Department of Agriculture, Conservation, Environment and Land Affairs

Feasibility Study for Sustainable Health Care Waste Management Scenarios for Gauteng

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January 2003

Dr. Patricia Hanekom
Head of Department
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1 Executive Summary

This Report is one of many outcomes of the Gauteng DACEL project for Sustainable Health Care Waste Management. The Feasibility Report defines and assesses selected health care waste management scenarios applicable for Gauteng Province. Each scenario is described and assessed technically, environmentally, financially and in terms of safety and health.

The health care risk waste management scenarios are compared against each other as well as against the estimated current costs and impacts caused by today's HCW management system in Gauteng (status quo).

The environmental and financial assessment of the selected HCRW management scenarios show that regionalised treatment system are financially most advantageous and that other containerisation systems than the current cardboard boxes are environmentally and safety-wise more advantageous and financially neutral or advantageous depending on the details in the management system configuration.

In general, the environmental analyses show that a considerable environmental improvement can be achieved by moving away from today's sub-standard on-site and off-site incinerators towards incinerators or non-burn treatment technologies that comply with the minimum requirements set out in the Gauteng HCW Management Policy of November 2001. The environmental analysis has not resulted in a clear recommendation for or against any particular type of HCRW treatment technology provided that the minimum requirements of the Gauteng HCW Management Policy are adhered to. However, burn and non-burn treatment technologies result in very different types of emission that are not easily comparable, but result in different degrees of local versus global impacts as well as different degrees of atmospheric versus soil and water impacts. However, the environmental calculations clearly demonstrate that there are significant environmental benefits in moving from disposable cardboard containers to reusable wheelie bins or reusable stackable plastic containers.

In terms of safety and socio-economic impacts the analyses have not resulted in any significant conclusion as to which HCRW management scenarios are most advantageous but there are indication that the reusable stackable boxes are safest closely followed by the 240 litre wheelie bin and only then the 770 litre wheelie bin scenarios. Any of the scenarios based on reusable containers are favourable in socio-economic terms due to the reduced occupational health and safety as well as reduced environmental impact.

In brief the following conclusions are made:

1. It appears possible to introduce new health care risk waste (HCRW) service concepts that while complying to improved performance standards, cf. the Policy, will have the same budgetary impact as the current sub-standard HCRW services, provided
2. Regionalisation is clearly preferable compared to onsite solutions
3. 2-4 regionalised treatment plants appear to result in the lowest overall costs due to economics of scale

4. Use of reusable wheelie bins or reusable stackable boxes is more cost efficient than use of disposable cardboard boxes, even when including the increased costs of transportation and disinfection of reusable containers
5. The reusable boxes appear to be safer than the cardboard boxes. The reusable stackable box appears to be safer than the 240 litre and the 770 litre wheelie bin.
6. Cost of transportation increased when using reusable containers, but the increase does not exceed the savings due to elimination of disposable cardboard boxes.
7. The estimated cost of the existing HCRW collection and treatment services in Gauteng appears high compared to the estimated cost of improved efficient treatment system
8. Implementation of the environmental performance requirements stated in the Gauteng Policy (Nov. 2001) will significantly reduce the environmental impact of HCRW management in Gauteng
9. The existing incinerators in Gauteng are emitting significant amounts of pollutants compared to internationally available state-of-the-art incinerators.
10. Incineration has in comparison to non-burn technologies the most adverse impact in terms of release of acid gases and dioxins/furans, whereas non-burn technologies have the most adverse impact on the emission of green house gases that lead to global warming. Furthermore, the use of non-burn technologies increased the transportation of materials in the province compared to the use of incinerators. Hence, it is not clear if incinerators or non-burn technologies are overall (globally) preferred environmentally.

Hence, in general it is recommended that:

1. The use of on-site treatment plants, in particular on-site incinerators should be discontinued
2. There should be a move towards fewer and larger HCRW treatment facilities in Gauteng.
3. Internal and external handling of HCRW receptacles should be mechanised and the manual handling should be reduced
4. It is not clear if incineration or non-burn treatment is environmentally significantly better than the other. Hence, both technologies are recommended for use provided that the stringent emission and destruction standards are enforced.
5. Reusable plastic containers are recommended to replace the current disposable cardboard boxes.

For the Pilot Projects to be implemented at selected health care institutions in Gauteng it is, in particular, recommended that:

1. The suitability of using various types of trolleys for reducing internal manual handling are tested to improve occupational health
2. The suitability of applying reusable bins (e.g. waste carts of the size of approx. 240 – 770 litre or reusable stackable plastic boxes) is tested as an alternative to cardboard boxes.

2 Introduction

2.1 Objectives

The Objective of this Feasibility Study is to assess different options available to address the most urgent problems related to health care waste management in Gauteng, and to present the most feasible solutions that will improve the status quo for integrated health care waste management systems based on environmental, occupational health and safety as well as financial criteria.

2.2 Scope of the Feasibility Report

The Feasibility Study is intended to draw comparisons between potential solutions that will address the following major HCW management related questions identified in Gauteng:

- Is it feasible to apply innovative solutions for waste packaging and containerisation?
- What collection and transport equipment should be utilised for the different types of HCW generated to ensure the most effective and integrated HCW management systems?
- Is on-site or regionalised Health Care Risk Waste (HCRW) treatment systems the most feasible option? The Status Quo Report (ref. 1) indicated that regionalised incineration is more cost efficient that on-site incineration, but the impact of other technologies as well as environmental and safety impacts need to be assessed.
- What number and capacities of treatment facilities are required to treat all HCRW generated in Gauteng to ensure the most cost-effective treatment?
- How should the HCW management services be organised in terms of ownership and rendering of services?
- What legislation is required to support the implementation of the most feasible integrated HCW management systems?

The Feasibility Study delivers the following outputs:

- Lists of selected alternative HCRW management technologies and procedures that can be applied to form integrated HCW management systems, including basic data on the technologies such as technical performance, cost estimates, environmental impacts, etc (Chapters 5 and 6)
- A number of different scenarios for integrated HCW management systems (Chapter 7)
- Discussion on siting criteria and ownership scenarios (Chapter 8 and 9)
- An assessment of the number and capacities of HCW treatment facilities that are required to ensure an appropriate service level, including the way in which these facilities can fulfil the requirements for environmental sustainability and the cost-effectiveness (Chapter 11)
- An assessment of the impact of the various scenarios with regard to environmental impact, occupational health and safety impact, socio economic impact as well as cost-effectiveness (Chapter 11)

- An assessment of the current legal framework and possible gaps with a view to informing the planning of the improved scenarios for HCW Management. (Chapter 10).

2.3 Background

All health care facilities generate HCRW that poses a special risk to human health as a result of its content of infectious materials, sharps, hazardous chemicals and / or radioactivity. In particular health care professionals (doctors, nurses, etc), cleaning staff and waste handlers, patients and visitors at health care facilities, workers at HCW transport companies as well as workers at HCRW treatment plants and disposal facilities are at risk. People, for example reclaimers, that may become exposed to spills and illegally disposed of untreated HCRW at landfills, are also at risk. Incorrect HCW segregation resulting in HCRW being disposed of with HCGW increasing the risk of injury to both waste management staff, as well as reclaimers.

Apart from the direct human health risks, poor management of HCRW poses a variety of potential environmental problems. Treatment of HCRW by means of poorly designed and operated treatment facilities creates residues and emissions that could affect both the natural environment as well as the health of the people living in the vicinity of that particular treatment facility.

Approximately 70 HCRW treatment facilities, all in the form of incinerators of which most are still operational, exist in Gauteng. The incinerators generally have small treatment capacities of as little as 9 kg/hour. Based on the results of the Status Quo Study undertaken in 2000 (ref. 1), it is evident that most of the existing incinerators are unable to meet the current DEAT Air Emission Guidelines (Ref. 4) that are considered to be lenient compared to international standards.

Although most health care facilities, and in particular those in the private sector, have established a formal HCW management system, there is, in general, a shortage of both human and financial resources, a lack of awareness and limited training in the various roles and functions required for responsible HCW management. Poor standards of HCW segregation mostly identified in public institutions, further increases the overall costs of a HCRW treatment and disposal service due to increased volumes. The resulting financial implications of this are often unknown to the health care workers and health care facility managers due to the current provincial accounting system being used for public health care institutions.

As an alternative to the existing HCRW incinerators, non-burn technologies have recently emerged as a treatment option, which may also have resulted from public pressure to address concerns around air emissions. In the absence of suitable national standards and regulations Gauteng has prepared a HCW Management Policy (ref. 3) that sets out provincial minimum requirements for compliance and monitoring for both burn- and non-burn HCRW treatment technologies.

2.4 Context

This Feasibility Study is carried out as part of a DACEL project on Sustainable HCW Management in Gauteng with financial and technical support of DANCED.

Based on the HCW Management Policy (Ref. 3) that was published for comments during November 2001, the Feasibility Study is dealing in detail with a number of major problems that have been identified during the Status Quo Study (Ref. 1) conducted during 2000.

Based on the outcome of the Feasibility Study, a detailed HCW management Strategy and Action Plan will, among others, be developed for Gauteng, defining the activities that will be required to implement an environmentally sound and financially sustainable HCW management system.

Apart from the HCW management Policy, Strategy and Action Plans for Gauteng Province, detailed HCW Management Guidelines for a broad spectrum of HCW management activities will serve as the practical tools for implementing the Strategy.

A further component is the development of a HCW Information System (HCWIS) that is intended to record the information required for effective waste management, planning and implementation of sustainable systems.

Selected pilot projects will be undertaken to develop, test and demonstrate some new concepts introduced in the Feasibility Study to improve the existing HCW management systems and to inform the development of the tender documents and technical specifications for the next provincial HCW service tenders.

The Feasibility Study is carried out in co-operation and in consultation with the key stakeholders, including:

- Gauteng Department of Health (GDoH),
- Gauteng Department of Public Transport, Roads and Works (GDPTRW)
- National Department of Health (NDoH),
- Department of Environmental Affairs and Tourism (DEAT),
- Department of Water Affairs and Forestry (DWAF),
- Danish Cooperation for Environment and Development (DANCED)
- Infection Control Association of Southern Africa (ICASA),
- South African Non- Governmental Organisation Council (SANGOCO),
- National Education and Health Workers Union (NEHAWU),
- South African National Civics Organisation (SANCO),
- South African Society of Occupational Medicines (SASOM),
- South African Bureau of Standards (SABS) and
- Gauteng Association of Local Authorities (GALA).

Furthermore, the HCW Service Industry has given valuable time and input in to the making of this report.

3 Scope and Definitions

The purpose of this chapter is to present a model for a HCW management system at a typical health care facility in order to define the different modules that a waste management system consist of and to establish a common framework for discussing various solutions within the different modules.

3.1 Description and Definition of the Overall Waste Management Model

An integrated HCW management system is in this context considered to be a waste management system that covers all the different types of HCW generated at health care facilities, from the generation of the waste to the final disposal of waste. The different modules of the waste management system, excluding radioactive waste, are shown in the diagram below (Figure 3.1).

Figure 3.1: *The Waste flow from the generation of waste to its final disposal at landfills, from cradle-to-grave (excluding radioactive waste)*

Module 1: Generation. HCW generation is considered to be the activity that will, in the process of rendering health care services, result in the formation of both HCGW and HCRW.

Module 2: ***Segregation*** is the systematic separation of solid HCW into HCGW and HCRW, after which it is further separated into subcategories according to the segregation level specified

Module 3: ***Containerisation*** is the physical activity of placing HCW in containers as well as the sealing and marking of HCW containers for further handling, storage, transport and treatment.

Module 4: ***Intermediate storage*** Intermediate storage is the placement of HCW in a suitable location within the health care facility where waste is isolated to ensure environmental and health protection as well as limitation of access, for the purpose of frequent collection of HCW for treatment and disposal. The intermediate storage area will only serve a section of HCW sources within any particular health care facility.

Module 5: ***Internal collection and transport*** is the action whereby HCW is removed from the intermediate storage area (or point of generation), for transport to the central storage area or treatment facility by internal transport that is movement of HCW by means of manual removal, or by means of a suitable designed vehicle.

Module 6: ***Centralised storage*** is the placement of HCW in a suitable location within the boundaries of the health care facility where isolation, environmental and health protection, and human control are provided, with the intention of near-future retrieval of HCW for treatment and disposal. The central storage area will serve all potential sources of HCW within that particular health care facility and should allow for easy access by HCRW collection vehicles.

Module 7B: ***External collection and transport of HCGW*** is the movement of waste by means of municipal or private waste trucks from the point of external storage, to the disposal site (*not dealt with further in this document*).

Module 7A: ***External transport of HCRW*** is the movement of waste by means of suitable designed vehicles from the point of external storage, to the point of treatment outside of the boundaries of the health care facility. This module is not valid for those cases where the HCRW is treated on-site.

Module 8: ***Treatment*** of the HCRW is any method, technique or process for altering the biological and physical characteristics of HCRW to reduce the hazards it presents and facilitate safe and cost-efficient disposal. The basic treatment objectives include sterilisation and volume reduction.

Module 9: ***Collection and transport*** of residues from HCRW treatment facilities is the movement of treated waste by suitable vehicle from treatment, to final disposal on a permitted, waste disposal facility.

Module 10: ***Disposal*** of residues is the intentional burial or deposit of residues from HCRW treatment processes or untreated HCGW at an appropriately permitted, developed and operated waste disposal facility.

3.2 Definitions of Waste Types

The Feasibility Study, in principle, covers all categories of HCW generated at health care facilities, excluding radioactive waste and animal carcasses other than those used for research purposes. HCGW is however only taken into consideration from generation to containerisations. The radioactive waste is addressed by the National Nuclear Regulator Act, 1999 (Act 47 of 1999) and is not discussed further in this document.

The Health Care Waste (HCW) stream is divided into Health Care General Waste (HCGW) and Health Care Risk Waste (HCRW).

3.2.1 Health Care General Waste

Health Care General Waste (HCGW) is the non-hazardous component of HCW from health care facilities that includes many of the same substances as domestic waste. HCGW is generated among others during the administrative and housekeeping functions of health care facilities as well as from patients and visitors. HCGW may include a number of recyclable materials.

- Health Care General Waste includes the following types of waste:
  - **Packaging materials:** e.g. cardboard boxes, plastic bags, clean packaging from needles, syringes and IV lines etc.
  - **Kitchen waste:** e.g. organic waste and packaging materials.
  - **Office wastes:** Mostly paper etc. **Other solid wastes generated from patient wards and other patient care unrelated to medical care:** Similar to household waste.
  - **Non-infectious animal bedding:** e.g. from veterinary institutions.
  - **Garden and park waste:** Organic waste from gardening activities.
  - **Building and demolition waste:** From construction and renovation activities.

3.2.2 Health Care Risk Waste

Health Care Risk Waste (HCRW) is considered to be the hazardous component of Health Care Waste (HCW) generated at both large and small health care facilities. HCRW has the potential for creating a number of environmental, health and safety risks, depending on the particular type of HCRW that is handled as well as the way in which exposure takes place.

- Health Care Risk Waste includes:
  - **Infectious waste:** All kinds of waste that is likely to contain pathogenic micro-organisms.
  - **Pathological waste:** Includes parts that are sectioned from a body.
  - **Sharps:** Includes sharp and pricking objects that may cause injury as well as infection.
  - **Chemical waste:** Includes all kinds of discarded chemicals, including pharmaceuticals that pose a special risk to human health and environment.
  - **Radioactive Waste:** This includes solid, liquid and gaseous waste contaminated with radionuclides.

3.3 Description of Sources of Waste

The sources of waste in this study are predominantly health care facilities, with limited amounts being generated at other facilities like old age homes, residential properties, etc. However, there are considerable differences between waste generated by the different health care facilities. While the smaller health care facilities (like e.g. primary health care clinics) only generate some of the above-mentioned categories of HCRW, the larger hospitals usually generates all categories of HCRW.

For the purpose of this feasibility study, the following definitions will apply:

Major generators: Health Care Facilities or similar generating more than 10 kg of HCRW per day

Minor generators: Health Care Facilities or similar generating up to 10 kg HCRW per day

It has been estimated that about 1 170 tonnes of HCRW is generated monthly in Gauteng. Some 600 existing major sources of HCRW has been found to contribute in the order of 89% of the HCRW stream whilst the 9 700 minor sources of HCRW identified were found to contribute in the order of 11% of the HCRW stream (Ref. 1).

4 Basic Data on Health Care Waste in Gauteng

4.1 Waste Quantities based on Status Quo Study

Table 4.1 presents a breakdown of HCRW generation in Gauteng, indicating the amounts of HCRW generated by each generator category. It also presents an assumed breakdown of the main HCRW categories, based on the number of different containers that were surveyed.

Table 4.1: *Summary of results from a HCRW survey conducted as part of the Status Quo Study for Gauteng, 2000 (ref. 1).*

Service	**Ownership**	**Monthly HCRW mass (tonnes/month)**	**Assumed masses of dry, wet and sharps HCRW per month (tonnes/month)***		
			Dry	**Wet**	**Sharps**
Hospitals	Public	430			
	Private, mining & military	460			
	Total (hospitals)	890	787	66	35
			88,5%	*7,5%*	*4,0%*
Clinics	Public	150			
	Private	11			
	Total (clinics)	161	144	0,8	16
			89,5%	*0,5%*	*10,0%*
Minor HCRW sources	Private	130	116	0,7	12
			89,5%	*0,5%*	*10,0%*
	Grand totals	**1 181**	**1 048**	**68**	**64**

*** Note:** This breakdown is for the purpose of estimating the number and type of containers used to assess the costs only. The “Dry” HCRW in this instance refers to infectious waste collected in 142-litre boxes; “Wet” HCRW refers to infectious waste collected in specicans, 50-litre boxes and 20-litre buckets and “Sharps” HCRW refers to infections waste collected in dedicated 5-10 litre dedicated plastic sharps containers.

