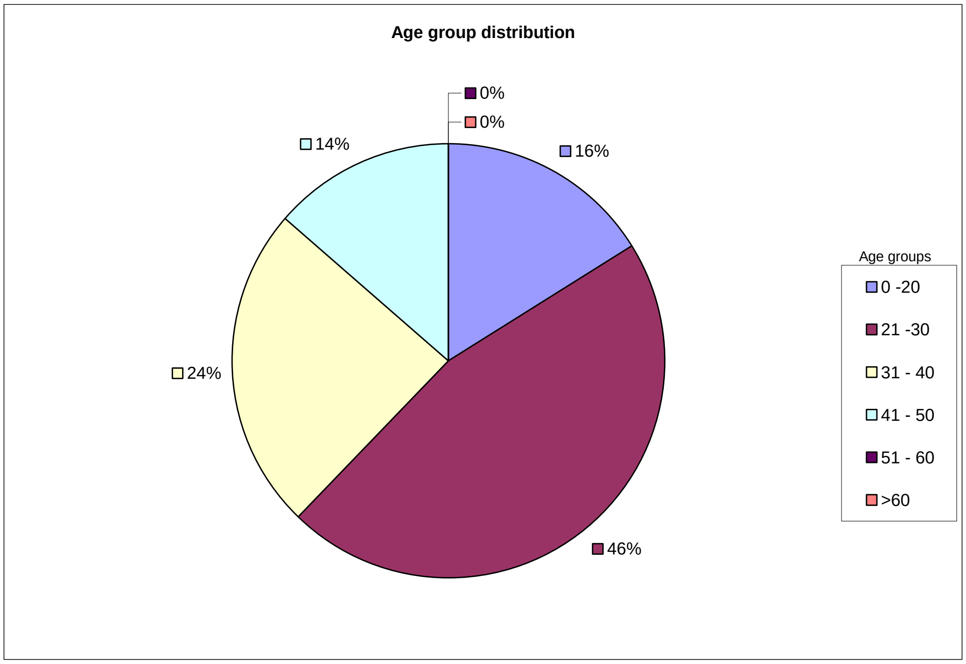
- hospital staff quarters
- hospital staff /visitors
- Taylor Hall
- Chancellor Hall
- Mary Seacole Hall
- Irvine Hall
- Preston Hall
- Rex Nettleford Hall
- Mona Commons
- Settlement in front of hospital main gate

A questionnaire was developed and used to ascertain if persons know that an incinerator exists at the hospital and their perception of its impact on them. The questionnaire is at Appendix 5.

Details on the number of respondents, their age and their responses to the questions are at Appendix 5.

The total number of persons interviewed were 37 with the largest number (46%) being in the 21 to 30 age group. No persons over 50 were included in the sample. Figure 9.1 provides a graphical representation of the age distribution of the persons interviewed.

Figure 9.1 Age distribution of persons interviewed



Most of the persons interviewed were from the hospital (43%), while an almost equivalent number were interviewed from the Mona Campus (41%). Mona Commons and the informal settlement in front of the hospital had an equal number of participants (8%). This data is shown at Figure 9.2.

