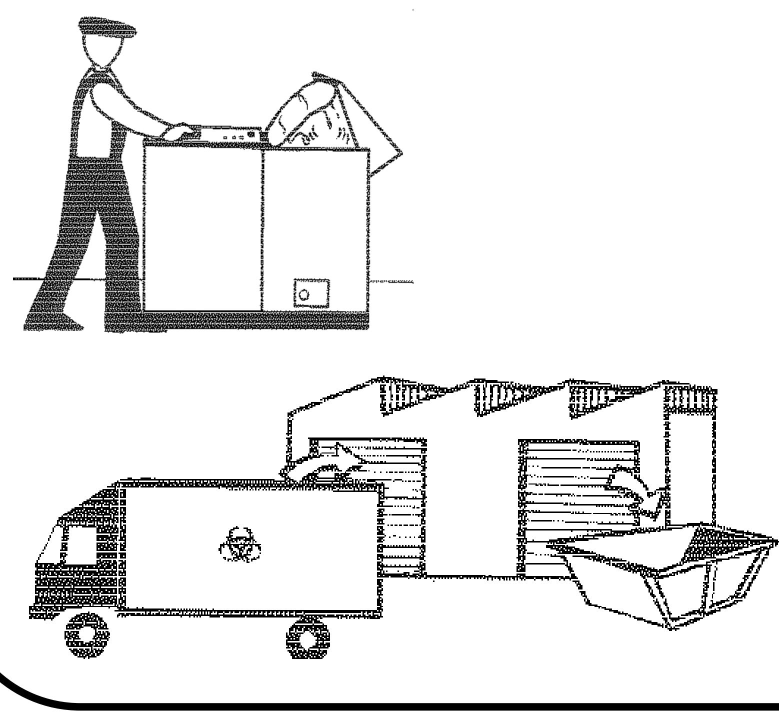
Guidelines on Sustainable Health Care Waste Management in Gauteng

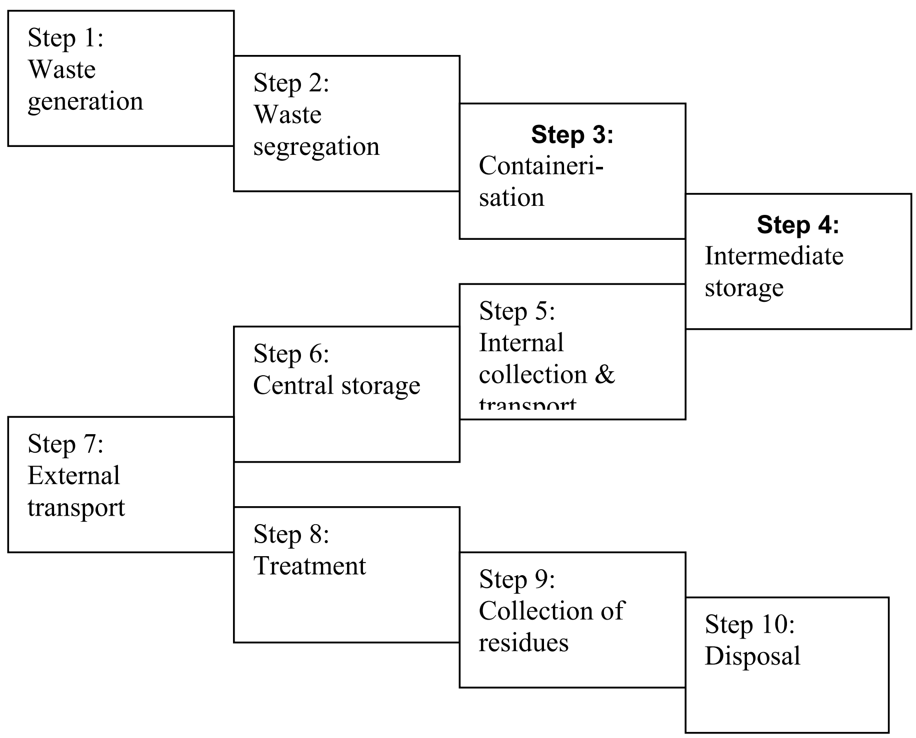
MODULE 6: Treatment of Health Care risk Waste:

- Health Care Waste Information System
- Presentation of different treatment technologies
- Advantages & disadvantages
- Examples on treatment technologies
- Environmental standards



6. Module 6: Treatment of HCRW – Principles for Operation

Box 6.1: Steps of the HCW flow included in this Module



6.1 Objectives of Module 6

The two main HCRW treatment technology categories are thermal and non-thermal treatment processes. The objective of Module 6 is to present recommendations on various options available for HCRW treatment, which is aimed at eliminating the infectious organisms and other hazardous materials in the HCW. Reducing the environmental as well as the occupational health and safety risks by elimination of such infectious organisms can in turn be considered to be the ultimate objective of integrated HCW management.

HCRW treatment can therefore be described to be any method, technique or process used for altering the biological, chemical or physical characteristics of HCRW in order to reduce the hazards it presents, to facilitate its ultimate disposal and reduce the costs of disposal. The basic treatment objectives include disinfection, neutralisation, volume reduction or other changes to reduce hazards.

6.2 Target Group

Module 6 of the Guidelines primarily targets senior and middle management of the HCRW treatment facilities. It does however also provide concrete information used during the decision making process for senior management at health care facilities, who are in terms of the Duty of Care Principle responsible for the treatment and safe disposal of HCRW. Environmental officers, environmental health officers and other professionals responsible for HCW management may furthermore benefit from this Module.

Management at health care facilities is inter alia to decide whether treatment of HCRW is from an environmental, health, safety and finally financial point of view more effective undertaken by operating an on-site treatment facility or whether such services are to be outsourced to service providers using regional off-site treatment facilities.

Since each particular treatment technologies have its own special operational requirements, these Guidelines will focus on generic matters that are considered to be relevant to all or most of the treatment technologies used in South Africa.

6.3 Scope of Module 6

The responsibility for environmentally sound treatment and final disposal of the HCRW is transferred from the generator to the transporter, and then to the HCRW treatment facility owner every time the HCRW is handed over to the next party involved in the HCW management process. However, the duty-of-care principle requires from each party to ensure that the HCRW and responsibility for its sound management is handed over to a competent organisation that will apply approved and permitted methods and systems only.

The Guideline therefore focuses on peripheral activities that are generic for most treatment options, for instance data recording on delivery, HCRW storage requirements, safe handling and onsite transport of HCRW during treatment and finally the management of residues.

6.4 Reference to Other Modules/Documents

The information in this Module is to be read in conjunction with Module 1, which is the Module designed to address all the cross cutting issues identified in the process of integrated HCW management. Readers of Module 6 are also encouraged to read Module 6 on transportation of HCRW and residues from treatment for a better understanding of the interfacing of transport with treatment, as well as Module 8 that deals with the sound disposal of residues.

6.5 How to record HCWIS Data

DACEL is in the process of developing, enacting and prescribing a record keeping and data reporting structure to be used by all HCRW treatment facilities; the Health Care Waste Information System (HCWIS).

The major objective of the HCWIS is to support management in undertaking strategic planning on HCRW management in Gauteng. Its second objective is to generate sufficient data for reporting on the State of Environment or systems.

The HCWIS is therefore intended to:

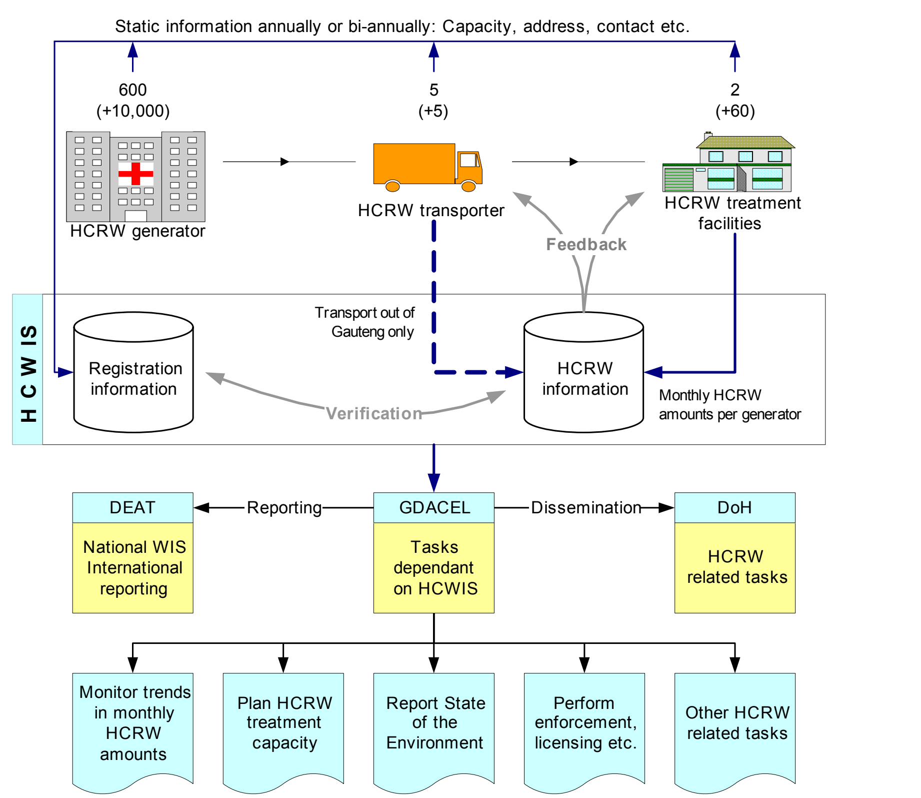
Periodically monitor trends in the amount of HCRW transported and treated within the Province, and
Assess the availability of HCRW treatment capacity within the province against the amount of HCRW being generated to plan for future HCRW treatment needs.