4.2 Predictions on future HCRW Quantities for Gauteng

It is expected that the effect of increased / decreased HCRW generation rates will be insignificant when comparing the various alternative HCW management options. For the purpose of completeness, a brief analysis on future HCRW quantities is included.

4.2.1 Factors with an impact on future HCRW generation

The following factors are likely to have an impact:

- Population growth;
- HIV/AIDS;
- Improved HCW segregation;

- Disposable containers;
- Increased/decreased use of disposable products;
- Influx / urbanisation towards the cities of Gauteng;
- National, provincial and local policies on health care services.

Population growth:
Although there is in general a positive growth in population for South Africa, the effect of HIV/AIDS is also to be considered. The larger the population, the more HCRW will be generated.

Effect of HIV/AIDS:
The effect of HIV/AIDS is considered to be two-fold. On the one hand there is a likely decrease in population growth as a result of deaths resulting from HIV/AIDS (thus reducing the HCRW stream), whilst on the other hand increase in the HIV/AIDS rate will result in more people requiring health services and ultimately increasing the HCRW generation rate.

Effect of improved HCW segregation:
It is expected that the HCRW stream that is presently treated before disposal, can be reduced by as much as 20%-30% through the introduction of effective measures for improved HCW segregation. The actual effect of improved segregation may, however, only be quantified during the Pilot Studies and similar initiatives to improve segregation efficiency, through which the introduction of appropriate containers, as well as more detailed training and awareness, will be used in an attempt to ensure improved segregation, ultimately reducing the HCRW stream that is to be treated.

Effect of disposable containers:
The use of disposable containers versus reusable containers does have an impact on the overall HCRW stream that is to be treated. In Gauteng it is estimated (ref. Section 11.1) that approximately 1100 tonnes of cardboard and 60 tonnes of PP liners are disposed of annual as a consequence of the use of disposable HCRW containers. A decision on the type of containers recommended for use will form part of this Feasibility Study.

Effect of increased / decreased use of disposable products:
Although there is a natural tendency towards an increased use of disposable products, the efficiency with which "green procurement" is introduced, will impact on the extent to which disposable products are used in the health care sector. This is however to be considered against, for example, the possible increased risk of infection that may result from re-using certain products if not done correctly. In the short term only limited improvements are expected.

Effect of influx / urbanisation towards the cities of Gauteng:
With Gauteng being the economic hub of South Africa, and South Africa being the economic hub of much of sub-Saharan Africa, there is an influx towards Gauteng.

National, provincial and local policies on to health care services:
Changes in policies around the rendering of health care services to the SA communities, can have a significant impact on future HCRW generation rates.

4.2.2 Expected increase / decrease in HCRW generation in Gauteng:

Although extensive research was undertaken to obtain reliable information on the above factors, thus being able to quantify the impact of each, the available information seemed to be limited. A report made available by Statistics SA. (Ref. 5) gave some reliable information on the expected population growth; with and without the impact of HIV /AIDS.

However, based on visits undertaken at a wide range of health care facilities of different sizes that are rendering different services, it is estimated that improved HCW segregation could result in a reduction in treatable HCRW by as much as 30% of the present stream. It is to however be stated that no proof of this exists at present. The HCRW stream analysis that will form part of the pilot studies will provide more reliable information on this.

In as far as the population growth is concerned, the report by Statistics SA presents results at 16 levels of aggregation / dis-aggregation, namely: RSA; urban and non-urban areas; 5 population groups (including "other/unspecified"); and 9 provinces. The estimates have been arrived at using the 1996 census figures as the base population, and making certain assumptions in the estimation of fertility and mortality. The estimates were finally made with and without the impact of additional deaths due to HIV / AIDS.

Table 4.2: *Projected annual population growth for Gauteng (ref 5.).*

	Exponential growth taking additional deaths due to HIV AIDS into account.	**Exponential growth without taking additional deaths due to HIV AIDS into account.**
Males	0.015699	0.016928
Females	0.018546	0.020166
Weighed Average	0.017102	0.018526

It can therefore be concluded that an average annual increase in population of 1.7 % would be realistic, which would under normal circumstances have resulted in a HCRW growth rate of approximately the same magnitude.

However, when considering the expected decrease in the treatable HCRW stream resulting from improved segregation, it can be expected that this improvement will only materialise over a period of time, during which time the waste stream will incrementally decreases. These phenomena will obviously depend on the rate with which improved HCW management systems will be implemented, with particular emphasis on training and awareness on improved HCW segregation.

Based on the above the following changes in the mass of HCRW are expected to materialise over the next 6-year period, as presented in Table 4.3.

Table 4.3: *Expected increase / decrease in the mass of HCRW to be treated in Gauteng,2000-2006*

Year	**2000 Status Quo**	**2001**	**2002 Present**	**2003**	**2004**	**2005**	**2006**
Population (millions)	7,834	7,967	8,102	8,240	8,380	8,522	8,667

Year	2000 Status Quo	2001	2002 Present	2003	2004	2005	2006
Population growth (% per annum)	0.0%	1.7 %	1.7 %	1.7 %	1.7 %	1.7 %	1.7 %
Segregation efficiency (% per annum)	0.0%	0.0 %	0.0 %	-10.0 %	-15.0 %	-5.0 %	0.0 %
Effective growth (% per annum)	-	1.7 %	1.7 %	-8.3 %	-13.3 %	3.3 %	1.7 %
HCRW generation (tonnes/month)	1 172	1 192	1 212	1 112	964	1.028	1.046
HCRW per capita (kg/capita/month)	0.15	0.15	0.15	0.13	0.12	0.12	0.12

If the trends in the population growth is continuing after 2006 and the efficiency in waste segregation is kept at the same improved level as it is in 2005, the total amounts of HCRW generated in Gauteng may continue to increase year by year as shown in figure. 4.4 below.

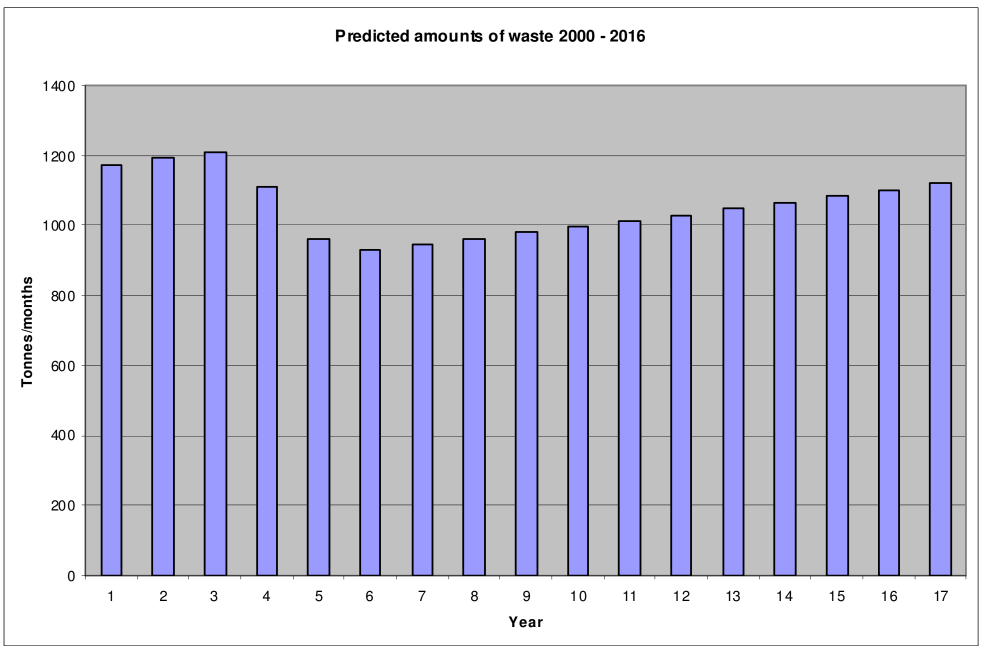


Figure 4.4: *Possible development of the amounts of HCRW generated in Gauteng in a 17 years period from now.*

4.3 Waste Composition

The composition of HCRW is not well studied internationally and not studied at all in South Africa. Table 4.5 summarises the results of statistics collected by means of an international literature study.

Table 4.5: *Composition of infectious waste and hospital general waste*

Material	HCRW	HCRW	HCRW	HCRW	HCRW	HCRW	HCW	HCGW
	% w/w	% w/w	% w/w	% w/w	% w/w	% w/w	% w/w	% w/w
	Italy	USA	China	China	China	USA	India (10 hospitals)	USA
Year	1992	1997	1993	1993	1993	1989	1993-96	1989
Paper&cardboard	34.0	45.0	16.0	34.0	51.0	31.0	15.0	39.0
Plastic	46.0	15.0	50.0	21.0	18.0	29.0	10.0	20.0
Rubber						12.0		1.4
Textiles			10.0	14.0	2.0	5.0	15.0	2.1
Food		10.0	21.0	17.0	7.0	1.0		11.7
Yard waste		3.0						2.0
Glass	7.5	7.0	1.0	11.0	8.0	3.2	4.0	4.8
Metals	0.4	10.0	0.5	1.0	9.0	1.1	1.0	7.2
Fluids	12.0					17.7		9.9
Misc. Organics	0.1	10.0	1.5	2.0	5.0			1.9
Anatomical	0.1							
Infections waste							1.5	
General Waste							53.5	
TOTAL	**100.1**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**
Reference:	Liberti L et al. (1994). Optimization of infectious hospital waste management in Italy. Part I: Waste management and research, 12(5): 373–385. Quoted in A. Prüss, WHO, 1999.	Robert Fenwick AHA Conf. 5/91. http://uvmce.uvm.edu:443/hlthcare/impact/EPA-HOLLY/index.htm, cleduc@zoo.uvm.edu, 12/22/1997	Chih-Shan L, Fu-Tien J (1993). Physical and chemical composition of hospital waste. Infection control and hospital epidemiology, 14(3):145–150. Quoted in A. Prüss, WHO 1999.	Chih-Shan L, Fu-Tien J (1993). Physical and chemical composition of hospital waste. Infection control and hospital epidemiology, 14(3):145–150. Quoted in A. Prüss, WHO 1999.	Chih-Shan L, Fu-Tien J (1993). Physical and chemical composition of hospital waste. Infection control and hospital epidemiology, 14(3):145–150. Quoted in A. Prüss, WHO 1999.	Brown (1989):H L Brown, Thomas Jefferson University Hospital Waste Characterisation Study, Drexel University, 1989	National Environmental Engineering Research Institute. Quoted in A. Prüss "Safe management of wastes from health-care activities	Brown (1989):H L Brown, Thomas Jefferson University Hospital Waste Characterisation Study, Drexel University, 1989

In July 2002 for a period of two weeks all HCW was weighed and representative samples were taken for a subsequent composition study at Leratong Hospital, Krugersdorp. Table 4.6 shows the preliminary findings of the study. In particular the data on HCGW is still being reviewed.

Table 4.6: *Pre- and Post Intervention Results from Leratong Hospital Sampled at Leratong Hospital 22 July – 2 August 2002*

		Pre-Intervention Study				Post-Intervention Study			
Waste Type	Waste Component	N	Proportion	Total Mass	Mass/day	N	Proportion	Total Mass	Mass/day
General Infectious Waste	Infectious	120	0.74173	3634.00	224.62	204	0.92722	4175.39	276.54
	Sharps		0.00120		0.36		0.00117		0.35
	Chemical		0.00490		1.49		0.00006		0.02
	HCGW		0.25216		76.36		0.06363		18.98
	Sealed Sharps		.		.		0.00782		2.33
	Other(Not specified systems		0.00000		0.00		0.00010		0.03
	Total Correct (Infectious)	120	0.74173	3634	224.62	204	0.92722	4175.39	276.54
	Total Incorrect		0.25826		78.21		0.07278		21.71
Sharps	Infectious	71	0.12055	238.55	2.40	94	0.21478*	29.00	0.44
	Sharps		0.85891		17.07		0.77509*		1.61
	Chemical		0.01992		0.40		0.00074		0.00
	HCGW		0.00061		0.01		0.00940		0.02
	Total Correct (Sharps)	71	0.85891	238.55	17.07	94	0.77509	29.00	1.61
	Total Incorrect		0.14109		2.80	94	0.22491		0.47
Specican & Amputations	Pathological	13	1.00000	67.45	5.62	31	1.00000	232.95	16.64
	Other	1	1.00000				0.00000		0.00
General Waste (HCGW)	Infectious	120	0.04352	21526.	78.07	129	0.02477	26968.0	47.72
	Sharps		0.00000		0.00		0.00065		1.26
	Chemical		0.00108		1.94		0.00011		0.21
	HCGW		0.95540		1713.86		0.97071		1869.86

		Pre-Intervention Study				Post-Intervention Study			
Waste Type	Waste Component	N	Proportion	Total Mass	Mass/day	N	Proportion	Total Mass	Mass/day
	Other		0.00000		0.00		0.00376		7.24
	Total Correct (HCGW)	120	0.9554	21526.5	1713.87	129	0.97071	26968	1869.86
	Total Incorrect		0.0446		80.01		0.02929		56.42
Lab, Morgue & Blood Waste	Lab			165.65	13.80			259.38	18.53
	Morgue			116.65	9.72			198.62	14.19
	Blood			82.45	6.87	56		31.38	2.24
Pigswill	Drums			2072.70	172.73			2174.00	155.29
Vials	Vials			.	.			37.00	2.64
Grand-total				27903.45	2325.32			34105.72	2436.13

NOTE: *) Due to the change in procedure for the handling of vials an error has occurred. The new procedure included separation of whole, empty and unbroken vials for placement is special containers for subsequent recycling/landfilling. However, there where some vials placed in the sharps containers. In the study these vials where erroneously classified as misplaced infectious waste, whereas, it should have been classified as correctly placed sharps. Hence, the sum of "infectious" and "sharps" needs to be considered when comparing to the Pre-interventions data. In our assessment and supported by numerous inspections in the wards, the amount of misplaced "infectious waste" had been significantly reduced. It is not unlikely that the real proportion of "infectious" in the sharps containers have been reduced from approx 12% in the pre-intervention study to perhaps 6% in the post intervention study. Hence, it can be assumed that the remaining part of the "infectious" was indeed the very heavy glass vials that should have been classified as correctly placed "sharps".

4.4 Health Care Risk Waste Treatment Facilities

The number of treatment facilities identified during the Status Quo Study is presented in Table 4.7. This is to be read in conjunction with Table 9.1, which shows the current service provision situation in Gauteng.

Table 4.7: *Categories of Health Care Risk Waste Treatment Facilities in Gauteng, none of which meets the DEAT Emission Guidelines or the European Union Standards (Year 2000).*

Type of Institution	Number of facilities with incinerators	Total number of incinerator lines	Number operational	Number Registered
Private Hospitals	14	14	13	5
Provincial Hospitals	32	38	28	11
Miscellaneous	8	11	10	2
Waste Service Companies	4	7	7	7
TOTALS	58	70	58 (83%)	25 (37%)

Table 4.8: *Summary of the status of the secondary burners at existing Health Care Risk Waste Treatment Facilities (Year 2000).*

Status on Incinerators in Gauteng	Number of incineration plants
Temperature ≥1100 ^{o}C (Secondary burner)	5
Temperature ≥850 ^{o}C but < 1100 ^{o}C (Secondary burner)	12
Temperature <850 ^{o}C (Secondary burner)	10
Not measuring temperatures	5
Not Operating/in use	10
Secondary Burners Not Fitted	15
Expected to comply with the Policy/DEAT Emission Guidelines (ref. 3 & 4)	0

5 Technical Options for HCW Management

This chapter presents a technical evaluation of what is considered to be some of the potentially viable options for HCW management system for Gauteng. A comprehensive list of technical options is presented, including motivation for some of those that are considered to be suitable within the framework of the Policy (ref. 3), ensuring compliance with the environmental as well as the occupational health and safety requirements.

The options are selected for each of the different modules, from segregation, through containerisation, storage, collection, transport and treatment to final disposal. The sequence, in which the modules are considered to follow the waste flow path from generation to final disposal, is illustrated in Figure 3.1.

Since appropriate HCRW treatment forms such a critical module, having such a large environmental and cost implication for the overall HCRW management strategy to be implemented, options concerning alternative treatment technologies are dealt with in more detail in Chapter 6.

5.1 Module 1: Generation of waste

There are a number of alternative procedures and methodologies available that will reduce the mass of HCRW requiring treatment, whilst ensuring that the waste will cause less environmental problems in managing it. These procedures and methodologies include:

- Waste minimisation
- Reuse
- Green Procurement.

Waste minimisation represents all measures required to prevent waste from being generated e.g. through more effective planning of work and ordering of material that will result in the correct use of appropriate products. Another way in which waste minimisation can be achieved is through effective segregation of HCW, thus reducing the amount of HCRW that requires treatment.

Reuse stands for renewed use of reusable rather than the once-off use of disposable products regularly used at health care facilities, e.g. different glassware such as petri dishes, linen, bandages, etc. Reuse of different products usually requires regularly cleaning / sterilisation of the items before being reused. Through careful investigation, a substantial number of disposable products used at health care facilities could be replaced with reusable products. However, new initiatives have to be considered against the background of possible risks of infection.

Green Procurement is the selection of environmentally less hazardous materials in the procurement process and products that generates less waste during and after use. This could for instance include procurement of mercury free thermometers, PVC-free plastic products or the substitution of plastic products that contains heavy metal dies or colouring. Products with only the minimum packaging required would further result in less waste being generated. New initiatives have to be balanced in relation to the functionality and cost effectiveness of the alternative products.

Finally, the introduction of a complete environmental management programme, like for instance the international standard ISO 14001 (ref. 6), can be considered. Such environmental management programmes do not only include waste management, but all environmental aspects related health care facilities, including wastewater management, emissions from energy production, energy savings, etc.