Figure 9.2 Grouped Area distribution of persons interviewed

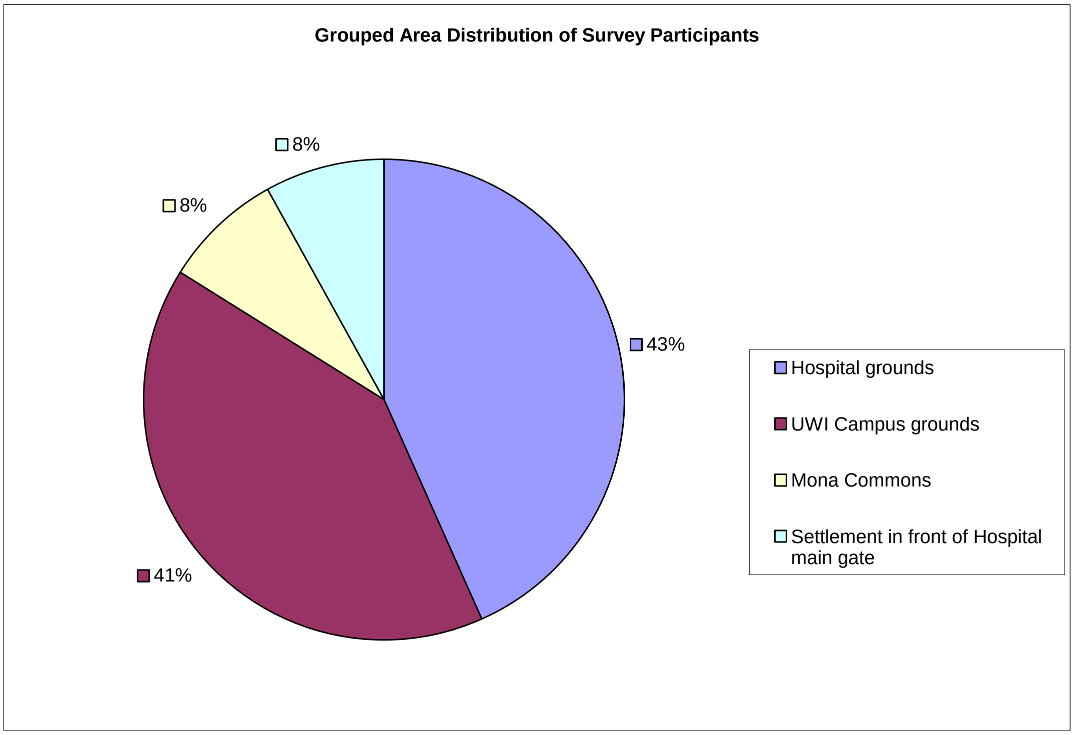


Figure 9.3 shows a more detailed breakdown of the locations which at the hospital and at the Mona Campus that were included in the survey. The area distribution of the persons who were interviewed indicated that Mary Seacole Hall had the largest group of participants (33%) and Irvine Hall having the least (3%).