Further issues to be addressed by the HCWIS, include:

To promote the recording of waste generation data for individual health care facilities;
To develop a data base on HCRW generators, transporters and treatment facilities;
To appropriately report on information gathered for the HCWIS for amongst others the Provincial as well as National State of Environment Reporting (SoER);
To identify priorities for HCRW management and at source separation training;
To monitor waste minimization programmes and the success of training for improved waste segregation;
Identify unit generation data, i.e. typical waste tonnages produced for different generator types.

Information for the HCWIS will be collected, processed and disseminated as illustrated in Figure 6.1 below. The main principle of the system is that each piece of information is collected only once, validated close to the source of information for correctness, and disseminated to the relevant bodies.

Figure 7.1: Overall principles of HCW information system



The HCWIS was designed to handle dynamic as well as static information regarding HCRW generators, transporters and treatment facilities. The information required for the HCWIS will include:

Basic information on HCRW generators;
Basic information on HCRW transporters;
Basic information on HCRW treatment plants (private and public);
From treatment plants (including onsite at hospitals and clinics) information will be obtained on the monthly amount of HCRW treated per generator as reported per transporters;
From transporters information will be obtained on monthly amounts HCRW transported out of the Province for treatment at approved HCRW treatment facilities in neighbouring provinces.

6.5.1 Registration

All HCRW generators, transporters and treatment facilities will be required to register with Gauteng DACEL. Initially only medium and large generators of HCRW (> 1kg per day) will be required to register and will be issued with a unique registration number. Small generators of HCRW, for example GP's may be accommodated by means of central collection points for which the Local Authority is responsible, in which case the Local Authority would register as a HCRW generator. There are an estimated 227 large generators (> 10 kg per day), 343 medium generators (1-10 kg per day) and approximately 9700 minor generators (< 1kg per day) within the Province (HCRW Status Quo Report, 2000)

In registering with DACEL, certain basic static information is required, such as the company name, postal address, telephone number, e-mail, contact person, permit status and coordinates. Furthermore, for treatment facilities, information on treatment capacity would be required, while for generators, information on number of beds and/or outpatients, occupancy and expected ranges in HCRW generated would be requested.

The unique identifier issued to generators, transporters and treatment facilities is required to distinguish between different companies submitting data to the HCWIS.

HCRW treatment facilities, and to a lesser degree HCRW transporters, will be the sources of information for the HCWIS. Static data will be collected on registration and thereafter updated annually or bi-annually. Dynamic data will initially be collected monthly and later during the process perhaps quarterly. In terms of the HCWIS, it will be required that all HCRW be weighed and that the amounts are reported in kilograms (kg).

The method used to weigh the HCRW either by the transporter or treatment facility is not prescribed. Similarly the means of capturing generator information is not prescribed, whether it is labels, bar codes or transponder systems. The only stipulation with regards to labelling is that each and every container be clearly marked with the generator's name and unique number.

6.5.2 Reporting

Data submission to DACEL can (in order or priority) be done by means of i) online reporting using the internet, or ii) reporting in computer file on diskette or via e-mail, or in exceptional cases iii) submission of data in paper format.
Reporting by either a treatment facility or transporter must contain the following:

Identification of reporter;
Month and year;
Amount of HCRW (kg);
HCRW category;
Generator registration number;
Transporter registration number;
Treatment facility registration number.

The reports for both the treatment facility and transporters are the same. The report allows for the capture of information on the Reporter, the generator producing the waste, the transporter delivering waste to the treatment facility (inside or outside of Gauteng), and the treatment facility receiving the waste.

For HCRW removed from Gauteng to another province, only the province name is listed under *Treatment facility*, since these treatment facilities will not be registered with Gauteng DACEL, and as such will not have a registered unique identifier. Similarly for waste received for treatment in Gauteng from neighbouring provinces, only the province name is listed under the *Generator* field. DACEL will however require more details on such treatment facilities and generators, to ensure that the same standards set for Gauteng, are met by outside parties becoming involved in HCW management for Gauteng.

6.6 Storage of HCRW at Treatment Facilities

Having collected and externally transported the HCRW from the various generators (e.g. health care facilities) where no HCRW treatment is done onsite, the HCRW is to be delivered to the storage areas at regional facilities where the HCRW treatment is to be undertaken. Such storage should consist of a suitable location at or near the HCRW treatment plant, but within the outer perimeter of the facility, with the intention of near future removal for treatment and disposal.

Some of the most important requirements with which HCRW storage areas at the treatment facilities are to comply, are presented in Box 6.2.

Box 6.2: Requirements for HCRW storage areas at treatment facilities.

The onsite storage area is to provide effective lockable access control that will make it inaccessible for humans, animals, birds and insects, ensure its isolation from the elements, provide protection against rodents and vectors as well as protection against environmental and health impacts;
The HCRW storage area door should have a signboard that clearly indicate the contents of the room, the contact details of the responsible person as well as contact details for use in the event of an emergency;
HCRW storage areas should be equipped with any monitoring facilities that may be required (e.g. monitoring for radioactivity, etc.);
The storage area should be easily accessible for the waste management personnel collecting HCRW as well as for waste collection vehicles delivering HCRW to the facility;
The HCRW storage area should be equipped with good lighting and at least passive ventilation;
The storage room should have an impermeable, hard-standing floor with a floor drain and water supply as part of a wash facility;
The HCRW storage room should be easy to clean and disinfect. For this purpose walls with smooth surfaces that can be readily disinfected are preferred;
A supply of cleaning equipment, protective clothing and waste bags or containers should be located conveniently close to the storage area;
The floor of the storage facility should at all times be free from damp and moisture, not only to prevent it from being slippery, but also to protect the containers, particularly where cardboard boxes are used for HCRW storage;
There should be no sources of open fires in close proximity of the HCRW storage areas that can result in the outbreak of a accidental fire;
The room temperature should be kept down by protecting it from temperature rises resulting from direct sunlight and un-insulated corrugated iron walls/roofs;
As most HCRW contains biodegradable materials, the packaging should be sealed and the storage time limited, particularly when considering the fact that the HCRW has already for some time been stored at the point of generation. Although it is preferred to have all incoming HCRW treated in daily cycles, the following time limits for non-cooled storage of HCRW should be followed in Gauteng to avoid odour problems and the breeding of vectors:
Maximum 72 hours in moderate climates;
Maximum 72 hours in hot climates.
Depending on the quality of the packaging and the robustness of seals anatomical waste may have be stored for shorter periods and treated as a priority to avoid unacceptable odour and esthetical problems.
Where required by abnormal high temperatures or long storage periods, refrigerated facilities are to be provided as part of the storage facilities;
The storage area is to be used for all potential categories of HCRW that is to be treated at that particular treatment facility, with some clearly demarcated area for HCRW that cannot be treated and that is to be removed for treatment at an appropriate facility somewhere else (e.g. pathological HCRW at non-burn treatment facilities);
If radioactive waste is detected, such waste should normally be of relative low radioactivity level and of very modest quantities and must therefore be handled and placed separately for further treatment/disposal in accordance with the level of radioactivity and risk associated with its presence;
Multiple box units are not to be stacked higher than 1.7 meters if handled manually and only if this is safe to handle and unlikely to result in boxes falling or collapsing;

Wheelie bins are not to be stacked at all;
Smaller units such as sharps containers and specicans should not be stacked and stored loosely but preferably contained in larger containers to limit the number of units to be handled and to safeguard against spills;
The stacking height for high density waste like for instance liquids in specicans, are to be limited to two layers of containers, that will reduce the risk of contamination of the storage area in the event of possible overturning of sealed containers;
The size of the HCRW storage area should be sufficient to cater for the HCRW storage equivalent to the maximum treatment capacity for a period of 3 days;
Pre-arranged contingency plans must be established to allow for transfer of waste for treatment at another treatment plant that will allow for planned or unplanned unavailability of the treatment facility.

The training required for the operators at the treatment plant shall go hand-in-hand with the training of the transport staff, which is likely to be responsible for the placing of containers inside the storage area at the HCRW treatment facility. Training is furthermore to include all safety and emergency response measures that are to be implemented and adhered to for the HCRW storage area.

6.7 Handling and Onsite Transport of HCRW

Details on the requirements for onsite handling and transport of HCRW are described in Box 6.3.