The full range of options for HCW generation are summarised in the Table 5.1 below, considering various options for waste minimisation, re-use of products, the introduction of "green-procurement" and implementation of environmental management systems:

Table 5.1: *Module 1: HCW Generation.*

Element 1.1: ***Options for Waste minimisation*** ▪ Procedures to reduce the generation of waste ▪ Effective segregation of HCW ▪ Recyclable materials separated from HCGW **Comments:** 1.1.1-1.1.3 All aspects considered are feasible, but will be dependant on effective planning, training and awareness.
Element 1.2: ***Options for increased use of reusable products*** ▪ Use of reusable products where appropriate ▪ Use of waste products for alternative applications **Comments:** ▪ This can be done quite effectively, provided that an evaluation is made on the practical viability (inter alia considering the risk of infection) of replacing disposable products with reusable products. ▪ It is not recommended that unsterilised waste products be used for alternative applications within health care facilities, due to the risk of infection. ▪ Sterilised wastes, e.g. plastics can be recovered and utilised for the manufacture of alternative products for use outside of health care facilities.
Element 1.3: ***Options for introducing "green procurement"*** ▪ Substitution of PVC containing products ▪ Substitution of heavy metal containing products, e.g. Hg-free thermometers. ▪ Non-heavy metal containing dies and colourings ▪ Substitution of supplies being excessively packaged ▪ Substitution of products with disposable containers **Comments:** ▪ It is unlikely that PVC products can in the short term be eliminated, but the amounts used can certainly be reduced significantly. ▪ Heavy metal containing products can be eliminated, but it will require that the procurement divisions be advised on what products not to purchase. ▪ Dies and colouring that do not contain heavy metals should form part of the procurement division's specification on all requests for quotations and tenders. ▪ Excessive packaging can be addressed by liasing with the suppliers of the various products, or by choosing alternative brand names. ▪ By giving preference to re-usable containers, will not necessarily result in a cost saving on the price of the product, as suppliers are often avoiding the use of re-usable containers. There will however be a reduction in the waste stream.
Element 1.4: ***Options for Environmental management systems.*** ▪ Introduction, execution and monitoring of Environmental management systems.

Comments:

- Introduction of certified environmental management systems would require extensive training and monitoring, which may not be viable in Gauteng in the short to medium term.

The above-mentioned procedures and methodologies provides viable options for reducing the amount of waste being generated in the various HCW categories and reduces the environmental impact of activities in the health care facilities. This, in turn, is likely to reduce the costs to be incurred by sound HCW management. It is to be noted, however, that in most cases new initiatives will require thorough investigations for each individual health care facility or department.

5.2 Module 2: HCW Segregation

Segregation of HCW is a crucial element that is on the one hand required to ensure the most appropriate and most cost-effective form of containerisation, transport, treatment and disposal for the various HCW subcategories. On the other hand segregation is required to prevent infection or injuries as a result of accidental human contact with untreated HCRW that was incorrectly packaged or disposed of.

5.2.1 Segregation procedures

Segregation of HCW will in all instances have to meet the minimum requirements aimed at reducing the risk of infection as well as any other occupational health and safety risks to the employees, the patients or the visitors. This will **at least** require segregating the HCW into the following categories:

- HCRW
  - Infectious waste (including pathological waste)
  - Sharps
  - Chemical waste (including pharmaceutical waste)
  - Radioactive waste

- HCGW
  - All HCW not classified as HCRW

As part of the segregation process, pathological waste will require separate handling in order to address ethical concerns that may arise with some forms of treatment, as well as due to handling and treatment problems, for instance with larger body parts.

For the purpose of reducing the environmental impact during HCRW treatment, segregation of PVC and heavy metal containing fractions from the HCRW stream should be considered. Segregation of PVC containing items will furthermore have a positive impact on the treatment plant, should incineration be the preferred treatment method. Preventing large amounts of chemical / pharmaceutical waste from entering treatment plants will reduce the risk of damage to equipment and excessive emissions or unacceptable quality of residues to be disposed after treatment.

However, if the aforesaid categories are segregated from the main HCRW stream, appropriate alternative treatment and disposal technologies need to be available to handle these particular fractions.

Having looked at the most important categories for HCW segregation, the following additional segregation aspects could be considered for further investigation:

- Should needles be segregated from the syringes, with the former being placed in the sharps container and the latter in the infectious waste containers, as opposed to the complete unit being disposed of in the sharps container, in order to save on the number of sharps containers being used?
- Is the use of syringes with retractable needles or small needle incinerators viable options for particular applications, once again reducing the use of sharps containers?
- To what extent should segregation of HCGW be aimed at the extraction of recyclable materials for separate collection thereof?

Table 5.2 provides details on the various levels of segregation at source as well as the supporting equipment that is required to achieve improved segregation.

Table 5.2 *Module 2: Segregation.*

Element 2.1: ***Options for the level of segregation at source*** ▪ Segregation meeting incineration requirements (avoidance of heavy metals and PVC); ▪ Segregation meeting non-burn treatment technology requirements (avoidance of heavy metals, large pathological waste and prion disease contaminated waste); ▪ Disposing of syringes together with needles; ▪ Separating needles from syringes; ▪ Making use of retractable needles; ▪ Destructing needles at source (needle incinerators). **Comments:** ▪ Segregation of waste containing PVC and heavy metals from the HCRW stream may not be practical, as it will complicate the segregation process even further. Green procurement should rather be encouraged. ▪ Segregation of pathological waste and prion disease (e.g. CJD and BSE) from the HCRW stream may be viable, but it is unlikely that removal of PVC and heavy metals will be viable. Green procurement should rather be encouraged. ▪ Combined disposal of needles and syringes increases the volume of sharps to be containerised at high costs significantly, but is the safest way to dispose of sharps ▪ This will have significant financial benefits as the volume of sharps is significantly reduced. The risk of needle prick injuries will however increase. ▪ The use of retractable needles has some potential (although it will not totally replace needles and syringes), but the cost implications may be unacceptable. ▪ Needle destructors may be viable for some applications where only small numbers of injections are given like at GP's, but will not be viable at for instance hospitals. As there may still be blood on the remnants the residues should be disposed of as HCRW.
Element 2.2: ***Options for providing supporting equipment for improved segregation:*** *(a) Appropriate nursing trolleys;* (b) *Brackets to attach HCW containers.* ▪ Make use of existing equipment; ▪ Modify existing trolleys by adding a rack for small red bags; ▪ Provide new nursing trolleys including racks for small red bags and space for a sharps' container; ▪ Provide dedicated brackets on walls for wall-mounting of sharps containers; **Comments:** ▪ Equipment used at present, result in HCRW and sharps containers being tied to nursing trolleys in

a number of ways that can result in spillage and infection.

- Modification to equipment is cheaper than to buy new equipment, provided that modifications are made in a way that will prevent accumulation of dirt.
- Supply of new trolleys will be ideal, but will be too costly for implementation as existing trolleys will have to be scrapped.
- Where nursing trolleys are not available, universal brackets for different size containers could be installed against walls, provided that it will not accumulate dirt and that it is not readily accessible to unauthorised persons.

5.2.2 Training and information

One of the central preconditions for proper waste segregation is that the staff of the health care facilities has the necessary information, awareness and motivation to follow the instructions. This requires:

- Appropriate training of those staff groups that generate waste, primarily health care professionals such as nurses, physicians, laboratory employees, etc.
- Appropriate training and information materials, as well as instructions.

It is important that all staff involved in HCW generation receives thorough training, and that refresher training is provided in between. Furthermore, information materials such as posters should be placed at strategic places and instruction materials such as clear guidelines on the procedures required should be made available to all staff members.

5.2.3 Supporting equipment

Another precondition for proper segregation of waste is that the necessary equipment be made available. This includes among others:

- Appropriately designed nursing trolleys;
- Sufficient HCW containers, that are easy to identify and to access, for each of the categories of HCW to be segregated, e.g. HCGW, sharps, pathological waste, chemical waste, other infectious waste, etc.
- Brackets to attach HCW containers, where appropriate.

5.3 Module 3: Containerisation

Containerisation is the physical activity of depositing HCW into the respective containers, as well as the sealing and marking of containers for further handling, transport, storage, treatment and disposal of waste.

5.3.1 Container selection

The size and type of HCW containers used will, in the first instance depend on the amount, density and categories of HCW being generated between collection rounds. Secondly, the selected containers will have to be compatible with the interfacing components of the HCW management process. Should the collection and treatment process not make allowance for the use (including sterilisation and return) of reusable containers, adjustments will be required on either side of the process for it to become compatible. Whatever the type of container system being used, it will have to meet the occupational health and safety requirements, whilst ultimately being affordable to ensure the system's financial sustainability.

Options for the different types of disposable as well as non-disposable containers, together with the logistics and operational implications associated with each types of container, is presented in Table 5.3.

Table 5.3: *Module 3: Containerisation*

Element 3.1: ***Options for disposable containers for HCRW and HCGW.*** ▪ Plastic bags for non-sharp waste; ▪ Disposable cardboard boxes with liners for non-sharp waste; ▪ Disposable cardboard boxes with lamination for non-sharp waste; ▪ Disposable puncture proof plastic containers for sharps. **Comments:** ▪ Plastic bags mounted on trolleys or in brackets against walls can be effective, provided that there are no sharps incorrectly segregated, as this can lead to needle prick injuries, when the bags are handled during collection and transport. ▪ Disposable cardboard boxes are effective to store and transport flat when empty or stacked in multiple layers when full. Plastic liners are often poorly installed, resulting in liquids damaging the boxes. Boxes provide limited protection against poorly segregated sharps. Boxes are costly consumables and add to the disposable HCRW stream. ▪ Disposable cardboard boxes with lamination will be more expensive than boxes with plastic liners, but this will eliminate problems with poorly installed liners. The other advantages and disadvantages will be similar to 3.1.2 ▪ Disposable puncture proof plastic containers are quite expensive and add a substantial amount to the total cost for HCRW management. Provided that the containers are well designed, the system meets the requirements for safe storage of sharps.
Element 3.2: ***Options for reusable containers for all HCRW.*** ▪ Reusable plastic containers for non-sharp HCRW; ▪ Reusable cardboard boxes with lamination for non-sharp HCRW; ▪ Reusable plastic containers for sharps. **Comments:** ▪ Reusable non-sharp containers can be effective, provided that the logistics are put in place for the sterilisation and return to source of containers. Although the capital layout is high, there is a significant saving in the operational costs. ▪ The risk of damage to boxes that are laminated on all sides during the sterilisation process is high. Although relatively cheap with the benefit of easy stacking, the box will have a limited life with a risk of spreading infection during re-use. ▪ Although the capital cost may be high, reusable plastic containers can result in a substantial operational cost saving. Emptying of containers can result in sharps causing injuries and infection to workers. Proper sterilisation is required.
Element 3.3: ***Options for sterilisation/ disinfection of reusable containers.*** ▪ Sterilisation / disinfection at the HCW source (waste generator); ▪ Sterilisation / disinfection at treatment facility. **Comments:** ▪ Sterilisation / disinfection of reusable containers at source will require duplication of infrastructure and it can make it difficult to control the sterilisation effectiveness; ▪ Sterilisation / disinfection of reusable containers at the treatment facility allows for economy of scale, as well as better quality control, but it requires the transport of sterile containers to and

storage at the various HCRW generators.

Element 3.4: ***Options for logistics for delivery of reusable containers.***

- Delivery of sterile containers during collection of full HCRW containers;
- Delivery of sterile containers during dedicated delivery rounds.

Comments:

- Delivery of sterile containers during collection of full containers will result in a saving on transport cost, but could be logistical difficult to manage and prevent contamination of sterile containers by waste collected in other containers.
- Delivery of sterile containers on dedicated rounds will result in additional transport cost, but it will be logistically easier to manage.

Element 3.5: ***Options for logistics for sterile reusable container storage.***

- Storage of containers at sterilisation facility;
- Storage of containers in centralised storage area at HCW source.

Comments:

- Storage of containers at sterilisation facility will require less storage space at the HCRW source, although it will also result in containers being less readily available at the HCRW source.
- Storage of containers at the source will require increased storage area in the relatively confined areas. Containers will however be readily available.

Element 3.6: ***Options for different sizes of containers.***

- Container size determined by waste density, thus by final mass of full container to be handled;
- Container size determined by rate at which HCW is generated;
- Container size determined by space available at HCW source.

Comments:

- With the density of the waste being used to size the container, containers will not exceed the allowable mass, although using too large containers can result in partially filled containers not being removed for quite some time.
- The containers size will be such that it can be removed frequently, but the use of large containers for higher density waste can result in overloading of containers, which could result in the collapse of containers or back injuries to workers.
- The space available in the area where the containers are to be placed at the HCRW source may be limited, thus requiring the use of smaller containers.

Element 3.7: ***Options for marking of containers.***

- Permanent pen markers;
- Bar-coding printing / stickers;
- Transponder tags.

Comments:

- Manual marking of containers by means of marking pens may be the cheapest, but it will be the most labour intensive with ample room for errors during marking and recording.
- Bar-coding will be more expensive than manual marking and will also require scanners at the point of recording, but will be faster and more accurate.
- Transponder tags will be the most trouble free system, but it will require scanner heads at the point of recording and will also be the most expensive option.

Element 3.8: ***Options for tracking system for containers.***

- Repeated weighing and manual recording;
- Manifest system;
- Transponder tracking system.

Comments:

- By weighing the individual containers and recording them at selected control points along the HCRW flow path, will ensure that all of the waste generated at source, is ultimately disposed of.

The repeated weighing is however labour intensive and, therefore, costly. The data can be recorded manually or electronically.

- The use of a manifest system to track the movement of waste is less secure, as it is not recording the existence and mass of each container, but it is providing some record of the movement of overall HCRW shipments by the number of containers or overall load. The system is relatively cheap, although it requires a lot of administration and generates a lot of paperwork. The data can only be recorded manually.
- A transponder tracking system is fast and accurate, as it can record a number of containers in a vehicle, without having direct access to each. The system is however expensive to provide. The data can only be recorded electronically.

5.3.2 Interfacing considerations

The important aspects that will have an impact on the remainder of the HCW management system, and that need to be considered when selecting any particular HCW container, are as follows:

- The space available for storage of HCW containers at source, in the sluice or at the central storage area;
- The need as well as the feasibility and desirability of stacking HCW containers in multiple layers at various storage areas, as well as during transport;
- The type of internal transport that is to be used, and the ease with which containers and the internal mode of transport can access all of the required areas;
- The need for ramps and lifting platforms, when transporting HCW containers internally, as well as externally, to the treatment facility;
- The protection that HCW containers will have against the elements throughout the HCW management process;
- The security measures that need to be taken to prevent tampering with any health care risk waste, particularly radioactive, pathological or pharmaceutical waste during the HCW management process;
- The feeding mechanism used at the treatment facility;
- The availability of sterilisation / disinfection processes for reusable containers;
- The availability of transport for distribution for sterilised/disinfected reusable or new disposable containers.
- The availability of storage facilities at the various points for new disposable or sterilised / disinfected reusable HCW containers.

5.3.3 Training and information

Training and information dissemination programmes for health care professionals as well as waste management staff should be designed around the particular type of containers that is in use. It is therefore important that all staff be trained in the system used in any particular facility, and that training previously provided at other health care facilities, transport contractors or HCRW treatment facilities not be considered to be generic and thus appropriate to all facilities. This requirement is of particular importance where temporary / contract staff is used.

5.4 Module 4: Intermediate storage

Intermediate storage is the placement of fully containerised HCW in a suitable location within the health care facility where isolation, environmental and health protection as well as human control (e.g. limitation of access) are provided, with the intention of near future retrieval of waste for treatment and disposal. The intermediate storage area will only serve the local group of HCW sources within any particular health care facility.

5.4.1 Intermediate storage requirements

The rate of HCW generation, the size of containers used as well as the distance to the central HCW storage area on the health care facility premises, will determine the need for intermediate storage facilities. Such intermediate storage facilities would ideally be within close proximity of the location where the HCW is generated and will not only be used for the storage of full HCW containers, but should also have sufficient space available for storage of some empty HCW containers, thus enabling immediate replacement of full containers.

Access to HCW containers should be restricted and the capacity of the intermediate storage facility should be sufficient to accommodate all waste generated between consecutive collection rounds. Provision is however also to be made for backup storage space in the event of a sudden increase in the HCW generation rate, or alternatively when there is a delay in the collection of HCW. The use of any particular size reusable containers is to be considered when determining the size of the intermediate storage area.

All HCW storage areas should be well ventilated to prevent a build-up of odours. Special attention is to be given to the frequent removal of “problem wastes” that may quickly start generating odours, like for instance pathological waste.

The various options available for intermediate HCW storage dealing with the location, size and the frequency of collection, is presented in Table 5.4.

Table 5.4. *Module 4: Intermediate storage*

Element 4.1: ***Options for location of intermediate HCW storage areas.*** ▪ Sluice rooms (no extra civil works needed); ▪ Dedicated intermediate storage areas (new civil works); ▪ Direct transport of HCW for storage at mortuary, at central storage area or at on-site treatment facility (no civil works needed). **Comments:** ▪ Where available, sluice rooms are quite effective for intermediate storage of HCRW. Limited space may however require frequent removal of HCRW. The sluice romm will provide limited space for storage of sterilised re-usable containers. ▪ Where there are no sluice rooms available, or where the sluice rooms provide insufficient storage space, it is suggested that dedicated storage rooms be provided. However, in addition to the costs implications, the location thereof may also be problematic in some or many institutions. ▪ Constraints related to infrastructure or alternatively the small amount of HCRW being generated may make it essential that full HCRW containers be moved directly from the source, to the central HCW storage area. This could cause disruption to health care professionals, who may be required to remove the HCRW containers once full.
Element 4.2: ***Options for frequency of waste removal from intermediate storage areas.*** ▪ Collection rounds undertaken less than once a day;

- Collection rounds undertaken at least once a day;
- On-call collection for "problem wastes" like pathological waste;

Comments:

- Less frequent HCRW collection, where insufficient waste is generated to fill a container within one day, may cause the emission of odours, particularly where pathological waste is present.
- Daily collection rounds will ensure the regular removal of HCRW, but could result in containers from some areas not being full at the time of collection.
- On-call collection in the event of low HCRW generation rates or for special waste categories like pathological waste that is to be removed as generated, is quite effective, but will require waste management staff to be available as and when required.