Figure 9.3 Area distribution of persons interviewed

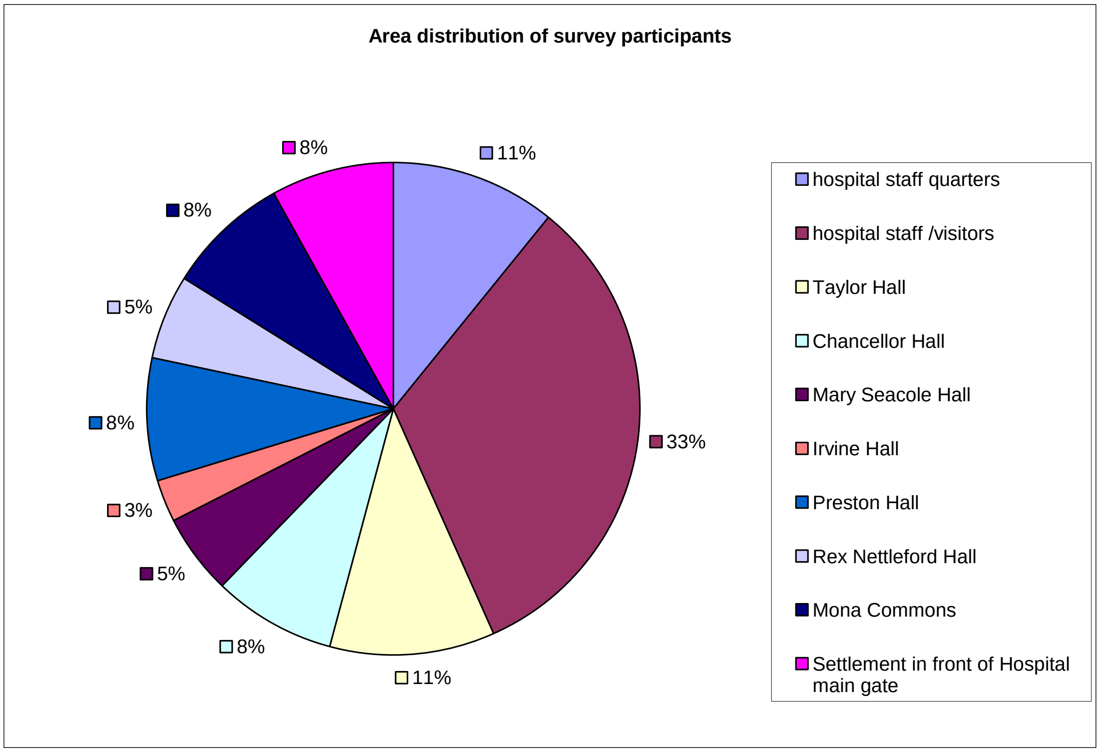


Figure 9.4 shows that most of the survey participants (56%) have worked or resided in the area for 1 to 3 years. No participants in the survey have worked or resided within the community for 10 years or more.

Figure 9.4 Number of years participants have worked or resided in the area

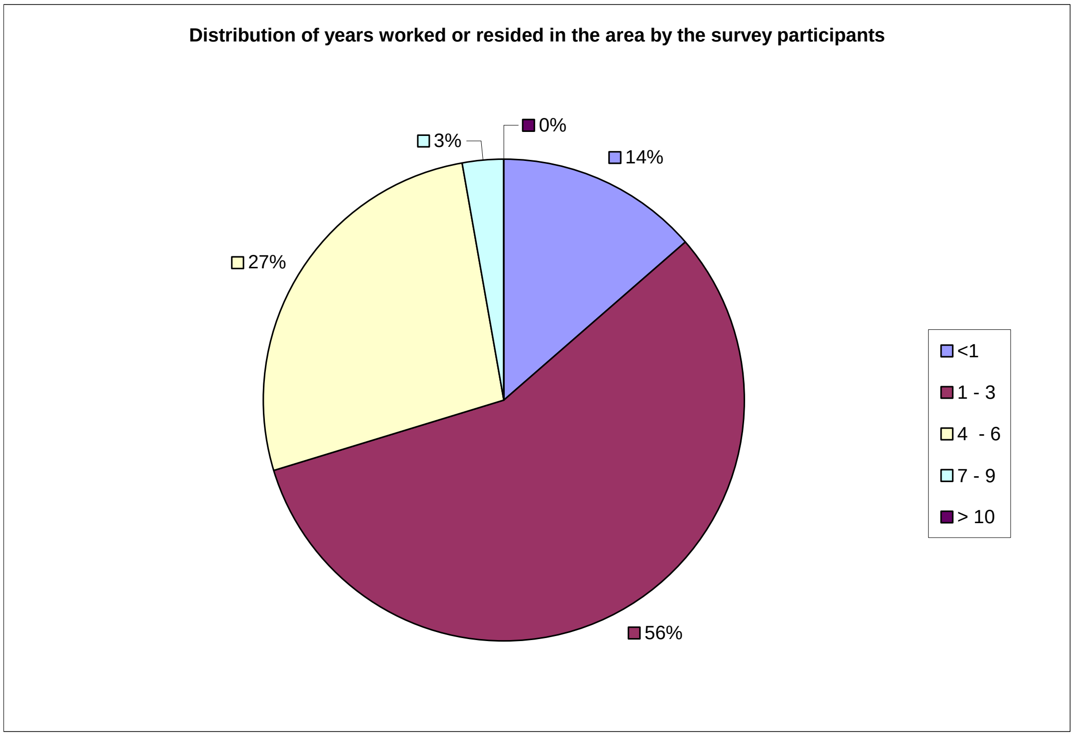
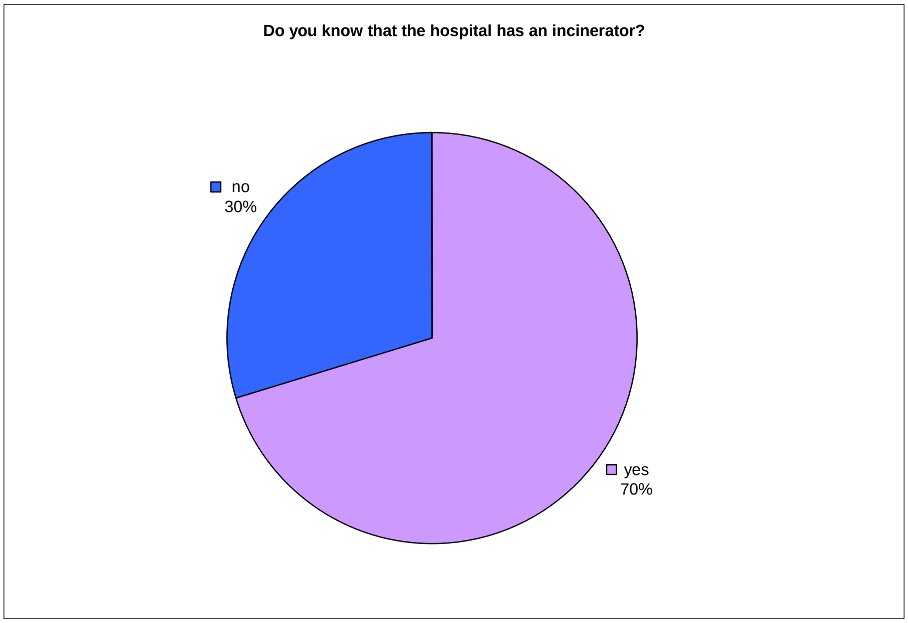