Box 6.3: Details on onsite handling and transport of HCRW.

Manual transport of HCW should be avoided wherever practical, with heavy or awkward lifts and manipulations not being permitted under any circumstances. Only in exceptional cases should manual lifting be allowed and only for units weighing less than 15 kilograms and that are designed for easy handling;
Dedicated waste management staff should carry out collection of HCRW from onsite storage areas;
Where manual transport of HCRW is for logistical reasons the only viable option, it should be assured that the workers doing this are appropriately informed about the risks of infection as well as the associated occupational health and safety aspects;
Workers are to be informed on the safe way in which HCRW containers are to be handled; like avoiding the carrying of HCRW bags directly against the body and limiting the number of containers carried to the maximum lifting load of 15 kg;
Workers are to be equipped with the required Personal Protective Equipment (PPE) like dust masks, aprons, gloves and safety shoes;
No HCRW shall be handled unless containerised and no form of segregation shall be undertaken at the HCRW treatment facility;
Where container collapse or spillage occurred, the prescribed emergency procedures should be followed for re-containerisation of the HCRW and disinfection of the affected area;
Removal of HCRW spills are to be undertaken by staff that are suitable trained and equipped with the necessary Personal Protective Equipment (PPE);
Onsite transport of HCRW at the treatment facility can be by means suitable designed trolleys or other wheeled systems;
The rate of HCRW treatment, the types of containers used, the distance between the onsite storage area and the treatment facility as well as the accessibility for different types of trolleys to both the storage area and the treatment plant will inter alia determine the onsite transport system to be used;
The types and sizes of containers to be transported onsite will determine the more precise trolley dimensions.

The design criteria for carts, trolleys or other vehicles for transport of HCRW between the onsite storage area and the treatment plant as indicated in Box 6.4 are important to consider.

Box 6.4: Design criteria for carts, trolleys or other vehicles for onsite transport of HCRW.

Equipment used for transport of HCW are to ensure safe transport thereof, avoiding spills and preventing unauthorised persons from getting in contact with the HCW. Trolleys, when loaded, shall not be left unattended;
The transport equipment used shall be easy to load and unload, whilst securing the HCW containers during transport;
HCRW containers shall not be loaded higher than the design level and no unsecured containers that may drop from trolleys shall be loaded onto the trolleys;
Transport equipment should be easy to move and manoeuvre and should be able to get easy access to both the HCRW storage area as well as the HCRW treatment plant;
The equipment used should be durable with low maintenance requirements. It should further be easy to clean and disinfect.

The required training for workers responsible for onsite transport of HCRW is detailed in Box 6.5.

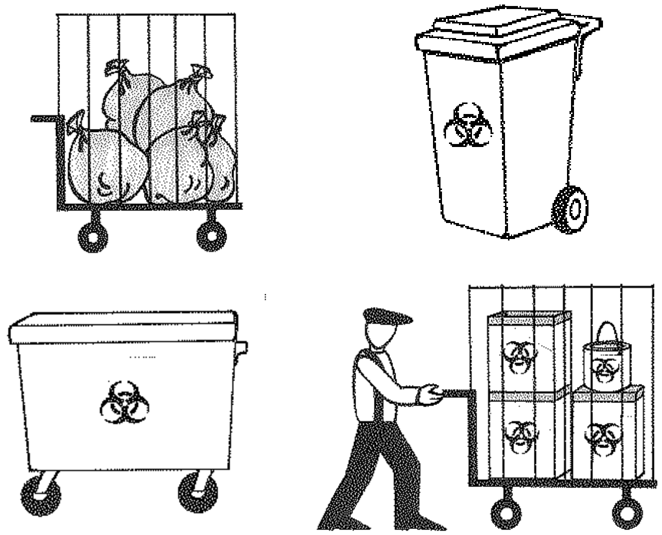
Box 6.5: Training Requirements for onsite HCRW transport.

Procedures for safe handling and loading of various HCW containers;
Emergency procedures in the event of an accident or HCW spillage;
Occupational Health and Safety requirements;
The correct use of PPE.

Certain standard procedures related to the safe onsite management of HCRW at the treatment facilities are to be compiled and distributed to all affected members of staff. In addition to this, the information is also to be conveyed by means of graphic illustrations like for instance posters, particularly as many of the persons involved in this activity may be illiterate, thus not being able to read written procedures and manuals.

Figure 6.2 below presents some different types of trolleys for onsite transport of HCRW.

Figure 6.2: Examples of trolleys used for onsite transport of HCRW.



In Table 6.1 below examples on technical specifications and typical prices of equipment for onsite transport of HCRW are shown.

Table 6.1: Guiding specifications and prices of waste collection and transport equipment

Item	Technical specification	Approximate price in Rand / piece
Bar fence trolley (refer to Figure 6.2.)	Painted steel	1000-2000
Bar fence trolley (refer to Box 6.2)	Stainless steel	3000-5000
600-800 litre wheelie bin	Xx	2000-2400
1100-1500 litre wheelie bin	xxx	2500-3000
Tractor unit	xxx	xx
Trucks for the tractor unit	xxx	xxx

6.8 Treatment of HCRW

This section on HCRW treatment includes both thermal (e.g. incineration) as well as non-thermal (e.g. sterilisation/inactivation) treatment technologies. Treatment plants can be located on-site at the source of the HCRW, for example at larger hospitals, or off-site for combined use by a larger group of HCRW generators on a regional basis.

Currently there are a number of HCRW treatment technologies available. Box 6.6 below gives an overview of such technologies, divided into two categories, i.e. "proven technology" and "technology under development".

Box 6.6: Alternative technologies for treatment of health care risk waste.

Thermal Treatment (followed by off-site disposal of residues):
Incineration (excess air, controlled air, rotary kiln or fluidised bed) (#);
Pyrolyse/plasma (high temperature gasification) (*).

Non burn technologies: Sterilisation (followed by off-site disposal/treatment of residues):
Steam sterilisation (autoclaves or retorts) (#);
Microwave sterilisation (#);
Chemical sterilisation (chlorine, iodophor, alcohol, formaldehyde, glutaraldehyde, etc.) (¤);
Gas sterilisation (ethylene oxides, formaldehyde, etc.) (¤);
Hot air/dry heat sterilisation (#);
Electro-thermal deactivation (high voltage at radio frequency) (#);
Irradiation sterilisation (*):
Cobolt-60 gamma rays sterilisation (*);
Electron beam sterilisation (*).

Notes:
(*): Experimental technologies or with limited commercial application today;
(#): Widely used HCRW treatment technologies;
(¤): Limited application for specific certain types of waste only.

Brief descriptions of the widely used technologies are presented in the following section, indicating advantages and disadvantages of the individual technologies.

6.8.1 Incineration

A typical HCRW flow for an incinerator plant is shown in Figure 6.3 below. Although some form of a heat exchanger/cooling system may be required, particularly where fabric filters are used as part of the flow gas cleaning system, it is unlikely that the generation of warm water will be financially viable in South Africa.

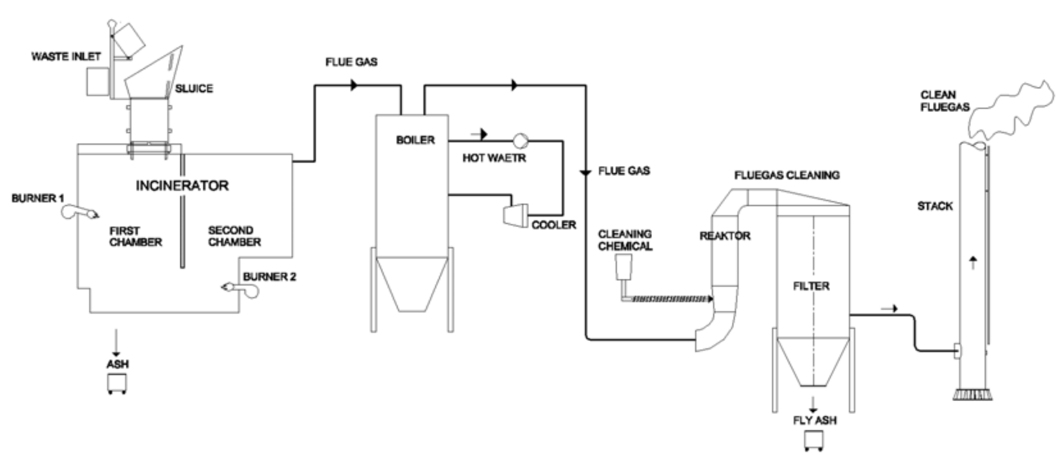


Figure 6.3: Flow chart for a typical incinerator plant with flue gas cleaning system.

Box 6.7 below shows a simplified material flow chart of the diagram in Figure 6.3. As indicated, the first step is the feeding of the containerised

HCRW into the incinerator, or more specifically into the primary combustion chamber, through a feeding system.

In the primary combustion chamber the newly loaded HCRW is either ignited through its contact with burning waste that may already be present in the chamber, or alternatively it is ignited by support burners (diesel oil or gas). The combustion temperature in the primary chamber should reach 850 ^{o}C to ensure that all organic materials and micro-organisms are converted into Gas.