Element 4.3: ***Options for size of intermediate storage area.***

- Intermediate storage area dedicated to each ward;
- Mutual intermediate storage areas.
- Storage capacity for HCRW only;
- Storage capacity for both HCRW and HCGW;
- Storage area for full containers only;
- Storage area for both full and empty containers;
- Allowing for the use of disposable containers only;
- Allowing for the use of any particular size reusable containers.

Comments:

- Dedication of intermediate HCW storage areas to each ward is handy in reducing the transport distance from the source to the storage area, but it may not be possible from a logistical point of view and could result in unnecessary duplication.
- Provided that there is sufficient storage capacity and that the travelling distances between the respective sources and the intermediate storage area is not too big, mutual storage areas may be beneficial.
- Where the limited space available makes the combined storage of HCGW and HCRW impossible, preference is to be given to storage of HCRW. This could however result in additional effort in moving all HCGW containers to the central storage area as generated, or alternatively HCGW could be stored in unauthorised areas.
- Combined storage of HCRW and HCGW is beneficial in terms of optimisation of storage area utilisation as well as service delivery during collection, provided that there should be no risk of the two waste types getting mixed through incorrect containerisation.
- Where the storage space is limited, it may require that only full containers be stored in that area. It will however result in disruptions and time wastage if there are no empty containers readily available to replace the full containers.
- Combined storage of full and empty containers is the preferred option in the sense that there will always be an empty container available to replace a full container, provide that empty containers are stored such that it cannot be contaminated by waste from full containers.
- One advantage of disposable containers is the fact that it can be stacked quite effectively in a folded form when empty, but also in multiple layers when full, thus requiring less floor area.
- Making provision for the storage of any type of container will require more floor area, or alternatively selection in the category of waste to be stored or whether both full and empty containers can be stored.

5.5 Module 5: Internal Collection and Transport

In order to prevent a build-up or prolonged storage of HCW at or near the point of generation, internal collection and transport of HCW is required. Internal collection of HCW is therefore the removal of HCW from the intermediate storage area (or point of generation where no intermediate storage area exists), for internal transport to the central storage area or onsite treatment facility (where applicable). Internal transport of HCW should be by means suitably designed vehicles (trolleys) and only exceptionally by means of manual movement.

5.5.1 Internal collection and transport procedures

Filled primary receptacles for HCRW is transported to intermediate storage rooms (e.g. sluice rooms) from where they are collected directly of reloaded into larger receptacles that are collected.

Dedicated cleansing or waste management staff should preferably collect HCW from intermediate storage areas that are isolated from the patients. Where such areas do not exist, collection is to be done from the point of generation, i.e. the wards or examination rooms. Should the latter situation apply, as for instance at small generators, it is possible that the health care professionals may be responsible for HCW removal.

The types of containers used, the rate of HCW generation, the distance between the internal collection area and the central storage area, as well as the accessibility for different types of trolleys to both the intermediate- as well as the central storage areas will inter alia determine the internal transport system to be used.

Door and passage widths, as well as the elevator sizes in multi storey buildings, will determine the approximate size of the trolleys that are to be used. The types and sizes of containers to be transported will in turn determine the more precise dimensions of trolleys. The building configuration, as well as the distance from the various HCW generation points to the central storage area, will determine whether a small tractor or other motorised vehicle will be viable as a driving mechanism for multiple trolleys.

The most prominent options for rendering of the internal collection and transport service is summarised in Table 5.5. These include consideration of the responsible parties, frequency of service delivery, as well as the alternative types of collection equipment to be used.

Table 5.5. *Module 5: Internal collection and transport*

Element 5.1: ***Options for service delivery by different parties.***

- Health care professionals at minor generators;
- Internal cleaning staff;
- External cleaning staff;
- Waste management staff.

Comments:

- Where the HCW generation rate is low, for example in small clinics, it will result in irregular filling of containers that will not justify to have dedicated waste management personnel for internal HCW collection and transport to a central storage area.
- The internal cleaning staff are well positioned to undertake the internal HCW collection and transport activities, provided that the volume of waste generated will not result in the cleaning staff not being able to fulfil their other duties. The frequency of HCW collection is then dependant on the frequency of rendering the cleaning service in any particular part of the health care facility.
- Using external cleaning staff will be similar to the use of internal cleaning staff, with the exception that there is likely to be a bigger turnover in staff, resulting in more need for ongoing training and awareness.
- Service delivery by waste management staff could also be sourced internally or externally. In the case of dedicated waste management staff, there is however less risk of a significant turnover in staff when outsourced. Ongoing training and awareness will in all instances be a requirement, but the intensity could vary according to the particular needs.

Element 5.2: ***Options for frequency of collection***
- Fixed schedule less than once a day;
- Fixed schedule once a day or more;
- When called upon to do so;
- When full containers are observed.

Comments:
- Where HCW generation rates are low, less frequent collection of HCW may be acceptable, provided that it is not stored for periods long enough to result in emissions of odours. Pathological waste is however to be removed at least once a day, although high temperatures may require more frequent removal.
- Where justified by the HCW generation rate, collection can be done daily or even more frequent, depending on the generation rate as well as the type of waste being generated and the prevailing temperatures during storage. This is once again beneficial for HCW staff allocation.
- Where the waste generation rate is so low or irregular that containers cannot be collected at predetermined intervals, waste can be removed when a container is full. However, pathological cannot be stored for long periods of time and should be removed daily as a minimum. This will however create a need for people to be more or less available when called upon to do so.
- The sensitivities around pathological waste would normally require an auditable paper trail where professionals sign for handing over pathological waste
- A system of HCW removal only when observed that the containers are full is likely to be executed by the general cleansing staff, who will as part of their daily routine check on the waste level in containers. This system will not be effective where HCW generation rates are high, as containers are likely to fill up between collection rounds more frequent collection could in such instances have a significant impact on the cleansing staff duties.

Element 5.3: ***Options for mode of internal transport.***
- Movement of HCW by means of individual trolleys over medium distances to central storage areas;
- Motorised movement of multiple trolleys over long distances to central storage areas.
- Manual carrying of containers over short distances to central storage areas if mechanical/wheeled transport is not possible/practical;

Comments:
- Provided that the weight of containers do not exceed the maximum allowable mass of 15 kg and does not create any risk of injuries from the contents of the containers, containers can be lifted manually. However, actual transport should be based on trolleys or similar to minimise the manual handling and ergonomic impact.
- Where the HCW is to be transported over medium distances (>25m), it will be justified to load a number of containers on a manually powered trolley for transport.
- Where the transport distances are long (>200m), the HCW generation rate justifies the use of multiple trolleys and the infrastructure in the health care facility allows for that, it may be justified to make use of multiple trolleys that will be powered by a small tractor.

Element 5.4: ***Options for type of trolleys for HCW container collection.***
- Trolley bins for loose or bagged HCW;
- Caged collection trolleys for bagged or boxed HCW.

Comments:
- Where justified, trolley bins can be used for the collection of either loose or bagged HCRW, with the understanding that where waste is loose or the bags are untied, HCRW is not to be double handled and the trolley is to be used for the transport of waste from the source, all the way to the treatment facility, in which case the trolleys are to be sterilised and returned to the HCW source. Trolley bins are not to be used to load waste stored in boxes, due to the inefficient use of space as well as the difficulty in removing the boxes from the trolley.
- Tied bagged or boxed waste can be loaded quite effectively in cage collection trolleys, with the waste then being double handled when collected from the central storage area, or alternatively transported to the treatment facility in the same trolley, with the understanding that the empty trolleys are then to be returned to the HCW source.

Element 5.5: ***Options for trolley driving mechanism.***
- Manual movement for single trolleys

- Mechanical movement for multiple trolleys.

Comments:

- Where the transport distance is short (<200m) and single trolleys are used, the trolleys can be moved manually.
- Where there are long transport distances (>200m) and the HCW generation rate justifies the use of multiple trolleys, a small tractor or similar vihicles can be used to move the multiple trolleys.

5.5.2 Training and information

The way in which HCW containers are to be handled, as well as occupational health and safety aspects that are related to this, should be conveyed to the affected staff not only as part of induction training, but also as part of ongoing refresher training.

The required training should inter alia include the following:

- Procedures for safe handling and loading of various HCW containers;
- Emergency procedures in the event of an accident or HCW spillage;
- Procedures for the marking of containers, should that be required;
- Dangers of contact with the HCRW, e.g. no manual compression of HCRW to safe space etc..

Certain standard procedures related to this 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 be capacitated by means of written procedures and manuals.

5.5.3 Supporting equipment

The supporting equipment required for internal collection and transport, will inter alia consist of the following:

- Appropriate Personal Protective Equipment (PPE) for staff that are responsible to handle the HCW containers;
- All emergency equipment required to deal with damaged containers or HCW spills;
- Trolleys that are designed to meet the needs, but also constraints, of the particular health care facility where the equipment is to be used;
- Small motorised vehicles(tractors) where the situation justifies the use of mechanised equipment to drive multiple trolleys;

It is important to recognise that the equipment is to be selected to meet the needs of the particular facility.

5.6 Module 6: Centralised storage

Having collected the HCW from the various generation areas (or intermediate storage areas) inside the health care facility, the HCW is to be accumulated at a central on-site storage area from where it is to be collected for on-site or off-site treatment.

Centralised storage can therefore be described as the placement of HCW in a suitable location outside the health care facility, but within the outer perimeter, with the intention of retrieval of HCW for treatment and/or disposal. The central storage area is to provide isolation, environmental and health protection, as well as human control (e.g. monitoring for radioactivity, limitation of access, etc.) and is to serve all potential sources of HCW generated within that particular health care facility.

5.6.1 Central storage requirements

The size of the centralised storage area will be affected by the total volume of HCW being generated between external collection rounds, with adequate allowance for backup in the event of a sudden increase in the HCW generation rate or alternatively a temporary breakdown in the HCW collection service. Should an onsite treatment facility be used, the size of the central storage area could be reduced, depending on the availability and efficiency of the on-site treatment operation. In general, on-site treatment is not regarded as viable or desirable as this requires relative high investments and costs monitoring as well as specialised skilled staff.

Although limited, their may be situations where the health care facility (thus also the various sections of the HCW generator) is spread over such a large area, that the establishment of a second central storage area may be justified to reduce the transport distance between the intermediate storage areas, and the central storage area.

Where required by abnormal high temperatures or long storage periods (but in all instances where pathological waste is to be stored for periods longer than 24 hours), refrigeration facilities are to be provided as part of the central storage facilities. For example pathological waste is often stored in the cooled stores of the morgue.

Depending on the needs of the particular facility, different categories of HCW can be stored separately or in the same facility. Where justified, bulk HCGW storage containers, with or without compaction equipment to reduce the volume, may also be considered as part of the central HCW storage facility.

In Table 5.6 a number of what is considered to be the most prominent options for centralised HCW storage are considered. These options are similar to intermediate storage, looking at aspects ranging from the location of central storage facilities, through to size, to possible storage configurations and finally the need for refrigeration of certain HCRW categories.

Table 5.6. *Module 6: Centralised storage of HCW*

Element 6.1: ***Options for location of central HCW storage area.***
▪ Single central storage area;
▪ Multiple central storage areas for larger facilities;
▪ Dedicated expired pharmaceutical storage area.
Comments:
▪ The most common scenario would be the availability of a single central storage area for the

storage of waste generated within a facility, with the understanding that it will provide good access to internal transport equipment, as well as to external waste collection equipment.
- Where the size of the health care facility is such that the internal transport distances becomes excessive without the availability of a mechanical internal transport system, it may be justified to consider the establishment of more than one central storage area from where the waste is to be collected. This is further subject to the HCW generation rate being high enough to justify the existence of more than one facility.
- To prevent the treatment of chemical (pharmaceutical) HCRW waste with other HCRW, as well as to reduce the risk of pharmaceutical waste being stolen for distribution, it may be justified to have a dedicated storage area for such chemicals/pharmaceuticals. Special marking of pharmaceutical HCRW containers increases the risk of such HCRW being stolen.

Element 6.2: ***Options for central storage area size.***
- Storage of HCRW only;
- Storage of both HCRW and HCGW in same area;
- Storage of full HCW containers only;
- Storage of full HCW containers with dedicated area for new/sterilised empty containers.

Comments:
- Where the central storage area is dedicated for the storage of HCRW, the access control can be enforced more effectively and the risk of mixing of HCW is reduced. It will however require a dedicated area for the storage of HCGW.
- Where HCGW and HCRW is stored together, there is a risk of waste being mixed or incorrectly collected, but the advantage is a single waste storage area for all HCW generated at the particular facility.
- If the central area is dedicated for the storage of full HCW containers only, the risk of contaminating empty/sterilised containers is reduced. However, an additional storage area will be required and the possibility of distributing empty containers during collection of full containers becomes more problematic.
- Where the space allows this to take place, the combined storage of full and empty containers makes the logistics of receiving and distributing empty containers more efficient, provided that the containers are stored separately to prevent contamination of empty containers. The access control over full and empty containers will in this instance be combined, thus making it more effective.

Element 6.3: ***Options for storage configuration.***
- Single layer stacking of containers;
- Multi layer stacking of containers;
- Storing smaller containers in larger containers for easier handling.

Comments:
- Single layer stacking of containers will be required for all reusable wheelie bin containers, which reduces the efficiency in floor space utilisation.
- In general, it is only disposal box containers that can be stored in multiple layers, provided that the height does not exceed the allowable limit at which the structural strength of the containers will be endangered.
- Storing of smaller containers (e.g. sharps containers) inside larger containers (e.g. HCRW boxes or wheelie bins), will improve the safety and ease of handling such containers, provided that it does not lead to excessive costs due to the duplication of containerisation.

Element 6.4: ***Options for waste removal frequency from central storage area.***
- Collection daily or more frequently;
- Collection less than daily;
- Collection on demand.

Comments:
- Depending on the HCW generation rate, it may be required to have external collection rounds undertaken quite frequently, e.g. daily or even more often, in order to save on the required central storage area.
- Where the HCW generation rate does not justify more frequent collection, HCW can be collected less often, provided that pathological waste is containerised in such a way that it will not result in the generation of odours.

- Where the HCW generation rate is quite low, for instance in the case of GP's, collection may be required only on demand, provide that this HCW does not include HCW with a potential to generate odours.

Element 6.5: ***Options for refrigeration of certain waste for extended storage.***
- No refrigeration facility;
- Dedicated refrigerated facility;
- Use of mortuary as refrigerated area.

Comments:
- Where no refrigeration facility is provided, pathological waste is to be removed at regular intervals to ensure that it is not allowed to generate odours. The general climatic conditions may however require that infectious HCRW other than pathological waste, be refrigerated to prevent the generation of odours.
- Where large amounts of pathological waste is generated, or where the climatic conditions require that infectious HCRW other than pathological waste to also be refrigerated, it will be justified to provide dedicated refrigerated storage areas.
- Where small amounts of pathological waste are generated and the facility exists, the use of the mortuary for storage of pathological waste will be justified.

Element 6.6: ***Options for storage of HCGW.***
- Storage of HCGW in disposable plastic bags;
- Storage of HCGW in small reusable containers;
- Storage of uncompacted HCGW in bulk containers;
- Storage of HCGW in bulk compactor containers.

Comments:
- HCGW stored in disposable plastic bags without any further containerisation will be restricted to small generators and may lead to the release of waste liquids. Such waste could be collected by means of Rear-End-Loader (REL) compactor trucks, or can be compacted by means of static compactors on site, which would ensure a good payload during transport. The bags may however also be deposited into open bulk containers but care should be taken to avoid storm water access to the containers making the waste wet and resulting in seepage of polluted water.
- The storage of HCGW in small reusable containers is quite popular where the local authority renders the service. Use of such containers is normally limited to relative small to medium generators, up to the size of clinics, and the waste must be protected against rainwater infiltration by lids, placement under roof etc. Such waste is normally collected by means of Rear-End-Loader (REL) compactor trucks as part of the council's waste management services, which is ensuring a good payload during transport.
- Bulk HCGW containers for uncompacted waste are used by large generators, and are normally associated with the waste service being rendered by private contractors or the council. Access to the containers is often problematic where provision is not made for a ramp from which the waste can be deposited into the containers, and the waste is normally exposed to water infiltration. The payload during transport of such waste is normally quite low.
- Where justified by the rate of HCGW generation, on-site static compactors are often used for the compacted storage of HCGW, which not only results in an improved payload during transport, but also reduces the volume, whilst protecting the waste against water infiltration during storms.

5.6.2 Training and information

The training required would go hand-in-hand with the training of the internal collection and transport staff, who will ultimately be responsible for the placing of containers inside the central storage area, as well as the maintenance of the facility. Training will furthermore include the particular safety and emergency response measures that are to be implemented and adhered to for the central storage area.

5.7 Module 7: External Collection and Transport

Where there is no onsite HCRW treatment facility available, all HCRW and HCGW stored in the central storage area are to be collected and transported to a regional treatment/disposal facility, as applicable for the respective types of waste.

External transport of HCW can therefore be considered to be the movement of HCW by means of suitable designed vehicles from the point of external storage, to the point of treatment/disposal outside the boundaries of the health care facility. External transport of HCRW would be in an uncompacted state as containerised at source, whilst HCGW may be in either an uncompacted or compacted state, which depending on the volumes generated and the containers used.

5.7.1 External collection and transport requirements

The type of HCRW collection vehicles used is to a large extent determined by the type of containers used, as well as the need to optimise the payload. The size of the vehicles would for instance depend on the volume of HCRW to be collected from each of the facilities to be serviced and the smaller the individual HCRW loads, and the longer the travelling distances between collection points, the smaller the required HCRW collection vehicle would be. This approach is however very theoretical and the practical conditions may require that the same vehicle doing collection from the large HCRW generators, also be used for HCRW collection from the smaller and more remote generators. Where transport of HCRW is to be undertaken over long distances like in the case of inter-provincial transport, HCRW collection vehicles are to be refrigerated.