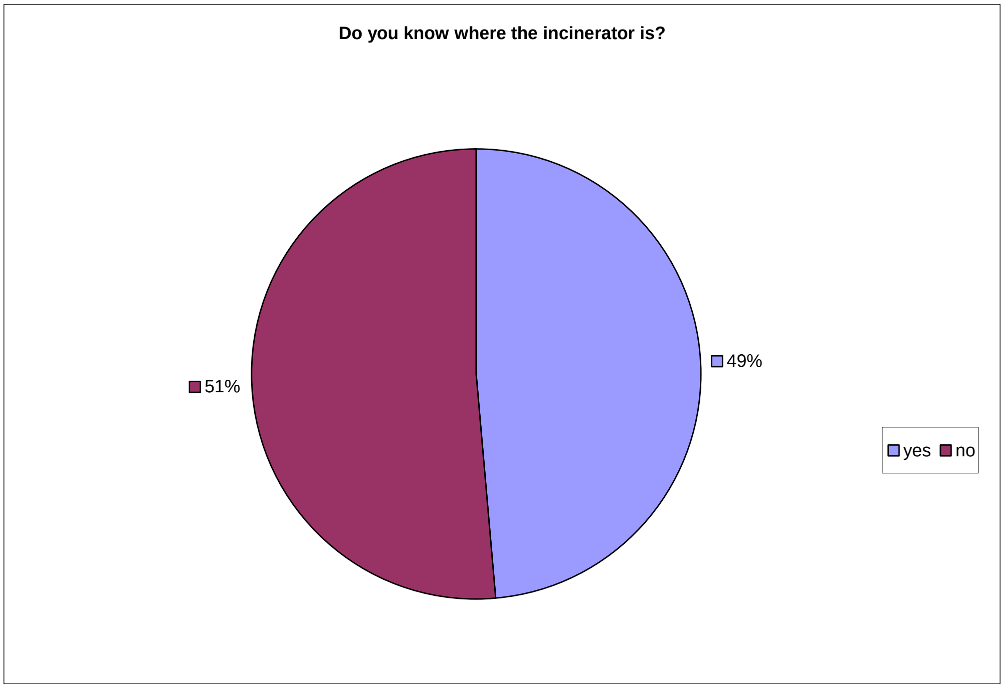
Figure 9.5 indicates that as much as 70% of the survey participants know that there is an incinerator at the hospital.