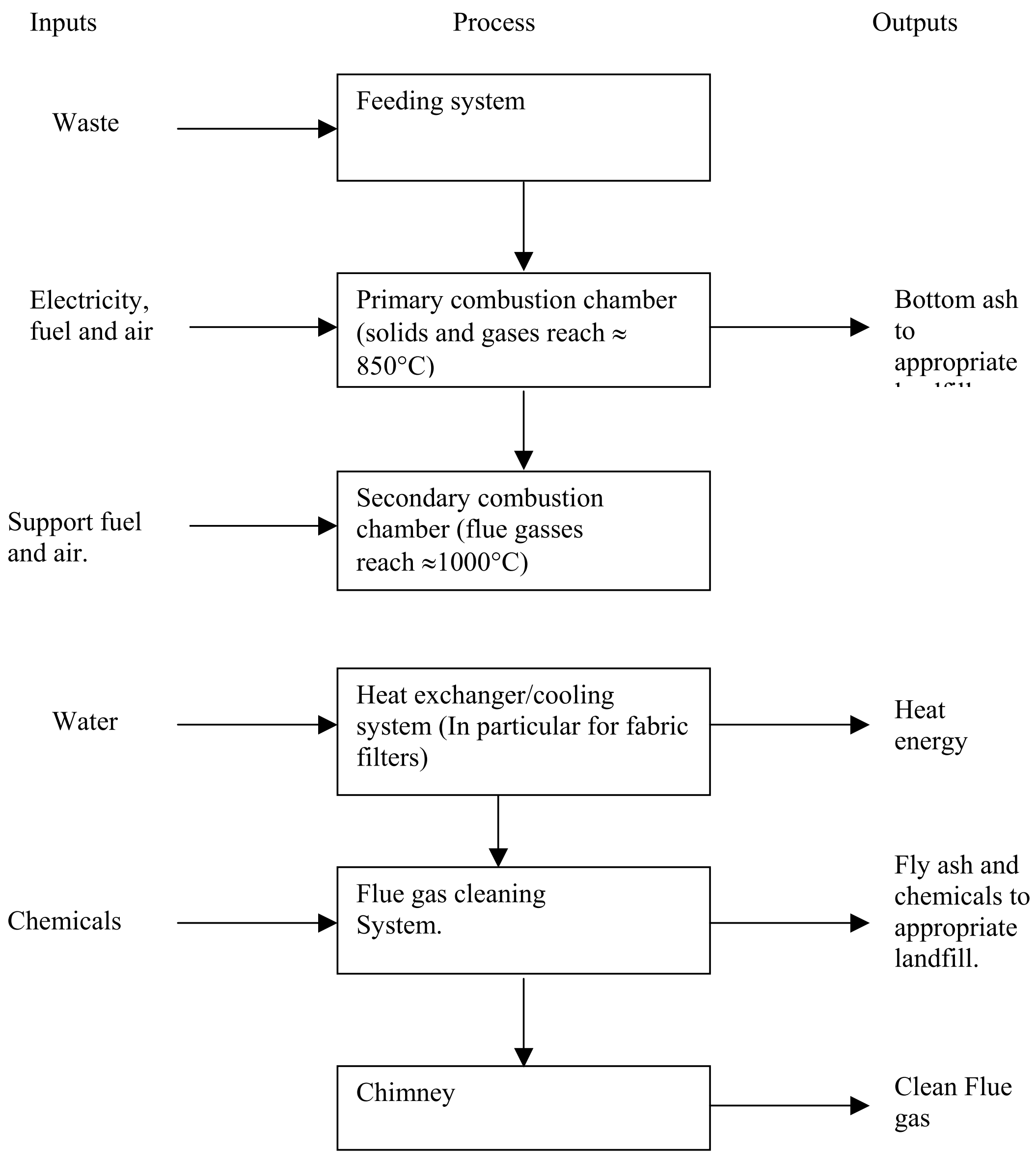
There are two kinds of residuals from the primary chamber; ash and flue gas. The ash is recovered at certain intervals and cooled down for collection, treatment (if required), transport and disposal to a landfill. The flue gas in turn is passed on to a secondary combustion chamber where the gases are heated to more than 1000 ^{o}C to ensure that some of the hazardous substances in the gases, e.g. dioxins, are converted into less hazardous substances.

From the secondary combustion chamber the flue gas is led through a heat exchanger that either works as a boiler where the heat is utilised (if financially viable), or as a cooling system. In both instances the temperature of the flue gas is reduced.

From there the flue gas is directed to the flue gas cleaning system that recovers some of the pollutants from the flue gas, e.g. acidic gases and particulates. Compliance with the DEAT Emission Guidelines requires that as a minimum, acid gases, dioxins and dust be removed from the flue gas. There are a number of different cleaning technologies, e.g. dosing of dry neutralising agents e.g. lime or sodium bicarbonate, often mixed with minor quantitative of activated carbon or use of wet or semi dry scrubbers followed by bag filters, ceramic filters or electrostatic precipitators.

The cleaned flue gas is then led to the stack, which is designed to ensure suitable dispersion based on local topography, distance to neighbouring buildings, height and dimension of neighbouring buildings and prevailing climatic conditions.

Box 6.7: Flow diagram for a typical incinerator plant



The amount of PVC plastics and other materials that can generate acid gases should be minimised. Acid gases corrode the incinerator plant, increase the risk of dioxin formation and, if not efficiently scrubbed from the gas emissions, can lead to a significant impact on the environment. Other plastics such as Polyethylene (PE) and Polypropylene (PP) do not pose the same environmental risks but they contribute significantly to the calorific value when incinerated. Please refer to Module 4 for possible substitution of PVC products.

Incineration is internationally the most widely applied HCRW treatment method, but the size, capacity, design, environmental and technical performance standards as well as the organisational set-up vary significantly from country to country. Non-burn technologies are increasingly taking over the market for dedicated HCRW treatment plants due to increasing costs of flue gas cleaning and public concern over incineration in general.

In Box 6.8 below the perceived advantages and disadvantages of incineration in relation to other treatment technologies are summarised.

Box 6.8: Advantages and disadvantages of incineration

Advantages of incineration	Disadvantages of incineration
Safe elimination of all infectious organisms in the HCRW; Can also treat most chemicals / pharmaceuticals in addition to infectious HCRW. (Chemical waste cannot be treated by any other HCRW treatment technologies.); Non-recognisable residues; Reduction of the volume by approximately 95%; Well proven technology; No pre-shredding required; No special requirements to packaging of HCRW; Full disinfection can be determined visually by observing the slag / bottom ash.	High* investment costs for incinerator and flue gas cleaning; Emissions to the air; By-products have to be handled as special waste; Chimneys are necessary, which can be perceived negatively by the community; PVC and heavy metals in the HCRW stream should be avoided as much as possible, e.g., by substitution of PVC by other plastic types and at source separation of batteries etc. * For SA, this is to a large extent influenced by the local content, due to the exchange rate of the Rand.

Figure 6.4 below shows a dual chamber incineration plant with advanced flue gas cleaning. Existing single chambered incinerators and other older incinerators based on around pre-1990 designs, are unlikely to meet the present flue gas cleaning standards. It is however to be emphasised that in terms of the HCW Management Policy for Gauteng, all HCRW treatment facilities (including existing facilities) are required to meet the DEAT Emission Standards by 1 January 2004.

All HCRW incinerators used in Gauteng should therefore be equipped with flue gas cleaning in the form of dry or wet scrubbers and filters for compliance with the DEAT Emission Guidelines.

Figure 6.4: Example of a dual chamber incineration plant for health care risk waste with flue gas cleaning