HCGW collection for small generators will be determined by the system provided by the local authority. Where the service for collection of HCGW from large generators is outsourced, the type of system to be implemented will depend on the HCGW generated rate, as well as the transport distance between the health care facility and the disposal site. The need to protect the waste against the elements and the frequency at which waste is to be collected are in all instances very important considerations.

External transport options will primarily be made up of alternative HCRW collection vehicle sizes, vehicle types required for collection of different container types, number of shifts per day, cleansing requirements and finally impact of alternative billing systems on the system efficiency, all of which are presented in Table 5.7.

Table 5.7. *Module 7: External transport of HCW*

Element 7.1: ***Options for size of HCRW vehicles used for external transport.***
▪ Light load vehicles (e.g. <1000 kg payload);
▪ Medium load vehicles; (e.g. 1000< X < 3000 kg)
▪ Heavy load vehicles. (e.g. > 3000 kg payload)
Comments:
▪ Light load vehicles will is generally only effective for collection of small loads, from collection points that are far apart.
▪ Medium load vehicles provide the opportunity for collection of waste from larger generators. The inherent low density of HCRW requires that large loading bays be provided, in an attempt to improve on the payload. Single layer stacking of reusable containers result in the loading capacity being determined by floor area, rather than the axle load.
▪ Heavy load vehicles are likely only to be used where some form of waste transfer is used for long

distance cross boundary movement of HCRW. Heavy load vehicles are expensive to run and difficult to manoeuvre, thus making them less effective for local collection of HCRW.

Element 7.2: ***Options for type of vehicle required for alternative containers.***

- Single level loading bay;
- Double level loading bay;
- Dedicated lifting mechanism.

Comments:

- Single level loading bay vehicles is the most common type of HCRW vehicles used. Although the loading mechanism is relatively simple, the available floor area, as a result of the low density HCRW being transported, will dictate the payload. This is particularly in the case where waste containers are to be loaded in single layers, e.g. when reusable containers are used.
- Where single level loading of waste containers is being used, a double platform HCRW collection vehicle provides the additional floor area required that would in effect double the payload achieved. This will however require quite sophisticated loading mechanisms.
- Dedicated lifting mechanisms will be a requirement in all instances where reusable wheelie containers are to be loaded. For double level loading, even more sophisticated lifting mechanisms are required.

Element 7.3: ***Options for single versus multi shift collection.***

- Single shift HCRW collection;
- Multi shift HCRW collection.

Comments:

- Single shift HCRW collection result in normal working hours being followed, with waste collection vehicles being under utilised in terms of its available efficiency.
- Double shift HCRW collection will require higher wages fro shift work, but it will allow for a large portion of the daily HCRW collection to be done outside of peak traffic hours. This will not only optimise the capital layout made for collection vehicles, but it will also improve the efficiency during the respective collection rounds. This will however require multi shift operation of the treatment facilities, or at least the facility to deliver HCRW after hours.

Element 7.4: ***Options for cleansing requirements for vehicles.***

- Daily cleansing with an anti-septic;
- Cleansing with an anti septic less than once a day.

Comments:

- The likelihood of spilling waste in the collection vehicle loading bay will influence the need for daily or even more frequent cleansing of vehicles.
- Where vehicles are cleaned less than once a day, it must be ensured that there is no risk of polluting the outside of containers that are to be handled by waste management workers.

Element 7.5: ***Options for billing system for optimum payload.***

- Billing according to number of HCRW containers (volume billing);
- Billing on total mass of HCRW removed;
- Billing as a combination of mass and number of HCRW containers.

Comments:

Note: In this discussion it is assumed that future payment will be made for waste actually collected, and not for number of containers distributed to health care facilities.

- Volume billing is advantageous for the waste transport contractor in the sense that irrespective of the waste mass being containerised for treatment, the contractor will still be paid per container. Poor payloads will therefore not affect the contractors, as they will be paid for the volume utilised inside the vehicle's loading bay. This can also result in HCRW generators trying to force more waste into HCRW containers, which is creating the risk of injuries and infection.
- Mass billing is advantageous for the HCRW generators, as the only penalty to them in under utilising the container capacity will be the cost of the container, whereas the waste transport contractor will have to transport a number of semi full containers, that is taking up volume for which limited payment is made.
- A fixed cost per container collected, together with an extra-over rate per kg of waste, will ensure that there is an incentive for the generators to make optimum use of the storage capacity in the container, whilst allowing some benefit for collection of low density HCRW.

5.7.2 Training and information:

The responsibility for collection and transport of a hazardous waste in the form of HCRW is considerable, and it is therefore important that staff expected to undertake this function, be properly trained and equipped to execute their duties not only to the required environmental standards, but also to the required occupational health and safety standards.

As for internal collection and transport, it is important that the staff responsible be trained and capacitated not only during induction, but also by means of refresher courses. The way in which the information is conveyed should be in accordance with the level of worker literacy. It should be noted that where temporary or contract workers are employed to render the service, such workers need to be trained in the same manner as permanent staff.

5.7.3 Supporting equipment

First and foremost is the need for appropriately designed HCRW collection vehicles that meet the requirements laid down by the National Road Traffic Act (Act 93 of 1996). The vehicles should further be compatible with the type of containers that are to be collected, which could include the need for a hydraulic lifting mechanism, as well as any practical measures that may be required to improve on the achievable payload.

Workers are to be equipped with the necessary Personal Protective Equipment (PPE) whilst vehicles are to be equipped with spill kits, fire extinguishers as well as all other emergency equipment required in terms of the National Road Traffic Act (Act 93 of 1996).

5.8 Module 8: Treatment

Effective treatment of HCRW can be considered to be most important objective of HCW management, thereby eliminating its risk of infection.

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

The range of HCRW treatment options can primarily be grouped as burn- and non-burn technologies. Details on the various treatment options will be presented in the following chapter, and will there fore not be discussed in any detail in this section.

Although the alternative options for HCRW treatment is discussed in detail in Chapter 6 of this report, there are a number of peripheral options associated with HCRW treatment that are dealt with in Table 5.8. The options are inter alia dealing with the location of the treatment facilities, the party responsible for service rendering, the possible need for refrigerated storage, the feeding mechanism used as well as the way in which the residues are to be stored on site.

Table 5.8. *Module 8: Treatment*

Element 8.1: ***Options for location of treatment facility.*** ▪ On-site treatment facility; ▪ Off-site (regional) treatment facility. **Comments:** ▪ On-site treatment of HCRW has the disadvantage that the smaller facilities are to be established and operated to meet the same environmental standards expected from large regional treatment facilities. This will imply that the certain fixed cost (like the cost of EIA's and air cleaning systems for incinerators) will be incurred irrespective of the size of the treatment facility. It does however have the advantage of eliminating the cost and impact of collection and transport. ▪ Regional treatment facilities are more economic to run due to the economy of scale, but it does require that untreated waste sometimes be transported over relatively long distances.
Element 8.2: ***Options for service rendering.*** ▪ Service rendered by health care facility staff, or provincial staff from other Departments in the case of public facilities; ▪ Service rendered by private contractor. **Comments:** ▪ The major limitation in service rendering by health care facility staff or even provincial staff from other Departments in the case of public facilities, is the fact that it is in most instances not their core business and therefore not their field of expertise, which often results in the service not being rendered cost effectively or to the required environmental standards and occupational health and safety requirements. These services are however rendered without any profit incentive. ▪ A private contractor that specialises in HCRW management is normally best equipped in as far as the available equipment and expertise is concerned. Such services are however rendered with a profit incentive that offsets the savings that may have been made through more efficient service delivery.
Element 8.3: ***Options for storage facility on treatment site.*** ▪ No refrigeration provided for pathological waste; ▪ Refrigeration provided for pathological waste; ▪ Refrigeration provided for all HCRW. **Comments:** ▪ Where no refrigeration is provided for pathological waste, the plant is either to be operated in such a way that, depending on climatic conditions, all waste is treated within 24-hours, or alternatively a system is required for the identification of pathological waste containers that will ensure that all such waste is treated as soon as it is delivered to the facility; ▪ Refrigeration of pathological waste will reduce the urgency with which such waste is to be treated; ▪ Although it may be expensive in some instances, refrigeration of all HCRW may be required in areas with excessive high temperatures, or where HCRW is not collected frequently.
Element 8.4: ***Options for categories of HCRW treated at facility.*** ▪ All HCRW excluding radioactive waste; ▪ All HCRW excluding radioactive and chemical waste; ▪ All HCRW excluding radioactive, chemical and pathological waste. **Comments:** ▪ Radioactive HCRW requires special handling and disposal methods, which makes it unique compared to the remainder of the HCRW stream. Only few categories of this type of HCRW are allowed to be incinerated; ▪ Although not to the same extent as radioactive HCRW, chemical (including pharmaceutical) HCRW also requires special handling and treatment before it is disposed of. The latter type of HCRW must not be treated by non-burn treatment technologies, but may be treated by incineration under certain preconditions.

- Although technically feasible, non-burn technologies that grind or "cook" pathological waste or that leave it recognisable should not be used thus requiring pathological HCRW to be incinerated. Burial in a cemetery may be required for certain anatomical waste for religious reasons.

Element 8.5: ***Options for HCRW Treatment processes***

- Thermal Treatment Technologies:
  - Multiple chamber incinerators
  - Rotary kiln
  - Fluidised bed
- Sterilisation (inactivation technologies:
  - Autoclave / steam sterilisation
  - Microwave
  - Electro Thermal Deactivation (ETD)
  - Chemical / heat disinfection
- Encapsulation
  - Encapsulation in impermeable media

Comments:

- All of these aspects are discussed in detail in Chapter 6, and will not be considered any further under this heading.

Element 8.6: ***Container system used for feeder mechanism***

Options:

- Bagged HCRW into feeder;
- Boxed HCRW into feeder;
- HCRW in small (two wheeled) wheelie bins;
- HCRW in large (four wheeled) wheelie bins;
- Flexible feeder system.

Comments:

- Manual feeding of waste in bags into the hopper is note preferred for safety reasons and is likely to be slow. Workers will be exposed to possible needle stick injuries from poorly segregated waste.
- By feeding the waste in disposable boxed containers, it could result in a need for a dedicated type of feeding mechanism that may not be suitable for feeding other types of containers. Boxes will also serve as fuel for incinerators. Excessive manual handling is not recommended.
- Feeding the waste by means of small (2-wheeled) wheelie bins should preferable be by means of a mechanised lifting- and tilting mechanism. Depending on the cycle time, this may however slow the feeding rate down due to the relative small volumes being loaded per cycle.
- Feeding the waste by means of large (4-wheeled) wheelie bins should be by means of a mechanised lifting- and tilting mechanism. The large volumes loaded per cycle are however larger, still making it effective if the loading cycle times are slightly longer.
- A flexible feeder system that can allow for a variety of container types is the preferred option, as it will be able to handle waste from a variety of sources.

Element 8.7: ***Type of energy source used***

Options:

- Diesel Fuel or Fuel Oil;
- Gas;
- Electricity.

Comments:

- Diesel and fuel oil will contribute to the release of polluting emissions. Planst using fosil fues would normally still need electricity supply also.
- Electricity is more expensive than diesel or oil.
- Back-up power supply may be required to e.g. to protect machinery in case of power failure. If piped gas is used e.g. duel fuel burners for oil could provide sufficient back-up in case of disruption of the gas supply.

Element 8.8: ***Type of flue gas cleaning system used for incinerators.***

Options:

- Wet scrubber system for flue gas cleaning.

- Bag filter system used for flue gas cleaning.
- Ceramic filter system used for flue gas cleaning.

Comments:

- All of these aspects are discussed in detail in Chapter 6, and will not be considered any further under this heading.

Element 8.9: ***Type of residue storage facility required***

Options:

- Uncompacted waste; open bulk container;
- Uncompacted waste; closed bulk container;
- Compacted waste; closed bulk container.

Comments:

- Uncompacted waste in open bulk containers is more accessible during the loading cycle, but it is also subject to the effects of wind and rain.
- Uncompacted waste in closed containers is better protected against the elements, but requires specially designed lids / covers that will provide easy access for loading of residues.
- Compacted waste in closed containers forms part of a static compactor system that will ensure loading of the waste by means of the compaction unit, thus ensuring volume reduction for low-density waste, whilst being protected against the elements.

5.9 Module 9: Collection and Transport of Residues

Transport of residues from HCRW treatment facilities is the movement of treated HCRW by means of suitably designed vehicles. This activity takes place from the point of treatment, to the point of final disposal at an appropriately permitted, designed, constructed and operated waste disposal facility.

The greater the volume reduction during treatment and the higher the density of the residues, the more cost effective the transport of the residues will be between the treatment- and the disposal facilities. Where the inherent density of the residues is low, the use of compaction equipment can improve the material density to the extent that the material can be transported with cost effective payloads.

Handling of the HCRW residues is to be done in a responsible manner, as there is, in addition to the occupational health and safety risks involved in its management, still a risk of infection (by incompletely treated HCRW) as well as environmental pollution from heavy metals that may be present in the residue.

Table 5.9 deals with the residue handling requirements, the equipment required for residue handling as well as the option for improving the payload of residues during transport can be achieved.

Table 5.9. *Module 9: Collection and transport of residues*

Element 9.1: ***Options for residue handling requirements***

- Manual loading of residues;
- Mechanical handling of residues.
- Automated handling of residues.

Comments:

- Manual handling of residues requires increased emphasis on the occupational health and safety of workers, whilst the production rate is likely to be relatively low in the case of large treatment facilities. Manual handling requires relatively unskilled labour;
- Mechanical handling of residues reduces the risk of injuries and infection to workers, although it requires more expensive equipment and more intensive training. Mechanical handling is less

flexible and more difficult to replace at short notice in the event of breakdowns. ▪ Automated handling of residues is less flexible during its use and is therefore to be designed for its particular application. Automated handling is almost free from labour, although the treatment facility can be brought to a standstill in the event of any breakdowns, unless the design makes provision for such incidences;
Element 9.2: ***Options for residue collection equipment*** ▪ Loadlugger for high density materials in skips; ▪ Bulk roll-on roll-of containers for low density material; ▪ Rear-end-loader (REL) compactor or front-end-loader (FEL) compactor for low density material; ▪ Static compactor with roll-on-roll off containers for low-density material. **Comments:** ▪ Only residues with an inherent high density that does not require further compaction to achieve an effective payload, is suitable for transport in skips. Ingress of rain and wind blown littering shall be controlled effectively. ▪ Bulk roll-on roll-off containers will increase the payload through its increased volume, rather than an increased density of the residues. The same principle regarding the provision of cover over the waste containers that applied to skips, will apply to the bulk open containers; ▪ REL or FEL compactors can be used quite effectively to increase the density, and thereby the effective payload of residues that would otherwise have a low density. FEL vehicles are more expensive but compact to a greater density and can be used where access to the storage areas is more difficult. The residues would be protected against wind and rain effects during transport, although not during storage. ▪ Onsite static compaction of low-density residues will reduce the residue volume during storage, whilst improving the payload during transport. Residues will also be protected against the effects wind and rain during storage and transport.
Element 9.3: ***Options for improved payload for residues*** ▪ Increased volume for bulk transport of low density material; ▪ Volume reduction for increased density through shredding. ▪ Volume reduction for increased density through compaction **Comments:** ▪ Compaction is not viable for incinerator residues but a necessity to achieve cost-efficient disposal of residues from non-burn treatment facilities. ▪ Increasing the volume for bulk transport of low-density residues, is one way of improving on then payload. Not only will the large volume of uncompacted waste take up a lot of storage space at the treatment facility, but it will also require the use of large vehicles with bulk containers; ▪ The volume reduction that can be achieved through shredding, will have a positive effect on the waste density, but this is to be considered against the cost required to achieve the required shredding, unless the shredding is also required as part of the treatment process. ▪ Compaction by means of static compactors placed on site is the preferred way of improving the payload, as it will already provide the advantage of a reduced volume during onsite storage. Collection and transport by means of REL or FEL compactor trucks will improve the payload, but it will not assist in reducing the volume that is to be stored.

5.9.1 Training and information:

It is important that the residues from the treatment process still be managed as if it is potentially infectious. Not only is there always a risk of injury by sharp objects, but the treatment process could also have been ineffective. The fine dust particles from incinerator ash is at all times poisonous which will not only require effective dust suppression, but it will also require the use of appropriate PPE.

As the waste residue has the potential to impact on nearby people other than those responsible for the handling thereof (like for instance dust from incinerator ash), all potentially affected parties should be trained in the health and safety measures that will be required to protect them. The people responsible for the handling thereof, should be capacitated on ways in which the waste residue is to be managed in such a way, that there will be the smallest possible risk for negative effects on the environment or any person coming in contact with the residues.

As before, it is to be ensured that the educational material is made available in a format that will be clearly understandable for the people that are to be capacitated.

5.9.2 Supporting equipment

The supporting equipment will in the first instance include the receptacles (containers) that are to be used for the collection of the residues. Once collected in containers, the residues are to be transported with appropriate vehicles to an appropriate disposal site. Similar to the HCRW collection vehicles, these vehicles are once again to meet the standards that are required by the National Road Traffic Act (Act 93 of 1996).

As in the case of collection and transport from the central storage areas, PPE is to be supplied to all affected staff members. Emergency equipment is also to be provided as required by the National Road Traffic Act (Act 93 of 1996).

5.10 Module 10: Disposal of Residues

Once the HCRW residues are delivered to a waste disposal site, the residues are to be disposed of in accordance with DWAF's *Minimum Requirements for Waste Disposal by Landfill and Minimum Requirements for the Handling, Classification and Disposal of Hazardous Waste*. Disposal of residues can be defined as the intentional burial or deposit of residues from HCRW treatment processes at an appropriately permitted, developed and operated waste disposal facility.

The classification of HCRW after treatment, will determine whether the waste is to be disposed of on a general waste disposal sites, or on a hazardous waste disposal sites. Such classification will in itself have a significant impact on the cost effectiveness of the HCW management system. The classification is to comply with DWAF's Minimum Requirements for the Handling, Classification and Disposal of Hazardous Waste.