Figure 9.5 Knowledge of the existence of an Incinerator



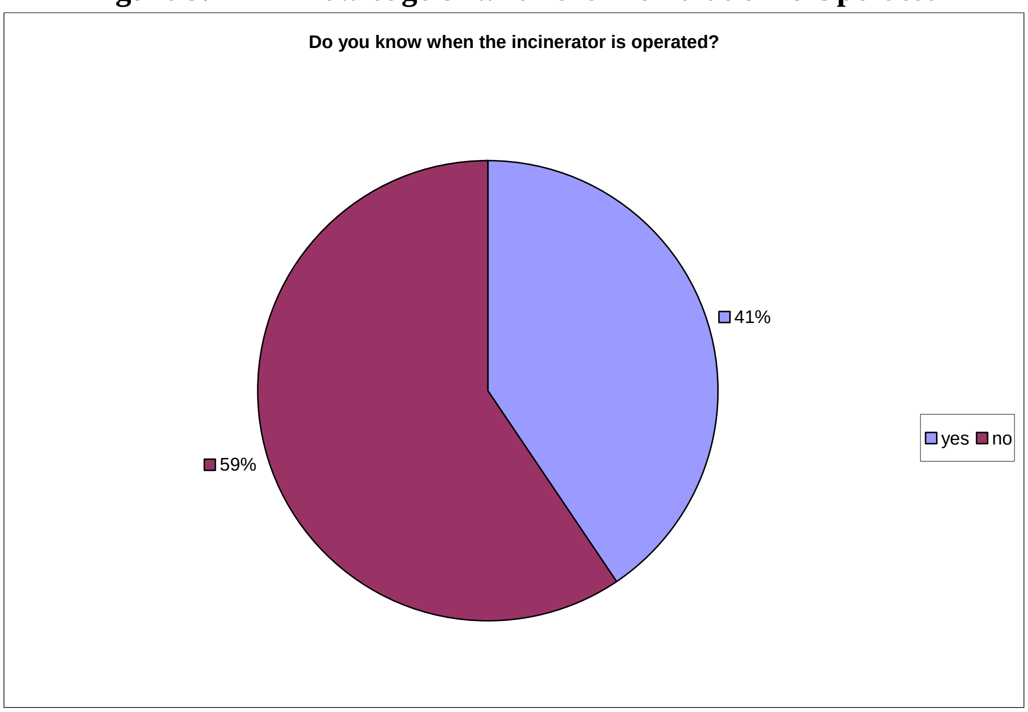
About half of the persons know where the incinerator is located on the hospital compound as shown in Figure 9.6.

Figure 9.6 Knowledge of the Location of the Incinerator



As shown in Figure 9.7, 59% of the participants do not know when the incinerator operates.

Figure 9.7 Knowledge of when the Incineration is Operated



Even though 41% of the participants knew when the incinerator was operated, up to 49% indicated that they were adversely affected by the operations of the incinerator as indicated in Figure 9.8. Making reference to Table 9.1 and Figure 9.9 the most common afflictions were:

- The smell from the incinerator – 25%
- The soot from the incinerator – 16%

The persons who made most of these complaints worked and lived on the hospital compound including security personnel.

About 34% of the persons interviewed indicated that they were not affected by the incinerator. All of these responses came from persons who did not work or live on the hospital compound with majority from persons living on the halls of residence at the Mona Campus. Survey participants from Mona Commons and the informal settlement in front of the hospital said they were not affected by the incinerator.