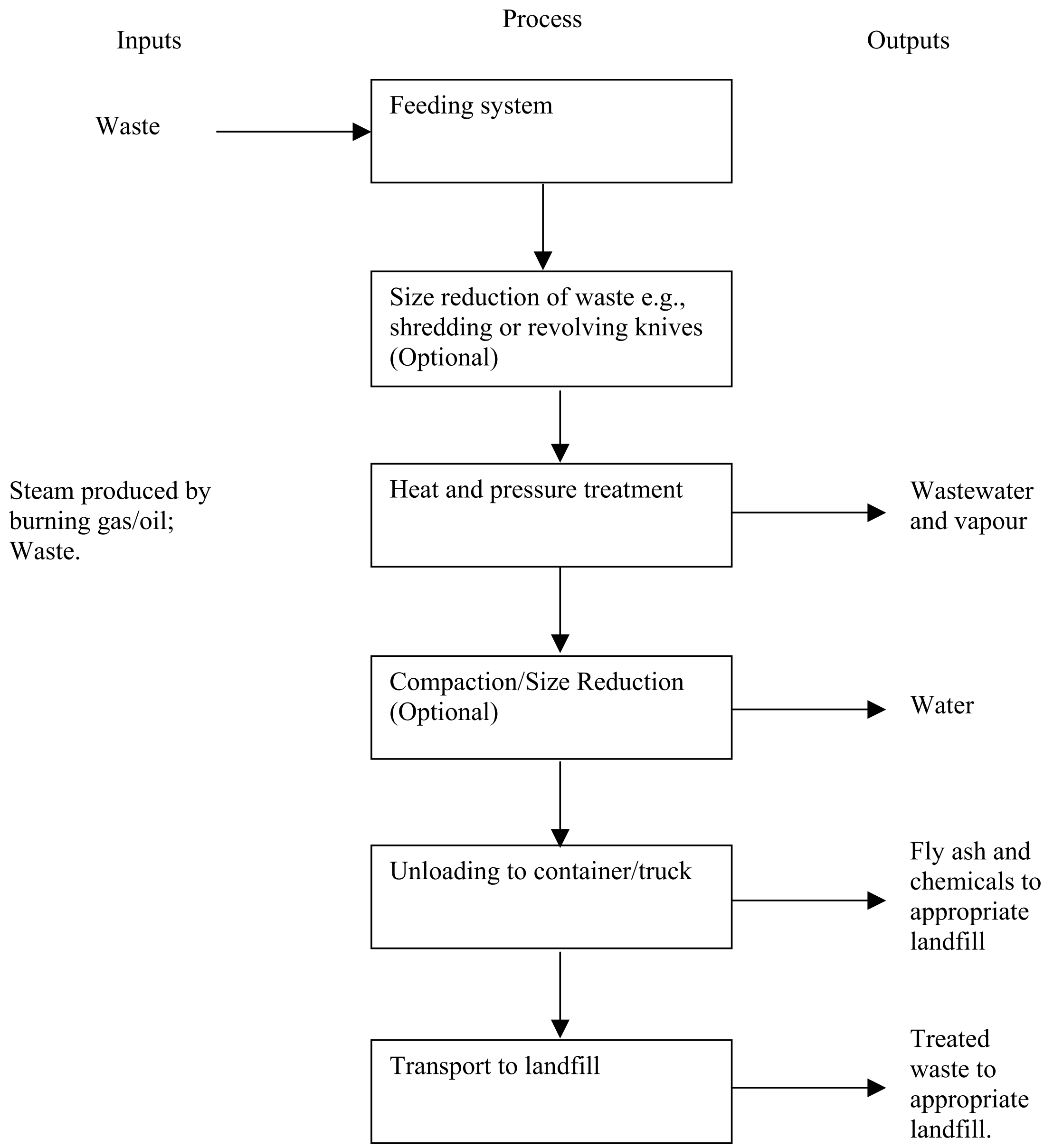
Incineration plant manufactured by Envikraft A/S, Denmark, including dual combustion chambers (middle of the photo) and dry flue gas cleaning system (on right hand side).

Internationally and also in South Africa, there are manufacturers of HCRW incinerators that will be able to comply with the DEAT Emission Standards.

6.8.2 Steam Sterilisation

The second most popular HCRW treatment technology applied internationally is steam sterilisation/autoclaving. Box 6.9 below shows a typical material flow of a steam sterilisation plant.

Box 6.9: Material flow chart of a steam sterilisation plant



A typical sterilisation plant primarily consists of a reactor, which is a closed container where majority of the necessary processes takes place.

The first process in a sterilisation plant is usually a size reduction through crushing / shredding of the incoming HCRW, for instance by means of a shredder. In addition to the volume reduction that is achieved, the purpose is to reduce the size of the waste so that the steam can readily penetrate the waste and to make the waste less readily recognisable for aesthetic purposes.

The next step is the actual sterilisation, which is the heating of the HCRW. The heating can take place in many different ways, but steam is often used at high temperatures and pressures (steam sterilisation). The steam is led into the chamber, where the HCRW is heated to approximately 130^{o} C and for an adequate time period, usually 15 to 40 minutes, that ensures that all infectious micro-organisms are killed.

In some cases the sterilisation plant includes a compactor where the treated HCRW is compressed or in some cases, it is first mixed with some stabilising materials, e.g. cement, before it is formed into blocks.

Finally the treated HCRW is containerised and transported to an appropriately designed, constructed and operated landfill, for which the classification will depend on the classification of the HCRW residues. As the waste may still contain hazardous substances, it has to be handled with the necessary care.

In Box 6.10 below, the perceived advantages and disadvantages of steam sterilisation are summarised.

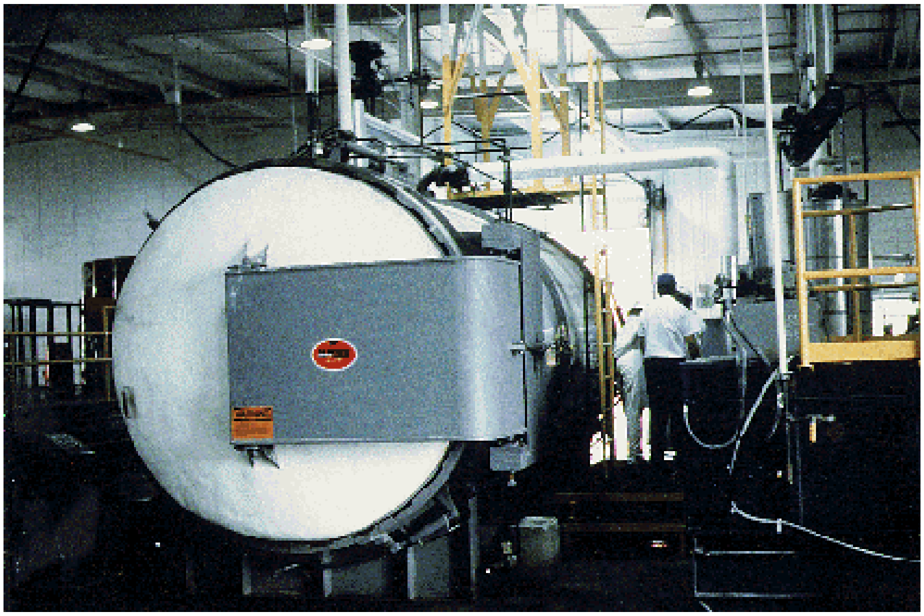
Box 6.10: Advantages and disadvantages of steam sterilisation

Advantages of steam sterilisation	Disadvantages of steam sterilisation
Low environmental impacts (low emissions);	Difficult to repair shredder in the event of blockages or breakdowns;
Moderate* investment costs;	HCRW must be well-segregated;
Low operation costs;	Cannot treat hazardous chemicals;
High disinfection level;	It is not possible to visually determine that HCRW has been sterilised;
Proven technology;	The total amount of HCRW must after treatment be transported to the landfill;
Easy to monitor by the Authorities;	A well operated landfill with daily coverage and no open burning is required for residue disposal;
Flexible capacity.	Air filter is required;
	Minimum temperature and pressure must be guaranteed;
	It cannot eliminate Creutz-Jacobs disease.

* For SA, this is to a large extent influenced by the local content, due to the exchange rate of the Rand.

Figure 6.5 A and B below show photos of steam sterilisation plants, one stationary (A) and one mobile plant (B).

Box 6.5 A: Example of a stationary steam sterilisation plant (autoclave plant)



Box 6.5 B: Example of a mobile steam sterilisation plant (autoclave plant)

6.8.3 Microwave Sterilisation

The third most popular HCRW treatment method used internationally is microwave sterilisation. Microwaves are used instead of steam to heat the moisture contained in and around micro-organisms / pathogens. Similar to steam sterilisation it is important that the microwave energy penetrates the entire HCRW matrix, and that all HCRW is sufficiently exposed to the radiation. The principle of this technology is that all moisture containing matter can be heated by being exposed to microwaves;

provided an adequate temperature is reached and for sufficient time, sterilisation of the waste is obtained.