As the aspect of waste disposal is dealt with in detail in the DWAF's Minimum Requirements series of documents, it is not considered justified to pay a lot of attention to that aspect in this document.

Table 5.10 presents a summary on some of the options for the disposal of residues, against the background of the Department of Water Affairs and Forestry's Minimum Requirements for Waste Disposal by Landfill, which includes waste minimisation measures, as well as disposal options for different waste categories.

Table 5.10. *Module 10: Disposal of residues*

Element 10.1: ***Options for minimisation of residues.***
▪ Disposal of all residues from the HCRW treatment process;
▪ Minimisation of residues by recovery of reusable (e.g. possible use of incinerator ash for road

construction) or recyclable (e.g. plastic and glass from sterilisation processes, etc.) materials.

Comments:

- Where it is not financially viable or technically feasible to reduce the residue stream from the various HCRW treatment processes, all residues are to be disposed at appropriate waste disposal sites.
- Where financially viable and technically feasible residue minimisation processes are identified, this is to be implemented as part of the overall waste reduction objective, even where it applies to treated waste residues.

Element 10.2: ***Options for disposal options for residues***

- Disposal of non-hazardous residues at general waste disposal site at reduced cost;
- Disposal of hazardous residues at hazardous waste disposal site at increased cost.

Comments:

- The cost for disposal of non-hazardous waste is significantly cheaper than that of hazardous waste, thus justifying the effort to have residues de-listed wherever possible.
- Residues that cannot be de-listed for disposal at general waste disposal sites, is to be disposed of at hazardous waste disposal sites at increased costs.

6 HCRW Treatment Options

6.1 Overview

The main treatment options for HCRW include:

- **Combustion Technologies,** i.e. thermal treatment/combustion technologies:
  - Incineration which includes: excess air, controlled air, rotary kiln and fluidised bed, and
  - *Pyrolysis*

- **Sterilisation/Disinfection Technologies,**
  - Steam sterilisation, e.g. Autoclaving
  - Chemical sterilisation, e.g. with chlorine, glutaraldehyde
  - *Gas sterilisation, e.g. with ethylene oxide, formaldehyde*
  - Dry heat sterilisation, e.g. oil heated screw feed technology
  - Electro-thermal deactivation,
  - Microwave sterilisation,
  - *Irradiation sterilisation*
    - *Cobalt-60 gamma rays*
    - *Ultra violet*
    - *Electron beam sterilisation*

The technologies indicated in italics are experimental or have limited commercial application internationally for HCRW in general.

All of the above treatment technologies result in a residue, i.e. ash in the case of burn technologies or a sterilised/disinfected waste in case of non-burn technologies that has to be disposed to landfill. Note that in terms of the South African Minimum Requirements for the Handling, Classification and Disposal of Hazardous Waste, HCRW cannot be landfilled unless it is declassified by an approved treatment technology.

In the sections below, combustion technologies and selected non-burn technologies are discussed in more detail and an approximate estimate of the investment and operating costs given.

There are some differences between burn and non-burn technologies and the most important of these are the types of HCRW that can be treated and the residues that are generated; these are illustrated in Figure 6.1. In the diagram it is assumed that the combustion treatment facilities and the non-burn treatment technologies met the Gauteng Policy (ref.3) and, therefore, can accept three of the major types of HCRW, i.e. infectious waste including sharps, chemical waste including pharmaceuticals and pathological waste, and that a gas cleaning system is used. Note that most of the incineration facilities currently used in South Africa are not able to handle chemical wastes; see below. Pathological (anatomical) waste, which includes recognisable human parts, should not be handled by non-burn technologies, see Section 6.3.3. Radioactive waste is not included in Figure 6.1, although selected low radioactive waste that comes from health care facilities could be treated in a permitted incinerator but not medium or high level waste. Only certain low-level radioactive waste can be treated by incineration technologies whereas non-burn technologies should not low level receive radioactive waste. Radioactive waste that exceeds the safety limits must be disposed to special permitted waste landfills/depositories or stored safely for a number of half-lives until sufficiently low levels of radioactivity are reached before further treatment or landfilling can take place.

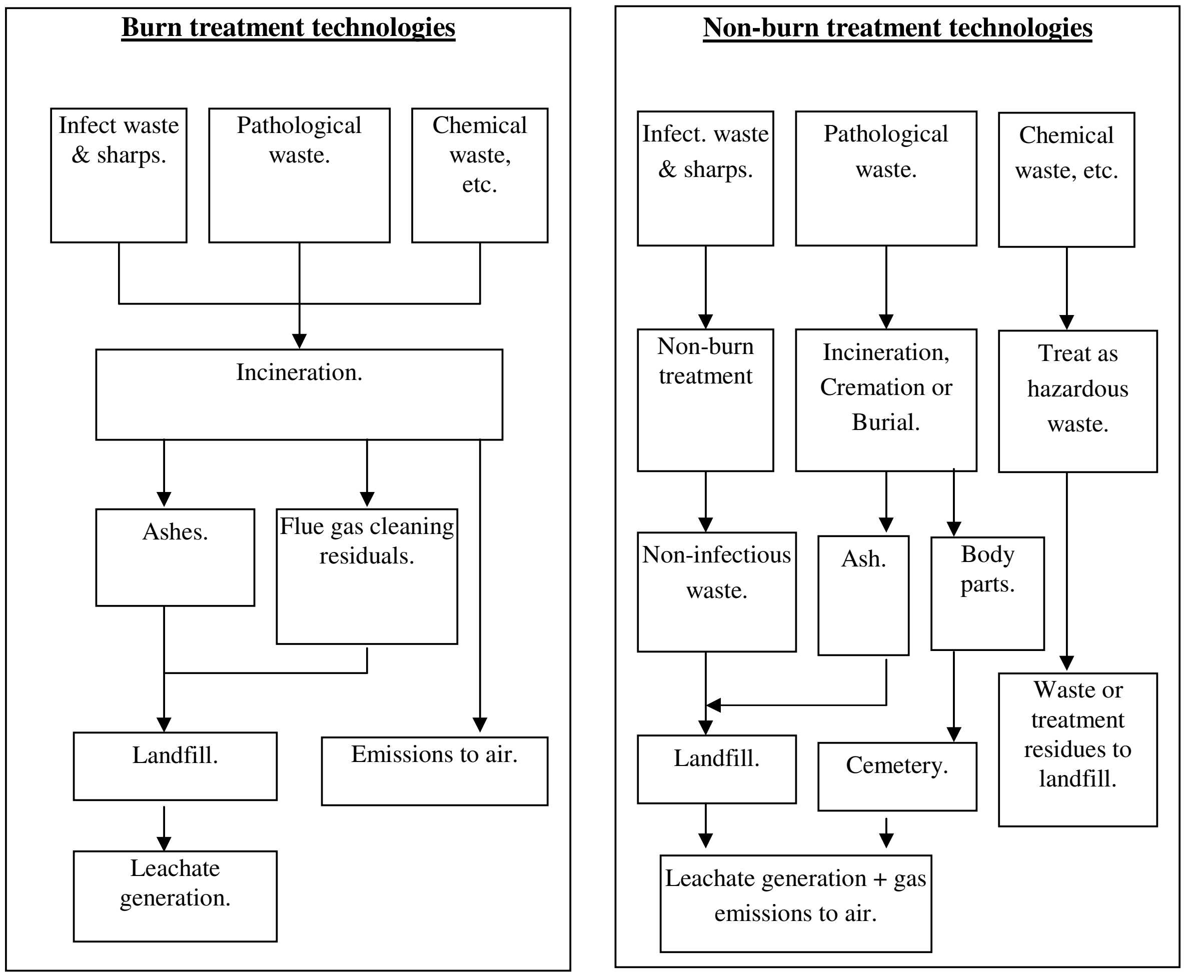


Figure 6.1: *Generic Differences Between Non-burn and Burn Technologies for the Treatment of Health Care Risk Waste (Radioactive waste excluded)*

In the Sections 6.2 and 6.3 below, the HCRW treatment technologies listed above are briefly described with their advantages and disadvantages. In Section 6.4, an estimate of the cost of selected treatment technologies is presented.

6.2 Overview of Combustion/Incineration Technologies;

Presently, incineration is the dominant technology for the treatment of HCRW both in South Africa, although, in many first world countries, steam sterilisation, microwaving and other non-burn technologies are rapidly becoming the dominant treatment technologies – due to increasing emission standards for incineration facilities. Historically single chambered incinerators have been used and there are many still in use in Gauteng. However, the major objective was sterilisation of the waste and the impact of the incinerator on the environment, a secondary consideration. Further, developments included the introduction of multi-chambered incinerators, both excess air and starved air/controlled air types specifically designed and permitted for the treatment of the infectious waste stream. As discussed briefly below these incinerators are only capable of handling small quantities of chemical hazardous waste.

Other common incineration technologies include rotary kilns and fluidised beds. Rotary kilns are widely used in the lime and cement industries in South Africa and, internationally, are used for the treatment of chemical hazardous waste. Rotary kilns are versatile and are capable of handling slurries, bulk solids and sludges also. The smaller plants are, however, expensive to operate and maintain and are, therefore, not normally used just for the treatment of the infectious waste stream from health care facilities. In some countries rotary kilns are used to treat both certain types of hazardous/chemical waste as well as HCRW. Separation at source of especially chemicals, pharmaceuticals etc. is not so critical if a rotary kiln is used, only the radioactive waste stream would have to be separated.

Fluidised bed technology is used in South Africa for the treatment of hazardous waste, but mainly for end of pipe applications, i.e. a single waste stream from a chemical plant is destroyed. Passing air through the bed fluidises a bed of sand and the rapid motion allows rapid heat exchange to occur between the hot bed and the waste giving excellent combustion efficiencies. So far, they have not been used for the treatment of HCRW in South Africa, although rotating fluidised bed incinerators are used, for example, in Japan.

Plasma Arc Technology achieves extremely high temperatures of between 2000^{o}C to as high as 8000^{o}C and thus results in effective destruction of waste. All waste streams can clearly be treated except for radioactive waste. The cost of treatment is high and, therefore, this technology is probably not cost effective for the infectious waste stream.

Pyrolysing incinerators or retorts operate at temperatures of ~600^{o}C in the pyrolyser, where the two products are carbon and volatiles. The volatiles are sent to an afterburner, where they are burnt with an excess of oxygen at temperatures above 1100^{o}C. The carbon may have some commercial value, e.g. as a fuel, although the material would have to be separated from non-combustibles such as metal and its reuse evaluated in terms of the Minimum Requirements and the emission standards. Pyrolysing incinerator facilities produce residues with very high contents of carbon and would not be able to comply with the Gauteng Minimum Requirement (Ref. 3) concerning a maximum ignition loss of 5% by mass and would have to be permitted using other relevant requirements regarding the quality and use of residues.

6.2.1 Technical Description of Incineration Technology

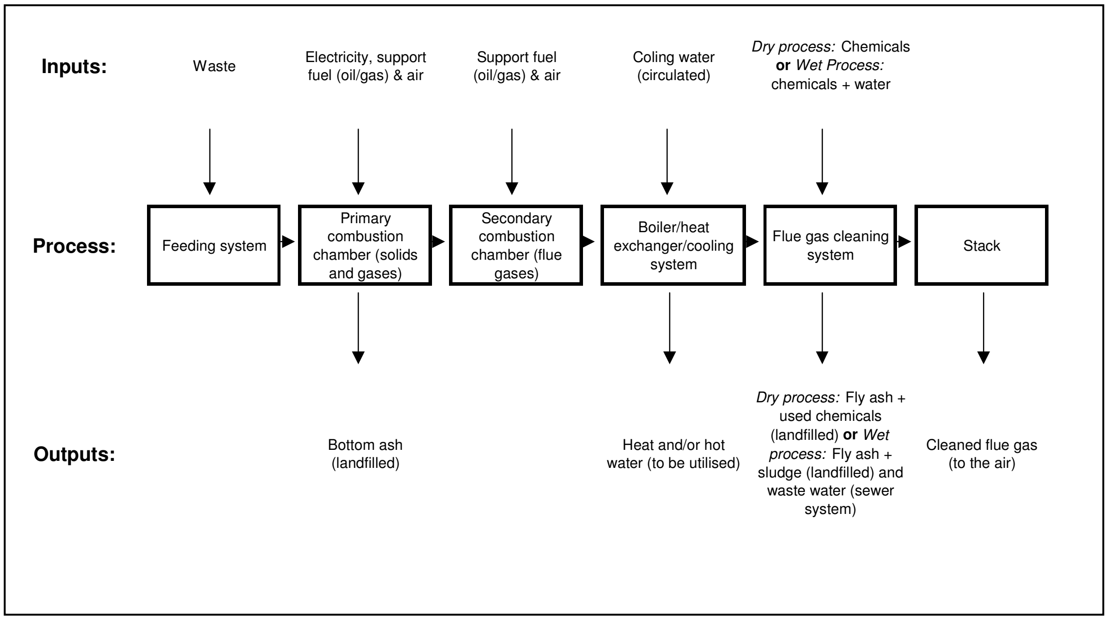
The main elements of modern incineration technology are listed in Table 6.2 and illustrated schematically in Figure 6.3:

Table 6.2: *Elements of a Modern HCRW Incineration Plant*

System	Description/Comment

System	Description/Comment
Feeding System:	An automatic or manual lift and feeding system is used for feeding the waste into the incinerator. Automatic doors or similar devices restrict the input of any excess air during insertion of the waste into the primary chamber.
Primary chamber:	In the primary combustion chamber, the waste is combusted/pyrolysed in a stoichiometric deficit of air at temperatures ranging from 650°C to 1100°C. A support burner, usually fired by fuel oil or gas, is used both during start up and intermittently during operation to achieve and maintain the required temperature. The result is a bottom ash or slag and a gas stream containing combustible volatile organic compounds, particulates and potential pollutants.
Bottom ash collection:	The bottom ash collects in the primary chamber and is manually deashed daily or automatically deashed by conveying it mechanically to a trench or sluice for removal.
Secondary chamber:	In the secondary combustion chamber, an excess of air is added and a secondary support burner fired by fuel oil or gas is used, if required, to maintain the temperature above 1100 °C to give complete burning of the combustible gases and solids from the primary chamber. A minimum retention time of 2 seconds is usually required.
Energy recovery:	In principle, energy can be recovered via a water/steam boiler giving steam or hot water for sterilisation, heating, cleaning of waste containers, personal hygiene etc. The financial feasibility of energy recovery depends mainly on the availability/demand situation for energy produced and cost of conventional energy. Due to the limited availability of energy recovered a full back-up system based on conventional energy sourced would normally be required. With the current low energy prices in South Africa, energy recovery from relatively small HCRW incinerators is only expected to be financially feasible in very particular cases.
Flue Gas Cleaning:	The flue gas is cleaned using either wet, dry or semi-dry flue gas cleaning including a dust filter. Normally wet flue gas cleaning is not economic for the relatively small size of HCRW incinerators. Hence, most plants make use of semi-dry or dry flue gas cleaning. Using flue gas cleaning systems, the strict emission limits for acid gases, particulates, heavy metals and dioxins/furans set by many countries can be achieved. Common filters used are bag house filters or the more temperature tolerant ceramic filters. Typical neutralising agents for acid gases used are lime or bicarbonate products, possibly with activated carbon added for dioxin or heavy metal removal.

Figure 6.3: *Flow Diagram of a Modern Incineration Plant.*



6.2.2 Inputs and Outputs from the Incineration Process

The typical inputs and outputs of materials and energy for the modern incineration process are listed in table 6.4

Table 6.4: *Inputs and Outputs for a Typical Modern Incineration Plant*

Item	**Inputs**	**Outputs**
Energy	❑ Fuel (fuel oil or gas) ❑ Electricity for motors, fans etc.	❑ Recovered energy from the combustion of waste and support fuel to produce water and/or steam
Solids & Liquids	❑ Waste ❑ Chemicals/water for flue gas treatment	❑ Bottom ash to be landfilled ❑ Fly ash/chemicals to be landfilled ❑ If wet scrubber system: Waste water to be lead to the sewer system after cleaning
Gases/air	❑ Air for the combustion process	❑ Cleaned flue gases emitted via the stack
Other	❑ Replacement of air/water filtration materials as required. ❑ Operational and maintenance costs, e.g. PPE and other consumables, spare parts and monitoring/auditing costs.	❑ Used fabric filters to be incinerated or landfilled
Staff	❑ Plant manager, assistants and general workers; numbers depend on the size and type of plant	

Currently, no incinerators used for HCRW in South Africa recover energy in the form of hot water or steam, as this is usually uneconomic. However, increasing fuel costs, higher operational standards and competition from non-burn technologies could see the introduction of energy recovery in the future. Energy recovery, which can require relatively slow cooling of combustion gases, can lead to increased dioxin formation. The ash and other solids and liquid wastes, e.g. from gas cleaning, must be classified, as required by the Department of Water Affairs and Forestry's Minimum Requirements for the Handling, Classification and Disposal of Hazardous Waste, and disposed to an appropriate hazardous or general waste landfill, see Section 6.2.4.

6.2.3 Advantages and Disadvantages of Incineration

The main advantages and disadvantages of incineration as a technology for the treatment of HCRW are listed in table 6.5

Table 6.5: *Advantages and Disadvantages of Incineration*

Advantages of incineration	**Disadvantages of incineration**
❑ Safe elimination of all infectious organisms in the waste at temperatures above ~700^{o}C ❑ Flexible, as it can accept pathological waste and depending on the technology chemical waste, *see text* ❑ Residues are not recognisable ❑ Reduction of the waste by up to 95% by volume or 83 to 95% by mass: typically 5-17% ash is obtained. Depending on the type of flue gas cleaning system additional residues are being generated reducing the volume and weight reduction ❑ Very well proven technology ❑ No pre-shredding required ❑ No special requirements for packaging of waste ❑ Full sterilisation is assumed to have occurred provided the high temperatures are maintained and the ash quantity is adequate. No monitoring of sterilisation efficiency is required.	❑ Normally higher investment costs required for incinerator and flue gas cleaning compared to non-burn technologies, see Section 5.4. ❑ Point source immediate emissions to the air (as opposed to attenuated emission of CH_4 and CO_2 from landfill body over a period of decades) ❑ Production of the highly hazardous dioxins and furans and heavy metals must be minimised and controlled. ❑ High cost of monitoring gas emissions and demonstrating compliance to emission standards. ❑ Solid and liquid by-products must be handled as potentially hazardous waste (may not apply to bottom ash if waste is well sorted and FGC residues handled separately) ❑ Incineration is perceived negatively by many sections of the community. ❑ PVC and heavy metals in the waste provide a significant pollutant load on the gas cleaning system (and for heavy metals on the quality of bottom ash also).