Figure 9.8 Those affected by the operation of the Incinerator

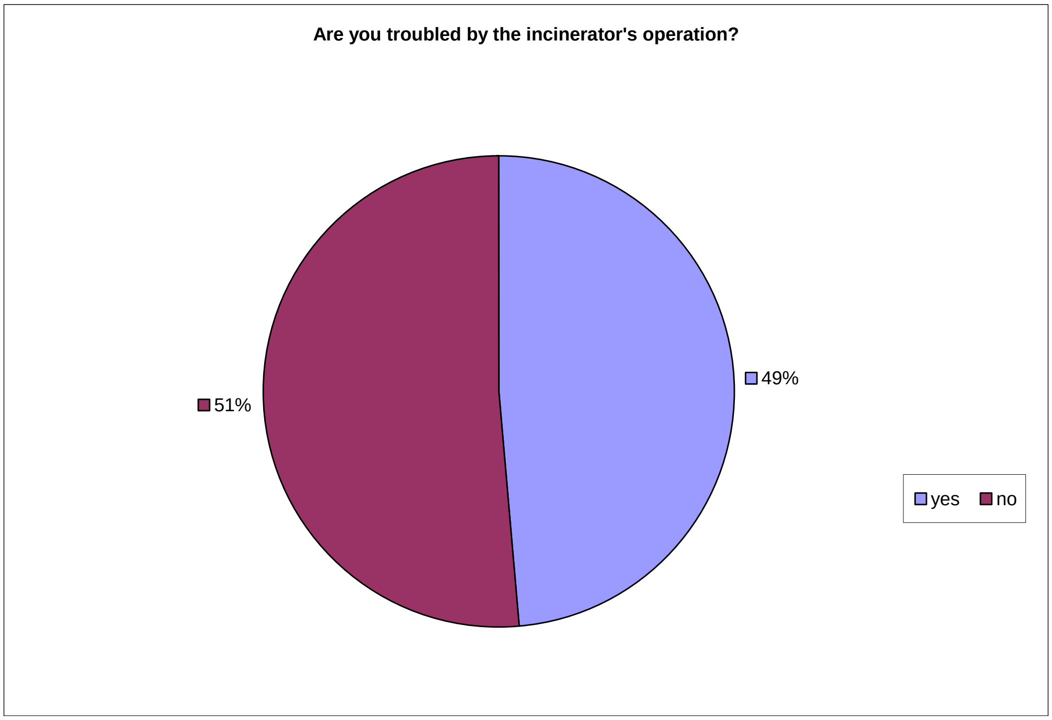


Figure 9.9 Distribution of Health Complaints

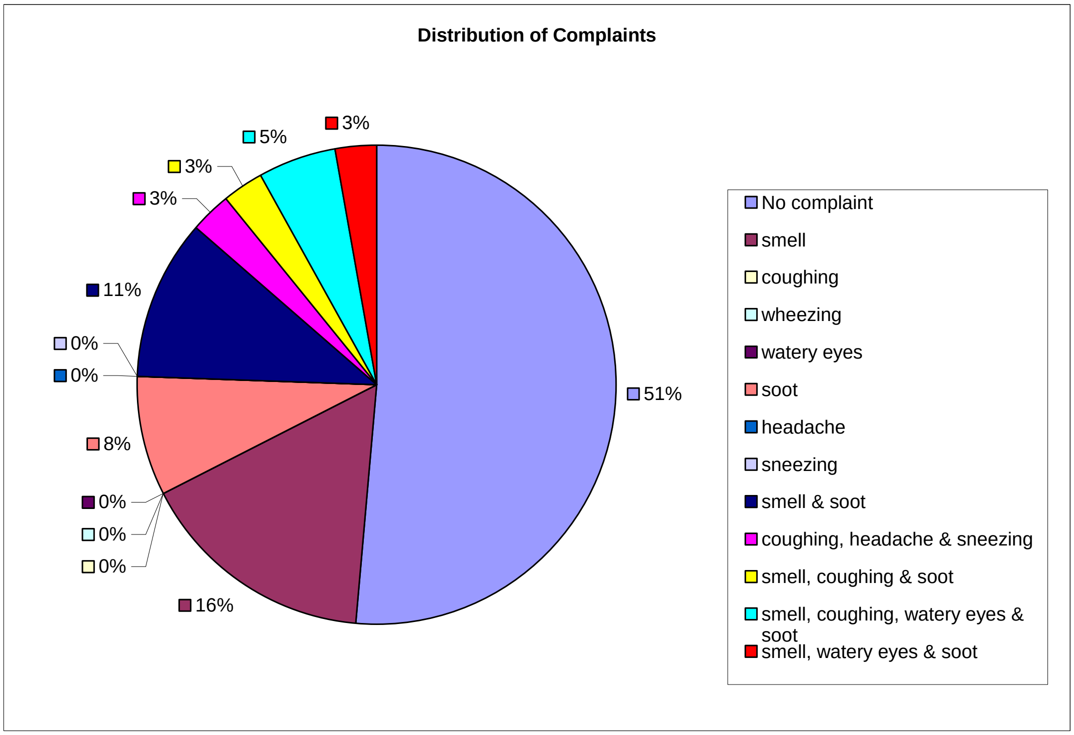
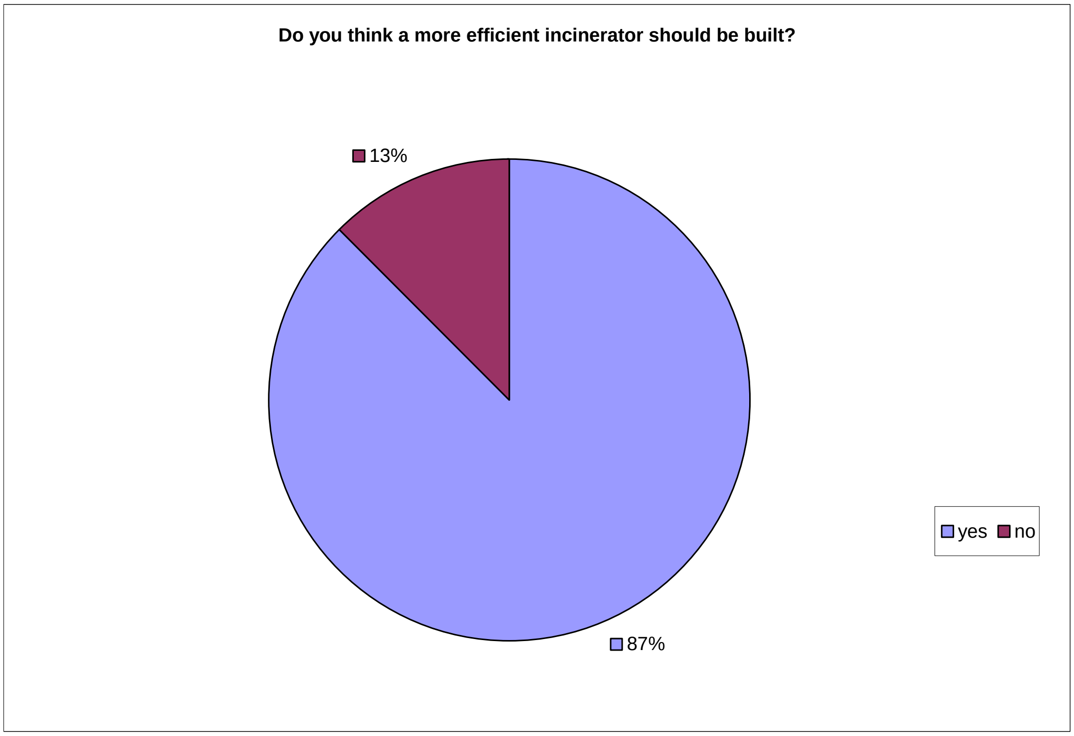


Table 9.1 – Health Complaints by Location

Health Complaint	Number of Complaints by Location											Total
	Persons on hospital compound	Security personnel	Mona Commons	Informal Settlement	Library	Irvine Hall	Chancellor Hall	Taylor Hall	Preston Hall	Mary Seacole Hall	Rex Nettleford Hall	
Smell	5	5	1		2						1	14
Coughing	3	1										4
Wheezing												0
Watery Eyes	2	2										4
Soot	6	4										10
Other	1	1										2
No Complaint			2	3		1	3	4	3	2	1	19
TOTAL	17	13	3	3	2	1	3	4	3	2	2	53