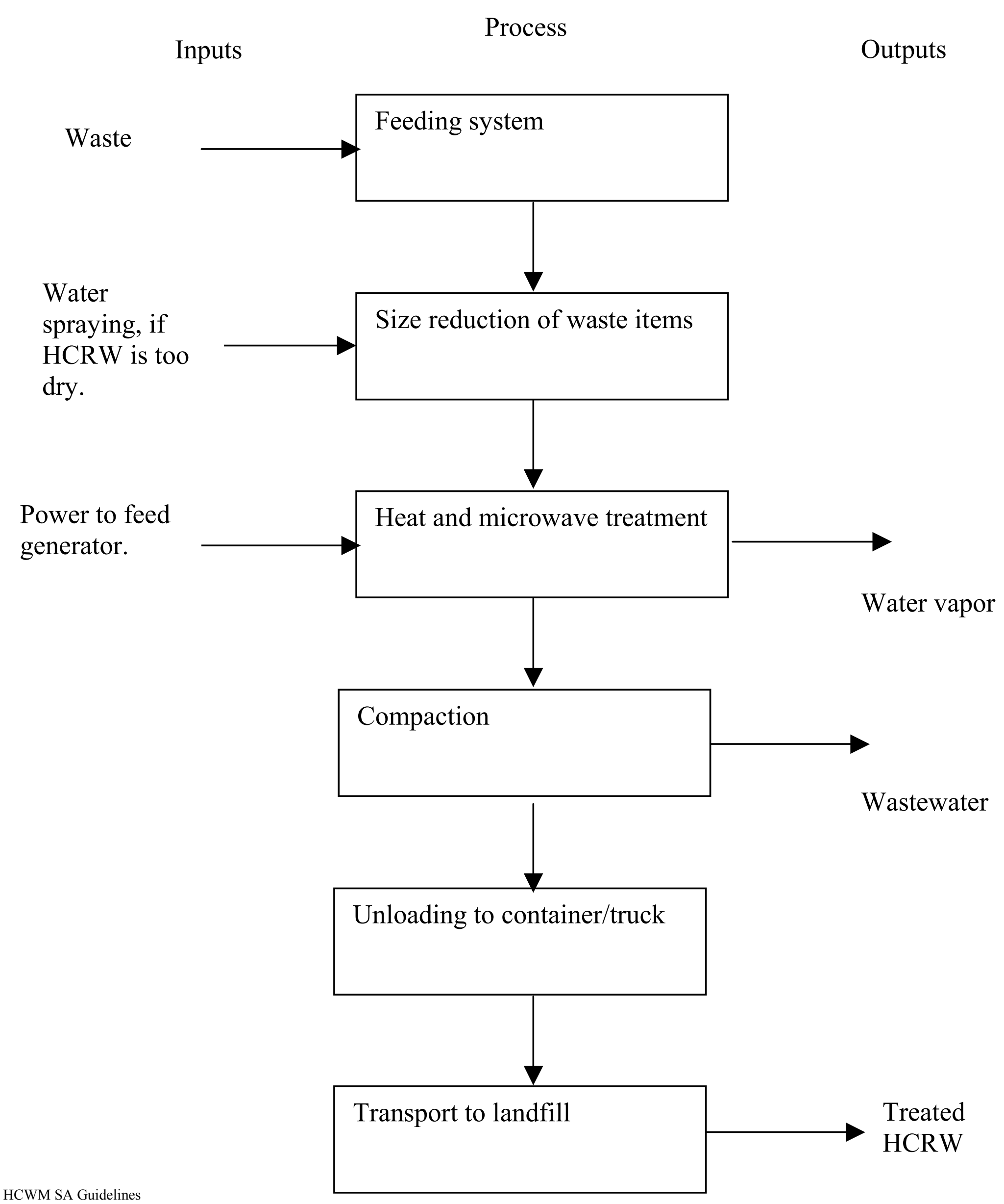
Large-scale microwave HCRW treatment is currently mostly applied in the USA, whereas smaller scale treatment units for laboratories and similar small-scale HCRW producers are applied worldwide.

It is important that there is sufficient moisture contained within the HCRW and it may be necessary to add moisture to secure adequate treatment. It is also to be noted that large quantities of metals, metal containers or similar will reduce the effectiveness of the microwaves penetration the HCRW.

Microwave treatment systems are available from very small to large scale. It is possible to purchase systems approximately the size of a dishwasher that can be installed in a sluice room or other suitable area. It is further possible to purchase mobile units mounted on vehicles as well as large stationary units capable of treating HCRW from several hospitals and other health care facilities on a regional basis.

A typical material flow for a microwave sterilisation plant is shown in Box 6.11 below.

Box 6.11: Flow diagram for a typical microwave sterilisation plant



The principles of a microwave sterilisation plant are in many ways similar to a steam sterilisation plant, except that the sterilisation of HCRW is done by microwaves instead of steam.

The sterilisation process works by microwaves heating the water within the HCRW, thereby destroying the pathological micro-organisms. In some cases water is to be added to the HCRW in order to ensure a high enough moisture level.

Microwave sterilisation plants are usually smaller than steam sterilisation plants.

In Box 6.12 below the perceived advantages and disadvantages for microwave sterilisation are summarised.

Box 6.12: Advantages and disadvantages of microwave sterilisation.

Advantages of microwave sterilisation	Disadvantages of microwave sterilisation
Low environmental impacts (low emissions); Units with small capacity are available for small HCRW generators.	High electricity consumption; Difficult repairs of the shredder in case of blocking or breakdowns; Some uprising of the HCRW mass HCRW to be segregated very well; Unsuited for high quantities of infected metal (e.g. needles); Cannot treat hazardous chemicals; Low disinfection temperature; Low maximum capacity; Limited application world-wide; It is not possible to visually determine that HCRW has been sterilised; The full amount of HCRW is after treatment to be transported to the landfill; Requires a well operated landfill with daily coverage and no open burning; It cannot eliminate Creutz-Jacobs Disease or other prion diseases.

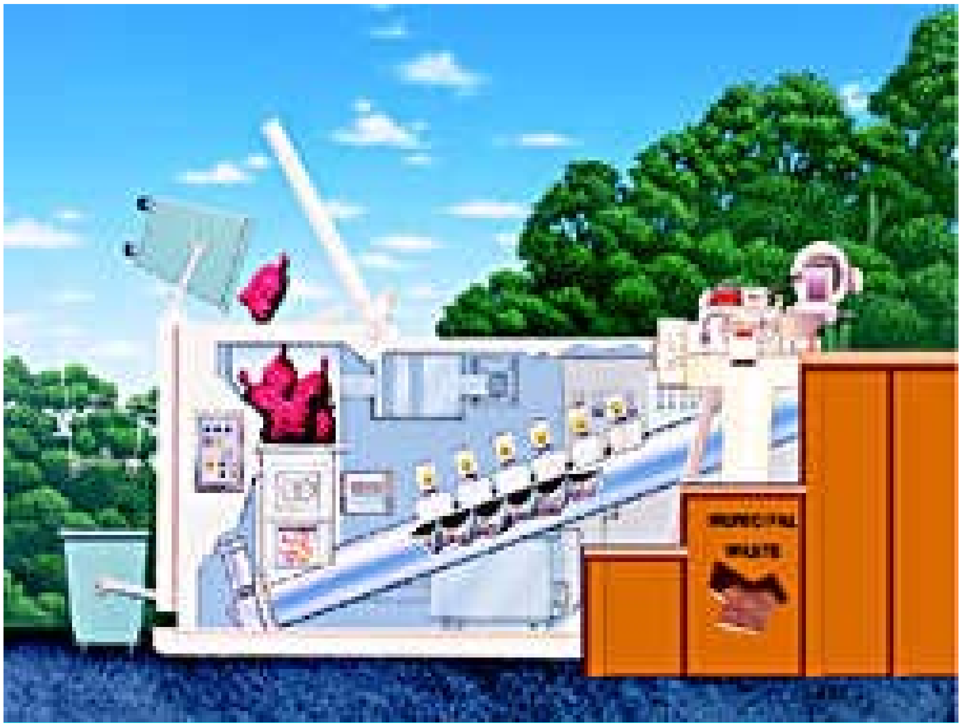
Microwave treatment of HCRW is, compared to thermal treatment process and steam sterilisation, a slightly newer technology. Microwave treatment is in principal similar to steam sterilisation.

As microwave treatment and steam sterilisation cannot treat hazardous chemicals, e.g. cytotoxic chemicals from laboratories and similar chemical wastes, some types of HCRW will continue to have hazardous properties after being sterilised. Health care facilities generating such hazardous chemical waste should ensure, as far as possible, that good separation of these wastes is obtained at source prior to treatment. General waste landfills can accept sterilised waste that contains limited amounts of chemical hazardous waste, but disposal to a hazardous waste landfill may be required, depending on the final classification of residues. Figure 6.6 A and B shows pictures of stationary and mobile microwave sterilisation plants.

Figure 6.6 A: Example of a stationary microwave sterilisation plant.