Separation at source is a key requirement for the correct management of HCRW, but incineration with flue gas cleaning is more forgiving than many other technologies, as it can accept pathological waste and, depending on the amount, the type of incinerator and its construction, chemical waste. For many of the pyrolytic dual chamber incinerators currently in use in South Africa, the amounts of chemical, including pharmaceutical waste that can be accepted is low. Thus, like normal household waste, which contains small amounts of hazardous chemical waste, the infectious waste stream must be expected to include small amounts of pharmaceuticals, chemicals used in wards, such as disinfectants, solvents, etc., even when a programme for separation at source has been instituted. An incinerator can readily accept this waste stream. However, most of the current incinerators available in South Africa should not deliberately accept chemical including pharmaceutical waste due to damage to the incinerator and significantly increased requirements for gas cleaning. Rotary kilns, fluidised bed incinerators, plasma arc and other facilities designed and permitted for the acceptance of hazardous chemical waste should be used, see Section 6.3.

6.2.4 Environmental, Health and Safety Impact of Incineration

Incineration has proven to be a very effective way of sterilising health care risk and no special tests to determine the efficacy of the sterilisation process is normally required. However, in the past, most of the HCRW incinerators in South Africa have been poorly operated and almost all have not been fitted with emission control equipment. Incinerators must be registered in terms of Air Pollution Control Act as a schedule 39 Process and must in Gauteng meet the DEAT emission guidelines that include limits for dioxins and furans plus heavy metals: these standards, except for acid gases and particulates generally compare well to those in Europe and the USA. Most of the current South African incinerators are incapable of meeting these DEAT emission guidelines. Gauteng Province has decided (ref. 3) that incinerators meet the DEAT Emission Guidelines as a provincial minimum requirement and this means that gas-cleaning equipment will be needed for incinerators. With modern wet or dry gas cleaning techniques, incinerators have been able to meet the stricter standards imposed in the USA and the European Union. However, the problems associated with the emissions of dioxins and furans by incinerators and the generally poor management of incineration facilities, has resulted in a significant anti-incineration lobby in South Africa.

Apart from gas emissions, incinerators produce an ash, which normally classifies as hazardous, although it can be delisted to general sites, if chemically stabilised with lime or treated by cementation; the volumes of ash generated are small. Gas cleaning can be accomplished by both wet and dry scrubbing. Dry scrubbing is generally preferred, as it is more economic for the typical HCRW incineration plant capacity, and, the resulting solid, which may be classified as hazardous, can be disposed to hazardous waste landfill, whereas the liquid wastes generated by wet scrubbing is charged a premium when disposed to landfill.

Incineration is still a very common technology for HCRW treatment internationally, as it can meet the required strict environmental requirements, provided they are well operated and have good emission control equipment. However, in world regions with no or limited mass incineration of domestic or commercial waste steam sterilisation, microwave treatment and other non-burn technologies are fast becoming the most effective HCRW treatment technology with increasing costs of flue gas cleaning.

6.3 Microbial Inactivation using Sterilisation Technologies

Increasing emission requirements resulting in increasing cost of flue gas cleaning for incineration plants as well as unfavourable perception of incineration in many world regions has lead to the development of a range of sterilisation/disinfection technologies for the treatment of HCRW, Section 6.1. Recently a number of companies have prepared Environmental Impact Assessments for non-burn technologies; specifically Autoclaving, Microwaving and Electro-thermal Deactivation (ETD) and their introduction into the South African market is expected during the year of 2002. Also, there have been proposals concerning the introduction of a Dry Heat Sterilisation (DHS) technology. These four technologies will be discussed in this section, but this does not imply specific endorsement of these technologies nor incineration compared to any others listed above. All these methods sterilise the waste by heating the waste to moderate temperatures, 90^{o}C to 160 ^{o}C, that lead to sterilisation provided all the waste is subjected to the required temperatures for sufficient time. These new technologies have both advantages and disadvantages compared to incineration and these are discussed in Section 6.3.3, below.

Gauteng Province has determined that the minimum level of sterilisation that must be demonstrated by HCRW sterilisation technologies, i.e. inactivation is required to be demonstrated for vegetative bacteria, fungi, lipophilic/hydrophilic viruses, parasites and mycobacteria at ≥6 Log_{10} reduction (99.9999% or 1 survival probability in a million).

Inactivation of B. sterothermophilus spores or B. subtilis spores at ≥ 4 Log_{10} reduction (99.99% or 1 survival in 10000 in a spore population) (ref. 15, 9 and 10).

6.3.1 Brief Technical Description of Microbial Inactivation Technologies

6.3.1.1 Autoclaving/Steam Sterilisation

Steam sterilisation of HCRW has been practised worldwide for some decades firstly as a simple sterilisation process and later by inclusion of reduction/shredding prior to the treatment and compaction after the treatment. In a modern autoclave, the waste is shredded and placed inside an autoclave, where, after evacuation of the air, steam is introduced under pressure from a boiler. Figure 6.6 illustrates the essential features of an autoclave plant for the treatment of HCRW. A combination of temperature, of 130 ^{o}C to 160 ^{o}C, pressure and time for periods of around 30 minutes ensures that the numbers of pathogens are reduced to below permitted levels.

Steam sterilisation has gained in some markets, because compared to incineration, the technology results in no or limited emission of gases, and is increasingly competitive for, especially, the on-site treatment market in countries where advanced flue gas cleaning is required.

Shredding and compaction reduce the volume of the final waste product, and the mass of the residue is about 80 to 90% of the original as some drying occurs.

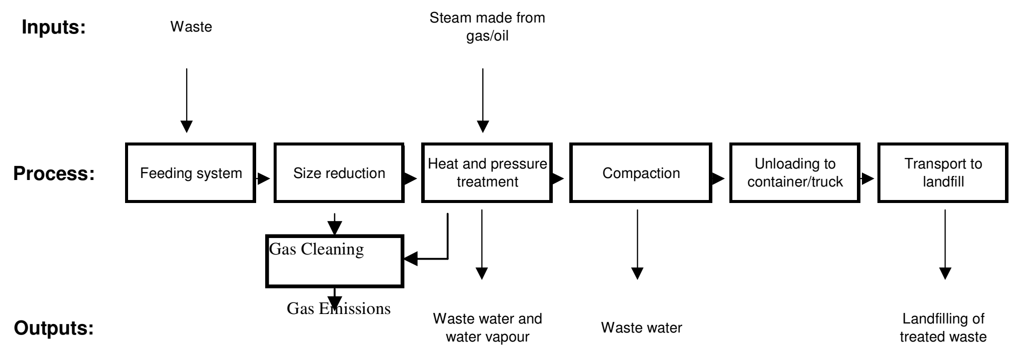


Figure 6.6: *Flow diagram of a Typical Autoclave/Steam Sterilisation Plant*

6.3.1.2 Microwave Technology

In the microwaving process, infectious waste is normally wetted or exposed to high-temperature steam, shredded and the moisture in the waste heated by a series of microwave generators for a specified period. The temperatures reach ~95°C and the microorganisms are killed in the process, resulting in a residue that is confetti-like and slightly moist. Microwaving has been used to treat such items as sharps, microbiological materials, blood, and biological fluids. It is not suitable for the treatment of pathological chemically hazardous, or radioactive wastes and large quantities of metals can reduce the effectiveness of the microwaves' penetration of the waste. Air emissions from the shredder and treatment plant are usually treated to remove moisture and volatile organic carbon compounds. The volume of the final waste product is reduced significantly by shredding and compaction of the final product, but almost no mass reduction occurs.

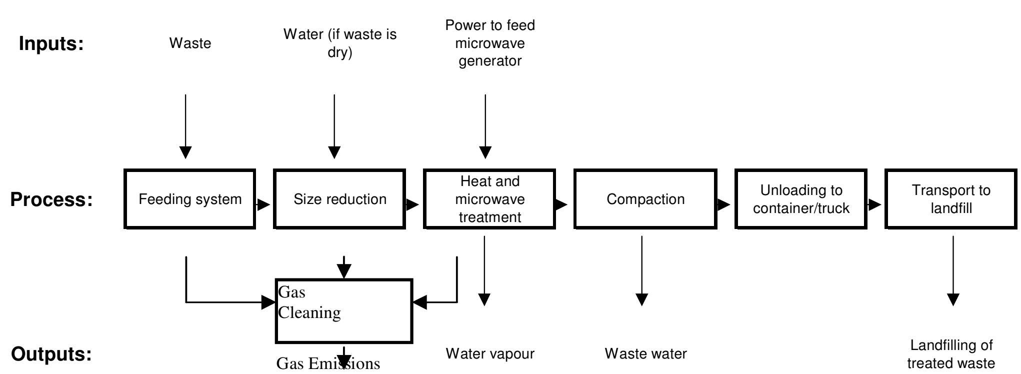


Figure 6.7: *Flow Diagram of a Typical Microwave Plant*

6.3.1.3 Electro-thermal Deactivation

The process involves shredding of waste, loading it into special containers, and heating with low frequency radio waves for a period that is adequate to destroy microorganisms. The temperature used is similar to that of microwaving, ~95°C. The flow diagram would be similar to that given in Figure 6.7 for a microwaving plant except that the waste is exposed to a high-intensity, oscillating electric field generated by low frequency radio waves (14 MHz), rather than microwaves. Heating is caused by absorption of the electrical energy. Air and potential dust and volatile emissions from the reduction plant and treatment unit are passed through cyclones, a dust filter and finally a carbon filter to remove volatile organic compounds. To optimise use of the facility, waste is segregated and some items are processed separately. Composition of the treated waste is identical to the original materials, except that it is shredded and disinfected. Shredding and compacting the final product significantly reduce the volume of the final waste product; the mass is about 80 to 90% of the original, as some drying occurs.

6.3.1.4 Dry Heat Sterilisation

In this technology the infectious waste is shredded and then passes into the processor, which consists of an internally heated screw conveyer, where the waste is sterilised. The flow diagram is similar to that for Microwaving, see Figure 6.3, except the waste treated by passing it through a number of screw conveyors where hot oil is passed through the centre of the screw. The waste temperature reaches about 105 °C and this is maintained for approximately 2 hours; moisture is removed and sterilisation is achieved. The moisture and other volatiles are condensed and the residual gases passed through an air filtration system, which includes passing it through carbon as a final polishing step. The sterilised waste is then compacted before being transport to landfill for disposal. The volume of the waste is significantly reduced to that of the original waste, but there is not a significant mass reduction.

6.3.2 Inputs and Outputs for Sterilisation Processes

The typical inputs and outputs of materials and energy for sterilisation processes are listed in table 6.8: the table does not include any resources utilised or produced other than those from the main plant itself, e.g. water utilised for cleaning containers or washing down the premises is excluded.

Table 6.8: *Inputs and Outputs for a Sterilisation Plants*

Item	Inputs	Outputs
Energy	❑ Electricity for motors, pumps, fans etc. ❑ Electricity for Shredders ❑ Electricity for generating microwaves or the electric field for ETD ❑ Gas, coal or oil for generating steam for Autoclaving ❑ Electricity for heating oil for DHS	
Solids & Liquids	❑ Waste ❑ Carbon or similar filters for polishing of gas emissions	❑ Sterilised waste to be landfilled ❑ Water to sewer for autoclaving and DHS ❑ Used filters to be incinerated or landfilled

Item	Inputs	Outputs
	❑ Water for Microwaving	
Gases/air	❑	❑ Fugitive emissions from waste. ❑ Steam and vapour?
Other	❑ Operational and maintenance costs, e.g. PPE and other consumables, spare parts and monitoring/auditing costs.	
Staff	❑ Plant manager, assistants and general workers; numbers depend on the size and type of plant	

The waste generated by the sterilisation technologies is either dry or in the case of microwaving a slightly damp material that is no longer infectious. However, in line with the Department of Water Affairs and Forestry's Minimum Requirements, the waste must be assumed potentially hazardous until proven otherwise. The USA EPA's Toxicity Characteristic Leaching Procedure must be applied and any leachable inorganic or organic species must be compared to the appropriate standard, i.e. the acceptable risk limit for the species. Treatment to reduce the toxicity may be required, particularly if inadequate separation at source has resulted in hazardous chemical waste being present in the original waste stream. However, the overall principle and the plant's financial viability is based on the assumption that there will be suitable separation of chemicals and heavy metals that will lead to the residue being classified as non-hazardous, i.e. similar to domestic waste, thus, allowing disposal in a normal general waste landfill.

6.3.3 Advantages and Disadvantages of Sterilisation Technologies

The main advantages and disadvantages of autoclaving, microwaving and ETD technologies are in many ways similar and these are listed in the first row of table 6.9: there are some differences, however, and these are highlighted in rows 2 to 4.

Table 6.9: *Advantages and Disadvantages of Autoclave, Microwave and ETD Sterilisation Technologies*

Advantages	Disadvantages
Autoclaving, Microwaving ETD and DHS (Cross cutting) ❑ High sterilisation efficiency under appropriate conditions; ❑ Volume reduction depending on type of shredding/compaction equipment that has been installed ❑ Formation of harmful dioxins and furans very low and often below detection limits. ❑ Low risk of air pollution ❑ Moderate operation costs ❑ Easier to locate as generally more acceptable to communities and neighbours than incineration ❑ Recovery technologies can be used on sterilised waste, e.g. for plastics	❑ Not suitable for pathological waste and chemical waste, including pharmaceuticals and cytotoxic compounds ❑ Good waste segregation required ❑ No or limited mass reduction ❑ Shredders are subject to breakdowns and blocking and repairs are difficult when the waste is infectious. ❑ It is not possible to visually determine that waste has been sterilised ❑ Waste is not rendered unrecognisable or unusable if not shredded either before or after sterilisation ❑ Significant monitoring costs to demonstrate compliance with sterilisation standards ❑ Treated waste must be disposed to landfill

	❑ Air filtration is needed ❑ Operation requires highly qualified technicians.
Autoclaving ❑ Proven system that is familiar to health-care providers ❑ Relatively High Sterilisation Temperature	❑ Significant amounts of volatile organic carbon compounds produced ❑ Contaminated water must be discharged to sewer ❑ Waste and containers must have good steam permeability, especially if there is no prior shredding ❑ No waste reduction
Microwaving ❑ Low capacity units are available for small waste producers e.g. clinics and GPs ❑ Moderate investment costs ❑ Low Sterilisation Temperature may lower energy costs	❑ Unsuitable for very high quantities of infected metal (e.g. needles from inoculation campaigns) ❑ Low sterilisation temperature increases time required for treatment.
Electro-thermal Deactivation ❑ Low Sterilisation Temperature may lower energy costs	❑ Relatively high investment and operating costs ❑ Low sterilisation temperature increases time required for treatment.
Dry Heat Sterilisation ❑ Low investment costs ❑ Relatively low maintenance costs for steriliser ❑ Low Sterilisation Temperature may lower energy costs	❑ Low sterilisation temperature increases time required for treatment.

Autoclave, Microwave, ETD and DHS technologies cannot accept all the HCRW streams. Pathological (anatomical) waste, chemical waste and radioactive waste should be separated as well as possible at source. However, it is estimated that these components only represent 5% of the total HCRW stream and therefore non-burn technologies can treat the bulk of the waste stream.

Currently, there is limited tradition and willingness to send relatively small amounts of source separated chemical waste to the few commercially operated hazardous waste landfills available. Hence, in the Gauteng and South Africa, non-burn technologies are disadvantaged compared to incinerators by their inability to treat the full HCRW stream generated at most district and regional hospitals. Hence, separate containerisation, collection and landfilling of chemical waste is required in case of non-burn technologies being applied: thus necessitating, among others, the provision of additional support tools in form of training and equipment.

Although pathological waste could be treated by these technologies, it is generally considered unacceptable to effectively cook human and possibly animal tissue at temperatures ranging from 95^{o}C to 160^{o}C. In addition, although some solid chemical waste would essentially pass through the sterilisation process unchanged and would only impact on the final disposal requirements of the waste; many chemicals used in hospitals cannot be treated in this way. For example, aerosols would release their contents, including the propellant, which is usually a liquefied petroleum gas or even a CFC in some pharmaceutical products, during shredding or when heated to the sterilisation temperatures used. Volatile solvents such as ether, alcohol and chloroform; disinfectants that contain phenols and/or chlorinated hydrocarbons or preservatives such as formaldehyde are common in hospitals and would volatilise at the temperatures attained during sterilisation. Thus, good separation at source is an essential requirement of these sterilisation technologies. Considering the poor status of HCRW management in many health care facilities in Gauteng, it is unlikely that good separation at source will be generally attained in the short to medium term. Provision must therefore be made to handle waste received at a sterilisation facility that contains some hazardous chemicals and therefore the facility should include using absorption columns to remove potentially volatile emissions that are obtained during shredding or during the sterilising process.

6.3.4 Environmental, Health and Safety Impact of Sterilisation Technologies

The environmental and health impacts of the Autoclaving, Microwaving, and ETD technologies are potentially low compared to incineration, which generates large quantities of gas that is immediately emitted to the air. Clearly, landfilling of sterilised waste will result in biodegradation of the waste, which can result in the generation of methane a gas, which is a greenhouse gas with greater impact than carbon dioxide. Table 6.4 gives a general comparison of the relative impacts of the two types of technology. Note that many of the disadvantages of a particular technology can often be minimised, e.g., application of technology for the cleaning or capture of emissions, utilising the appropriate protective equipment, by training, etc., and these will be included as part of an overall environmental management programme by well operated facilities.