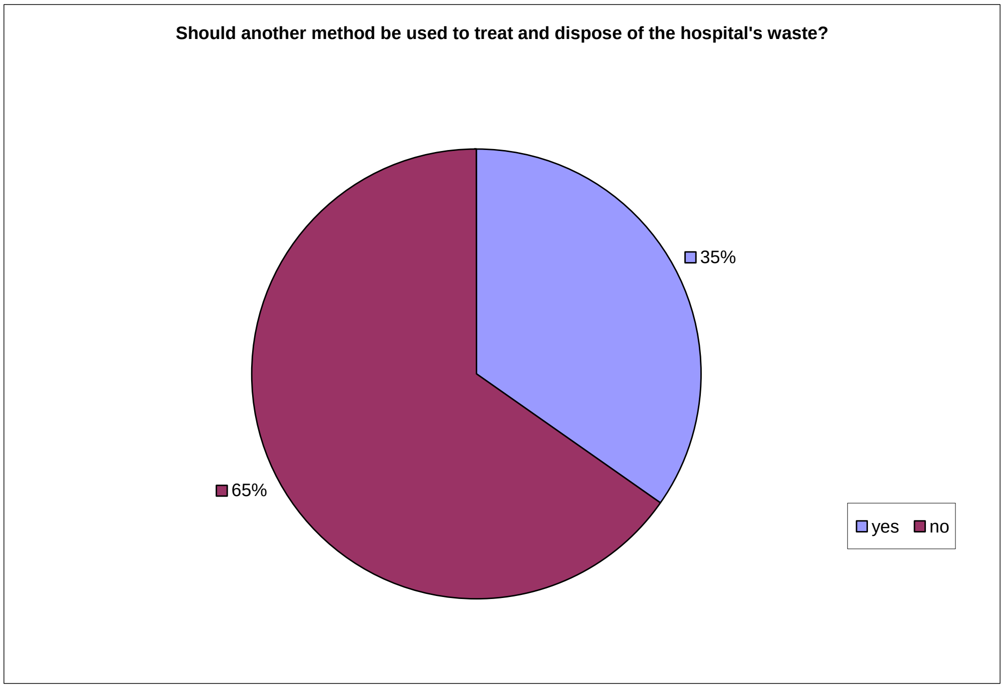
The majority of persons participating the in survey, (87%), believe that a new incinerator is required as shown in Figure 9.10.

Figure 9.10 Those who think a new Incinerator is required



Many of the persons who said that a new incinerator is needed also indicated that other alternatives should be used. 69% of the participants supported looking for an alternative method for the disposal of medical waste other than incineration as shown in Figure 9.11.

Figure 9.11 Those who think an alternative to incineration should be used



9.1 Conclusions from the Survey results

The results imply that the persons who are most noticeably affected by the operations of the incinerator are those who work and live on the hospital compound. This is to be expected as they are more familiar with the times of operation of the incinerator and are closest to its location where they would notice the smell and see soot that emanates from it.

Persons outside of the hospital compound who were participants in the survey understandably would not necessarily notice the impacts from the incinerator. Firstly, they are physically removed from the location and therefore do not have a constant reminder of its presence. Secondly, there are other factors which may cause them greater concern within their immediate environment. The informal settlers in front of the hospital for instance may smell more vehicular exhaust than odours from the incinerator because they are close to the heavy traffic which uses the road on which the hospital is located.

There seems to be support for an incinerator to be used to treat and dispose of medical waste but at least a half of those persons also feel that alternatives to incineration should be used.

9.2 Non-Governmental Organisations

Consultations with the National Environmental Societies Trust (NEST) indicated that there are no registered or known non-governmental organisations in the surrounding communities.

9.3 Interagency Consultations

This project will not materialize without the involvement of the following agencies:

- National Environment and Planning Agency which must grant planning and environmental permission for the project. A licence to discharge emissions must be applied for when the legislation governing the same is enacted.
- The National Solid Waste Management Authority (NSWMA) must grant permission for the incinerator as the chosen method for medical waste disposal and also the UHWI must enter into special arrangements with them for:
    - The disposal of ash
    - The disposal of hazardous wastes such as discarded medical waste containing mercury
    - The disposal of the dismantled incinerator
- Where the NSWMA is providing a service such as special arrangements for disposal of special wastes, a cost will be associated with the service.
- The Fire Brigade will need to approve the fire prevention arrangements proposed for the new incinerator
- The Environmental Health Unit will need to approve the design of the proposed incinerator for effectiveness.