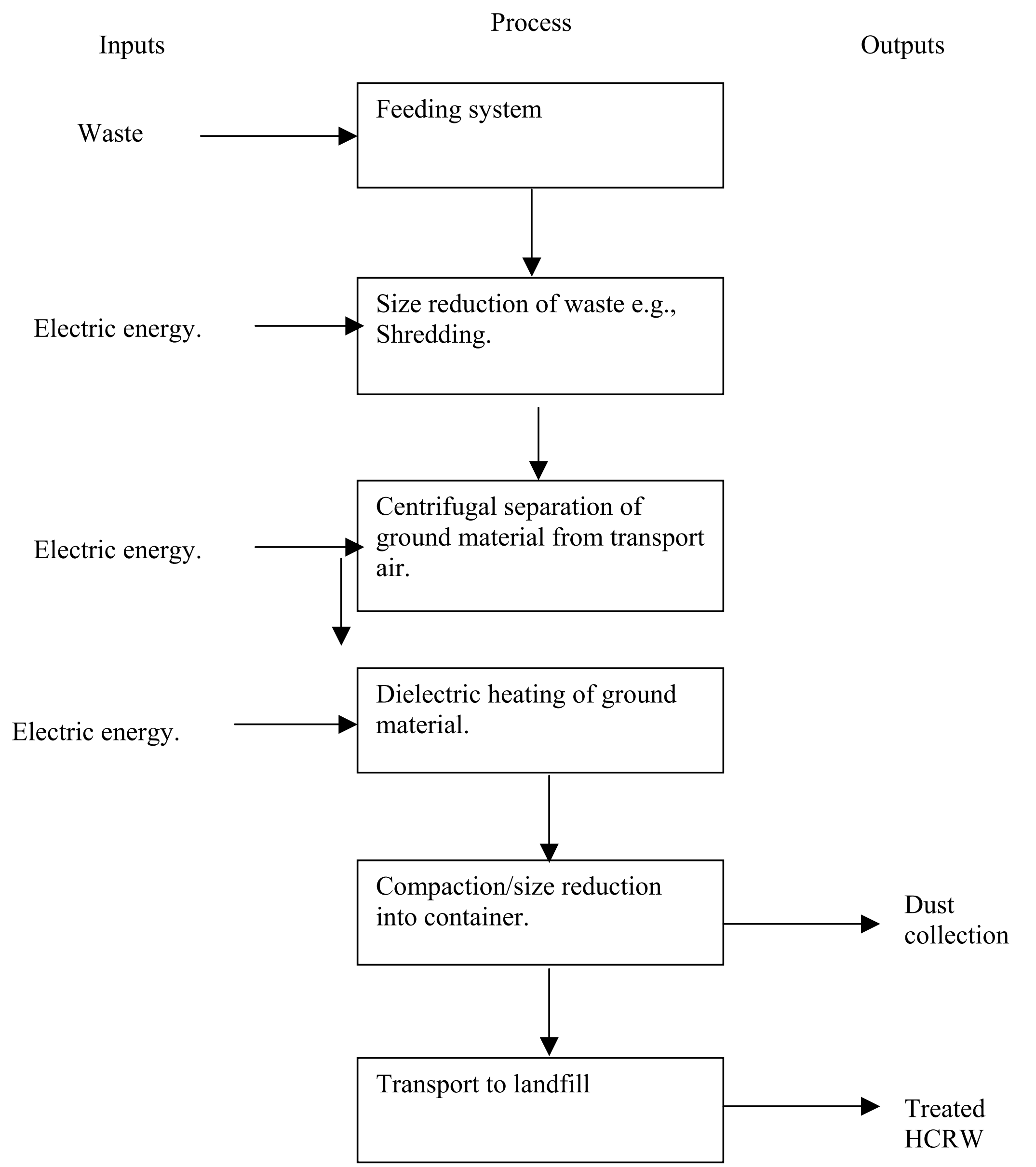
6.8.4 Electro Thermal Deactivation (ETD)

Figure 6.6 B: Example of a mobile microwawe sterilisation plant.



A further HCRW treatment technology applied internationally is electro thermal deactivation (ETD). Box 6.13 below illustrates the flow of HCRW from the point where it enters the electro thermal deactivation plant, to the point where the treated HCRW is finally disposed of on an appropriately permitted, developed and operated landfill

Box 6.13: Material flow chart of an electro thermal deactivation plant



The first phase in the process of electro thermal deactivation is size reduction through crushing / shredding of the incoming HCRW, for instance by means of a shredder. In addition to the volume reduction that is achieved, the purpose of this process is to ensure that the deactivation process is undertaken more effectively by creating unobstructed access to all parts of the HCRW that is to be treated.

The size reduction occurs under negative air pressure (vacuum) provided by the process fan. The ground material is then transferred via high velocity airflow in sealed ducts to the low energy cyclone, where the material is separated from the transport air by means of the centrifugal force. The material is then transported on a sealed transfer conveyor. A high-energy cyclone removes any small dust particles that may have remained in the transport air. Such dust particles are then also deposited on the transport conveyor.

The next step is the actual deactivation, which is accomplished by the selective absorption of energy at differential rates (due to their organic nature) by the cells of the microbe. The cell membrane weakens under the imposed high voltage field and ruptures. With cell rupture, the cell cannot reproduce and dies. This phenomena takes place at atmospheric conditions at temperatures less than the boiling point of water. There is no liquid emission due to the recycling water system.

In some cases the electro thermal deactivation plant includes a compactor where the treated HCRW is compressed. Thereafter the treated HCRW is unloaded, irrespective of whether it is in the form of loose waste or whether it is compressed.

Finally the treated HCRW is transported to an appropriately designed, constructed and operated landfill, for which the classification will depend on the classification of the HCRW residues. As the treated HCRW may still have an extremely low infection risk and may contain chemical and hazardous substances, it should be handled with the necessary care.

In Box 6.14 below, the perceived advantages and disadvantages of electro thermal deactivation are summarised.

Box 6.14: Advantages and disadvantages of electro thermal deactivation

Advantages of electro thermal deactivation	Disadvantages of electro thermal deactivation
Low environmental impacts (low emissions); High disinfection level; Proven technology; Flexible capacity.	High* capital investment costs; Difficult to repair shredder in the event of blockages or breakdowns; HCRW must be well-segregated; Cannot treat hazardous chemicals; It is not possible to visually determine that HCRW has been sterilised; The total amount of HCRW must after treatment be transported to the landfill; A well operated landfill with daily coverage and no open burning is required for residue disposal; Air filter is required; It cannot eliminate Creutz-Jacobs disease. * For SA, this is to a large extent influenced by the local content, due to the exchange rate of the Rand.

Figure 6.7 below shows a photo of an electro thermal deactivation plant.

Figure 6.7: Example of an electro thermal deactivation plant

Photo to be added.

6.8.5 Other HCRW Treatment Methods

Besides the HCRW treatment technologies described above, several other HCRW treatment technologies exist. However, none of these appear to have the same potential for large-scale treatment of HCRW due to various constraints inherent to these technologies.

Some technologies such as: i) chemical sterilisation, ii) gas sterilisation, and iii) ultra violet treatment can currently only treat limited types and amounts of HCRW. Other technologies such as dry heat sterilisation is increasingly being applied with success in for example the UK.

Cobalt-60 gamma rays and electron beam sterilisation are mostly at an experimental stage and are not widely yet used on a commercially. Some of these technologies may also require particular skills and expertise by the operators that are not readily available on-site at health care facilities or in the HCRW management industry.

6.9 Operational Requirements

6.9.1 Operational Requirements for Thermal Treatment Facilities

In the absence of suitable South African flue gas emission standards, Gauteng will enforce the Emission Guidelines as published by DEAT.

It is expected that National Government will revise the current lenient air pollution prevention legislation of the “Atmospheric Pollution Prevention Act, 1965” (Act 45 1965) as it does not set any measurable limits in the form of maximum allowable concentrations of selected pollutants per standard volume of flue gas.

In Table 6.1 below the threshold limit values for HCRW incinerators in SA, EU and USA are presented in comparison.

Table 6.1: Threshold limit values for incinerator plants

Schedule 2, Process 39 Atmospheric Pollution Prevention Act 1965 *Guidelines(DEAT)*		**EU**	**US**
		Dec. 2000	Sept. 1997
Type			S/M/L*
Units	mg/Nm^3	mg/Nm^3	mg/Nm^3
PM/dust	180	10	53/26/26
CO	-	50	36
TOC	-	10	-
Dioxin/furan (nanogram) TEQ	0.2	0.1	1.76/0.46/0.46
l	30	10	17
HF	-	1	-
SO_2	25	50	112
NO_x	-	200	366
NH_3	-	10	-
Pb, (same for Cr, Be, Ar, As, Sb, Ba, Ag, Co, Cu, Mn, Sn, V, Ni)	0.5	0.05	0.92/0.05/0.05
Cd (same for Tl)	0.05	0.05	0.12/0.03/0.03
Hg	0.05	0.05	0.42

Note: *) S/M/L: Small (<200lb/h)/Medium/Large facilities (>500lb/h). Limits recalculated to same standard conditions
Ref. Cond.: 11% O_2, 273 Kelvin, 101.3 kPa

In principle, the environmental as well as the health and safety impact of any HCRW treatment facility shall be of such nature that the facility could be erected anywhere, without creating a risk to the environment or the surrounding communities. However, siting requirements shall take into account any nuisances to the public, neighbouring areas etc. (cf. the EIA procedures) and preferably such facilities shall be placed on or near already compromised land, industrial areas and similar areas.

6.9.2 Operational Requirements for Non-burn Treatment Facilities

Suitable measures shall be taken to prevent emission of any pathogens via exhausts or similar. Such measures shall include a requirement for filter materials as well as for the maintenance and replacement of filters to be documented.

As far as microbial inactivation is concerned, Gauteng DACEL requires microbial inactivation based on the Technical Assistance Manual: State Regulatory Oversight of Medical Waste Treatment Technologies, April 1994, issued by the State and Territorial Association of the USA. Hence, for demonstration and investigation monitoring the following is required (in brief):

Vegetative bacteria, fungi, lipophilic/hydrophilic viruses, parasites and mycobacteria: *$\geq$6 Log_{10} reduction;*
B. stearothermophilus spores or B. subtilis spores: *$\geq$4 Log_{10} reduction;*
Representative biological indicators, as described in the *Technical Assistance Manual of the State Regulatory Oversight of Medical Waste Treatment Technologies*, or their equivalents that area available in South Africa, shall be used.

For routine monitoring the use of B.subtilis spores is normally specified.

6.10 Alternative Considerations when selecting a HCRW Treatment Process

In order to take a decision on the most appropriate HCRW treatment process, all of the alternative options available for HCRW treatment, as presented in Box 6.15, should be taken into consideration.

Box 6.15: Overall considerations when selecting a HCRW treatment process:

The use of on-site HCRW treatment facilities versus the use of off-site (regional) facilities;
HCRW treatment service for public facilities rendered by health care facility staff, provincial staff from other Departments (Public Works), or by a private contractor;
Refrigeration provided for pathological HCRW only or for all HCRW stored at treatment facility;
The options for inclusion or exclusion of certain radioactive, chemical, and pathological HCRW in the treatment process will depend on the treatment technology selected;
Options for thermal HCRW treatment technologies are:

- Multiple chamber incinerators
- Rotary kiln
- Fluidised bed

Options for non-thermal sterilisation (inactivation) HCRW treatment technologies are:

- Autoclave / steam sterilisation
- Microwave
- Electro Thermal Deactivation (ETD)

- Chemical / heat disinfection

Optional encapsulation of HCRW treatment technologies include:

- Encapsulation in impermeable media

The HCRW treatment facility loading mechanism for could allow for the use of disposable containers like plastic bags or cardboard boxes, or reusable containers like plastic boxes or wheelie bins of different capacities;
Electricity, diesel or oil fuel used as energy source for HCRW treatment facility;
Wet scrubber, bag filter or ceramic filter used as flue gas cleaning system for thermal HCRW treatment facility.

6.11 On-site Management of HCRW Treatment Residues

The state of the HCRW residues will be dependant on the type of treatment technology used, and in particular whether it is a burn or non-burn technology. Incinerators will result in the generation of ash with a significant reduction in volume, whereas non-burn technologies will produce a residue that will, even though significantly transformed from its original state, not have the same reduction in volume. In some instances the non-burn technologies are therefore supplied with a compactor and/or solidifier unit that encapsulates the residues e.g. in cement.

The need for shredding of HCRW for non-thermal treatment processes to be effective, will result in a reduction of volume (although not as much as for thermal treatment process), whilst the addition or removal of moisture during the respective treatment processes could in turn result in a significant change in mass. Whilst these aspects will to a great extent determine the physical process requirements for onsite storage, containerisation, transport and disposal of the residues, aspects such as the chemical composition and the remaining risk of infection must also be considered.

When evaluating the impact of the various HCRW treatment technologies on the state of the residues, it is to be recognised that the way in which residues are managed thereafter, will have a further impact on this. Table 6.2 provides some details on the expected impact that the respective treatment technologies will have on the volume and mass of the residues.

Table 6.2: Impact of alternative treatment technologies on the volume and mass of HCRW residues. TO BE COMPLETED

Treatment process	Effect on Volume	Effect on Mass
Incineration Autoclaving Microwaving Electro Thermal Deactivation	…….. ……… ………	…..

Box 6.16 provides information on important considerations when managing HCRW residues.

Box 6.16: Important considerations in managing of HCRW residues.

The higher the residue density (and proportionally lower the volume), the more effective the payload that can be achieved during transport of residues;
For residues with low density and high volume, increased payloads can be achieved by compacting the residues, either with a static onsite compactor, or by making use of rear-end-loader (REL) compactor trucks for collection and transport of residues;
The residues should, from both an environmental as well as an occupational health and safety point of view, not be handled in any way that will create a risk of residues being scattered through wind or rain action;
Should it from a logistical point of view not be possible to store the residues in an enclosed environment, provision is to be made for containerised residues to be

protected against the elements by means of suitable covers such as plastic sheets; It is important to recognise that even though the HCRW may have been treated, there is, in addition to the risk of sharp objects, always a risk of infection where the treatment process may not have been fully successful. All residues are therefore to be handled with the same care and caution, as was the case before it was treated.

6.12 Treatment of Waste containing Radioactive Substances

The treatment and disposal of low-level radioactive waste uses somewhat different management principles to those used for infectious or chemical wastes. Radioactive wastes cannot be destroyed, they can only be contained or stored, e.g. in a landfill, and allowed to degrade without causing harm to humans and the environment, or they can be dispersed into the environment in such a way that they become so diluted that they no longer pose any danger. The discharge to sewer or the thermal treatment process of selected low level radioactive wastes with the infectious waste stream lead to significant dilution. An example is the incineration of C^{14} containing low level waste; the C^{14} burns to give $C^{14}O_2$ (C-14 carbon dioxide), which is diluted with the enormous quantities of carbon dioxide generated by the burning of the infectious waste and any fuel used to maintain the high temperatures required.

The Department of Health, Directorate of Health Technology controls the incineration of low-level radioactive waste and an *incinerator operator must have an authorisation from the Directorate to accept such waste*. Regular monitoring of the radioactivity levels of incinerator ash will be required. For radioactive waste under their control, the holder of an authority must at all times ensure that:

(a) Disposal of radioactive waste to the infectious waste incinerators is restricted to suitable waste, which includes flammable solid waste (excluding sealed sources), animal carcasses, vials containing organic solvents and bulk solvent;

(b) G1ass vials with closed metal caps are not disposed of because of the risk of an explosion and the possibility of radioactive glass residue in the slag; the contents of these should be transferred to plastic containers for incineration. However, glass vials with plastic caps can usually be safely disposed of in limited numbers. Plastic vials containing organic solvents are perfectly acceptable provided the smoke emitted from the incinerator stack does not contravene the standards laid down by air pollution control legislation applicable to the area.

(c) The activity per waste package of 74Bq/g and the total activity disposed of per month do not exceed authorised limits;
Short-lived materials not meeting the activity and/or surface dose-rate limits for packages are stored until they have decayed to below the specified limits;
Accurate records are kept of the nuclides and total activity disposed of per month to the incinerator;
When disposing of radioactive waste at an incinerator, the holder of the authority or his agent shall liase with incinerator operators to develop mutually convenient procedures for the receipt and disposal of the waste, which will minimise health hazards:

(g) When a package is sent to an incinerator, it carries the following markings:

The warning sign for ionising radiation, information as to the sender;
Information regarding the mechanism of disposal (i.e. "for incineration"),
Information as to the radionuclide content and activity,
A statement that the surface dose rate does not exceed 5 microsievert per hour (0.5 mR per hour),
Note: that an incinerator designed for infectious waste treatment cannot normally accept some of the waste listed above, such as bulk solvents.

The discharge of low-level liquid radioactive wastes, i.e. for an authorised medical facility is limited to $10ALI_{min}$ per month. For discharge to sewer of the low-level radioactive waste under her/his control, the holder of an authority must at all times ensure that:

Radioactive waste for disposal to the sewer is restricted to aqueous solutions of radioactive materials and macerated biological material where this is acceptable to the waste water authorities;
The activity per release and the total activity per month do not exceed the limits specified in the code.
Accurate records are kept of the nuclides and total activity disposed of per month via the sewer;
Release of radioactive waste is confined to one release point for each laboratory;
At each release point there shall be a visible sign stating that radioactive waste may be released into the sewage system;

Water to dilute the discharge is flushed before and for at least one minute after the discharge;
Plumbing personnel are warned of the possible hazard prior to performing maintenance;
Liquid scintillation counting vials containing chemically toxic organic compounds (e.g. toluene, xylene, etc.) are not disposed of via the sewer.

6.13 Importance of Cooperation

With the HCRW treatment process being the most important component of the disinfection process, it is important that this be linked to all processes, starting from generation and containerisation, all the way through to delivery of HCRW for treatment at the treatment facility. Box 6.17 below presents examples on how earlier processes in the waste flow will impact on HCRW treatment.

Box 6.17: Examples of the way in which earlier processes will impact on HCRW treatment:

Poor procurement procedures on the materials that will form part of the HCRW stream will impact on the HCRW treatment process, for instance by the amount of PVC present in the HCRW to be incinerated (PVC creates acidic gases that increasing the corrosion of the metal parts of the plant);
Poor segregation could lead to radio-active waste being dispose of in the treatable HCRW stream, or pathological waste being disposed of in the non-thermal treatment HCRW stream;
The use of containers that are not compatible with HCRW loading system of the treatment plant;
The delivery of HCRW at times that is not compatible with the treatment plant operations, will result in a build-up of HCRW.

Based on the above, it is evident that operators of HCRW treatment facilities should consult, either directly of indirectly, with all parties that may have an impact on the treatment process.

The efficiency of the treatment will have a direct impact on the risk of pollution, as well as infection, of all parties associated with the containerisation, transport and disposal of HCRW residues.

6.14 Annexure 6.1: Proposals for posters and other info materials

(TO BE FINALISED AND INSERTED ON COMPLETION OF THE PILOT PROJECTS)