Table 6.10: *Comparison of Principle Environmental Impacts Depending on Choice of Technology*

Step of process	**Impact by incineration technology**	**Impact by sterilisation/inactivation technologies**	**Principle Difference in impacts**
Separation at Source	Except for radioactive waste separation at source is not that critical provided the facility is designed to accept chemical waste	Radioactive, chemical (incl. pharmaceutical), and pathological waste must be separated at source and should not be treated	Chemical waste increases the toxicity of sterilised waste
Generation, Sorting and Collection	Impact during production of disposable and reusable receptacles as well impact from distribution and collection of receptacles	Impact during production of disposable and reusable receptacles as well impact from distribution and collection of receptacles	None, except: Sterilisation technologies may require the use of particular temperature sensitive bags etc.
Storage	Energy consumption for cooling (if required)	Energy consumption for cooling (if required)	None
Transportation for treatment	Emissions from vehicles (fuel consumption)	Emissions from vehicles (fuel consumption)	None
Treatment - shredding	Not normally used	Utilises electricity or hydrocarbon fuels (emissions) Can result in gaseous emissions of VOC's, water vapour, etc Possible health impact when cleaning or maintaining shredders	Energy used and emissions generated by non-burn technologies Difference in potential health impact on staff
Treatment	Conversion of organic matter/carbon to CO_2 and other gases immediately. Use of support fuel, if calorific value low	Delayed conversion of organic matter/carbon to CO_2, methane and other gases Considerable use of energy (electricity)	Difference in duration of degradation process for organic matter and the products of this process. Difference in net energy

Step of process	Impact by incineration technology	Impact by sterilisation/inactivation technologies	Principle Difference in impacts
	Possibility of energy recovery (waste-to-energy)	No possibility for energy recovery Recovery technologies can be used on sterilised waste, e.g. for plastics Some non-burn technologies use electromagnetic radiation which could have a health impact	consumption May be differences in radiation exposure
Transportation of residues to landfill	Mass reduction resulting in reduced need for transportation of residues	Limited mass reduction resulting in higher emissions from vehicles	Larger quantities of emissions caused by transportation of residues from non-burn technologies
Disposal of residues	The volume of residues reduced to 90% and mass reduced to 20% Residue is inert and does not lead to the formation of landfill gas (CH_4, CO_2 etc.) Leachate produced at landfill does not contain any nutrients, but only salts/metals	Volume reduction of 15-70% depending on technology and no or limited mass reduction mass reduction. Residue is degradable and leads to formation of methane (CH4) and/or carbon dioxide depending on quality of landfill operation and use of cover, moisture content etc. Leachate produced at landfill contains both nutrients and salts/metals	Difference in volume and mass of residues Difference in landfilling properties as well as the quality of leachate Difference in the duration and type of gases emitted due to degradation/combustion of carbon/organic matter Non-burn technologies lead to higher negative impact on the greenhouse gas emissions
Gas Cleaning	Significant quantities of gas produced Highly toxic dioxins/furans can be produced under poor operating conditions Solid and/or liquid gas cleaning residues for disposal	Small amounts of water and VOCs can be produced Minor amounts of gas cleaning residues disposed	Differences in gas volume and quality Differences in type and quantities of residues for disposal
Dismantling of installations after end of use and rehabilitation of area	Recycling and disposal of infrastructure Land rehabilitation	Recycling and disposal of infrastructure Land rehabilitation	None

As discussed in Section 6.4.3, small amounts of gaseous emissions must be expected to be released during the sterilisation process and shredding, particularly if the waste has been poorly segregated at source, and appropriate precautions must be taken to remove these. Also, most sterilisation technologies require the waste to be shredded and, if accomplished before the sterilisation process, there are potentially significant health and safety risks for the staff, when a shredder breaks down or becomes blocked, e.g. by a large metal object. The cleaning procedure must be well defined, include the use of appropriate PPE and preferably include disinfection or sterilisation of the waste before manual cleaning and repair is undertaken.

For the microwaving and ETD processes, special precautions are taken to protect personnel against the electromagnetic radiation that is used.

With all three technologies, the main operational requirement is to ensure that all the waste is treated, e.g. the steam used in autoclaving must be able to penetrate into parts of the waste. Compared to incineration, the temperatures used for sterilisation are relatively low, but are sufficient, provided all the waste reaches the desired temperature and sufficient time is allowed for the sterilisation process to take place; this is normally achieved by maintaining the required temperature for two to three times the actual amount of time required.

The sterilisation process does not lead to significant amounts of mass reduction compared to incineration. As indicated in Section 6.4.2, this waste must be evaluated as a potentially hazardous waste and then disposed to an appropriate permitted landfill.

6.4 A Cost Comparison of Selected HCRW Treatment Technologies

Financial estimates of the costs of the various HCRW treatment technologies were based on data obtained from suppliers, and companies that are actually in the process of setting up or are operating such facilities. The data has, however, been adjusted for civil works, environmental protection measures, and should be viewed as indicative costs only. The assumptions used are given in the box below.

Box 6.11: *Assumptions for the Financial Estimates:*

- The cost for the establishment of a new building or renovation of an existing building to house the plant is included in the estimated costs.
- A standard fixed amount for consultancy fees and other expenditure required to obtain an EIA authorisation from the Province plus any other legal requirements such as a Schedule 39 registration certificate for an incinerator was included.
- Salaries were based on normal South African rates.
- The cost of equipment was based on International/South African price levels and was obtained from suppliers, plant operators and international publications. Incinerators include gas-cleaning equipment, i.e. lime treatment plus a ceramic filter. Note that building some or all of a plant in South Africa can considerably reduce costs and the capital estimates for incinerators include this assumption.
- The costs of civil works and installation were based on South African prices
- The following costs are not included:

    i) Infrastructure at the generator's sites,
    ii) Establishment of public utilities used, e.g. landfills
- Depreciation period: the model allows the user to select depreciation periods for wheelie-bins, trucks and treatment facilities. Suggested values are: - wheelie-bins: 3 years; trucks: 5 years; treatment facilities: 12 years. (Although land is generally not depreciated, and buildings and civil works are generally depreciated over 20 years, the Scenario Cost Model depreciates land, civil works and buildings over the **same period** as the treatment plant. This was considered justified here as (i) it leads to conservative {i.e. higher) costs, and (ii) land and buildings constitute a relatively small percentage of total facility costs.)
- The operational hours for the plants were based on operation for 26 days per month and 12 months per year. However, the maximum operational hours were varied as follows:
    i) Incinerators < 200kg/hr: 12 hrs per day with manual de-ashing
    ii) Incinerators ≥ 200kg/hr: 20 hours per day with automatic de-ashing
    iii) Non-burn Technologies: 24 hours per day
- The costs for disposal of residues, such as the ash (lime treated) and gas cleaning waste from incinerators, and sterilised the waste from non-burn technologies, were estimated using current disposal costs.
- For non-burn technologies an estimate of the costs of disposal of pathological waste and chemical waste that could not be treated by the technology was included.

Figure 6.12 give the costs derived for typical microwaving, autoclaving and incineration plants determined according to the criteria given in the box above; typical costing sheets are included in Annexure 4. Estimates of the costs of intermediate size plants were made based on a few discrete points on the curve using the usual cost relation for mechanical plants, i.e.

$$Investment(A) \approx Investment(B) \times \left(\frac{Capacity(A)}{Capacity(B)} \right)^X$$

The value of X in the formula for each technology was determined by fitting the curve to the few discrete points that were available: hence, the estimated costs and the curves derived from these should be regarded as indicative only.

Figure 6.12: Comparative Annual Running Costs for Various HCRW Treatment Technologies (ref. Annexure 4)

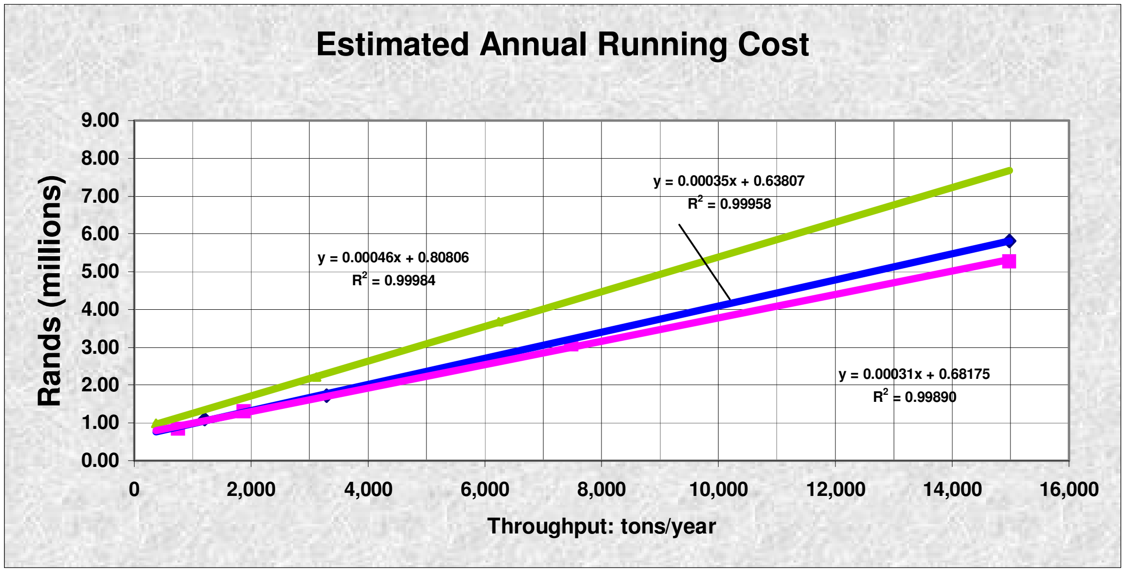
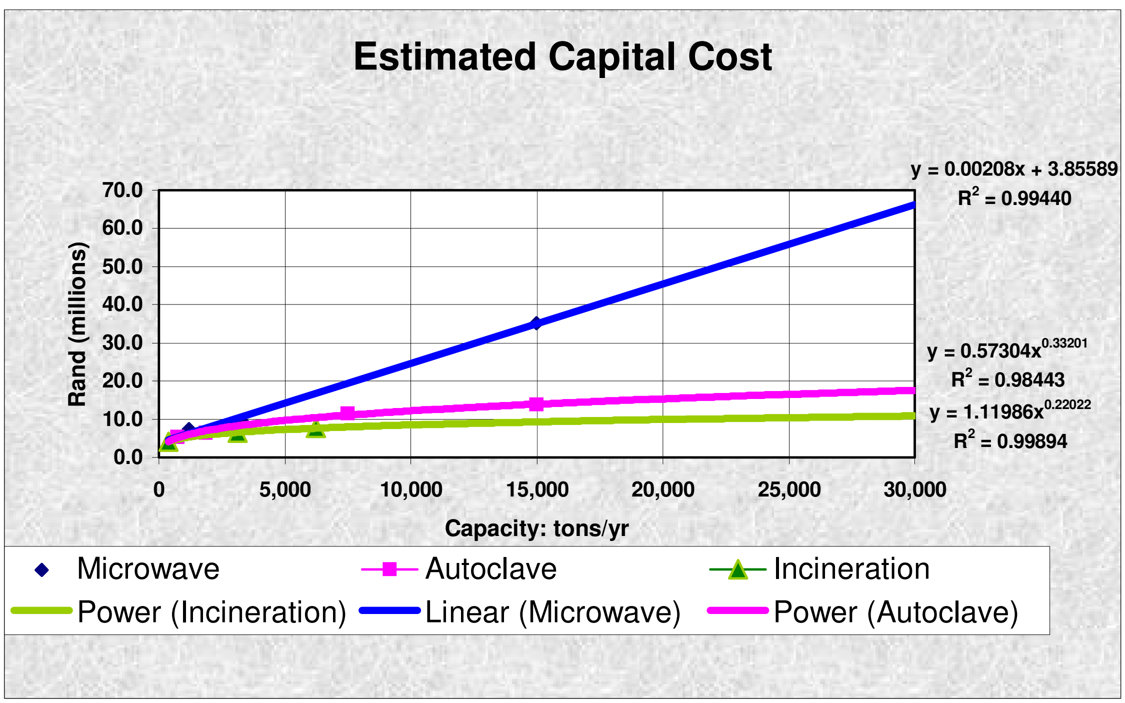


Figure 6.13: Comparative Capital Costs for Various HCRW Treatment Technologies (ref. Annexure 4)

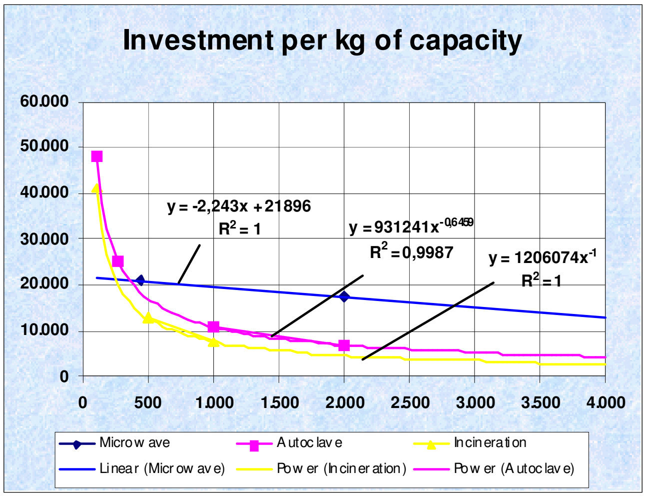


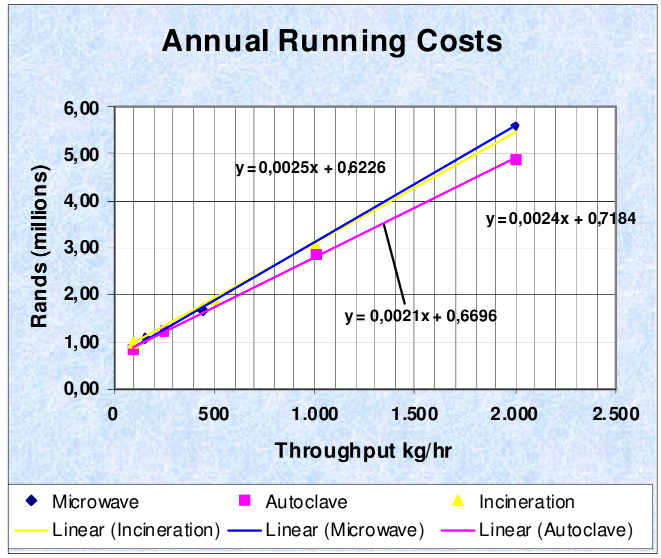
The cost of waste treatment in R/kg versus the capacity of the treatment plant is plotted for incineration, microwaving and autoclaving technologies in the figure above. The data for microwaving and autoclaving technology can be taken as being illustrative of the costs expected for the other non-burn thermal technologies such as the ETD and Dry Heat Sterilisation, as the investment costs and operational costs are expected to be similar for these technologies.

The results indicate the following:

a) As expected, the cost for treating a kg of waste decreases dramatically as the capacity of the plant increases.
b) For incineration, there is a discontinuity that occurs below 200kg/hr due to the assumptions made, i.e. the capital cost for the larger plants is increased because automatic de-ashing is included but this is accompanied by an increase in the maximum operating hours for the larger automated plants from 12hrs per day to 20hrs per day. This increase in operating hours decreases the expected cost per kilogram significantly: for example for the 100kg/hr incinerator, an increase in operating hours from 12hrs to 20hrs per day decreases the treatment cost.
c) The costs in figure 6.12-13 are based on operating the facility at its maximum capacity. Clearly, the treatment facility should be operated as far as possible at full capacity, as this decreases the overall costs of treatment: a central facility handling waste from many sources will clearly be more cost effective than many small plants, particularly in urban areas, where the transport distances are relatively small.
d) According to the available data microwaving is relatively expensive compared to the other two technologies but the costs per kilogram treated become comparable with those of other technologies at higher loads.
e) At low capacities, incineration is more expensive than autoclaving but the costs become comparable as the volumes of waste increase above 200kg/hr: this is largely due to the increased hours of operation for incineration above 200kg/hr.
f) The capital costs for incineration appear to be relatively low compared to the other two technologies. This can, at least in part, be attributed to the fact that the cost of the incinerators are based on them being manufactured in South Africa, whereas capital costs for the other two technologies are based on imported equipment.
g) The costs per kilogram of HCRW are comparable to those currently charged internationally, e.g. in Denmark, where the cost is R2.50/kg at the current exchange rate of R1.32/DKK and those in South Africa, e.g. in Gauteng, where the charges are currently in the range R0.90/kg to R2.73/kg.

Figure 6.14: *Comparison of Investment and Running Cost of Treatment for the various Treatment Technologies and Capacities.*





7 Scenarios for HCRW Management in Gauteng

This chapter includes the formulation of a number of scenarios that will be used to illustrate the present situation and selected alternative solutions, each of them representing integrated health care waste management systems for Gauteng. Each of the scenarios will be evaluated in terms of the technical appropriateness of the systems and in terms of their environmental, financial and legislative implications. This will allow for comparison of the different scenarios, and identification of the most feasible solution.

Scenarios are understood to be possible future health care waste management systems where the individual modules are fulfilling the overall principles of the scenario to form an integrated and holistic system, covering the whole province.

7.1 Methodology for selecting scenarios

The scenarios are created by combining the different options mentioned in the chapters 5 and 6 to form integrated health care waste management systems, as illustrated in the table below. The scenarios are designed according to the following overall aspects:

- Containerisation of the HCRW
- Transport vehicles and distances
- Technology applied for treatment of the HCRW
- Number of the treatment facilities.

In table 7.1 below the selected options for the various modules of the four scenarios are shown.

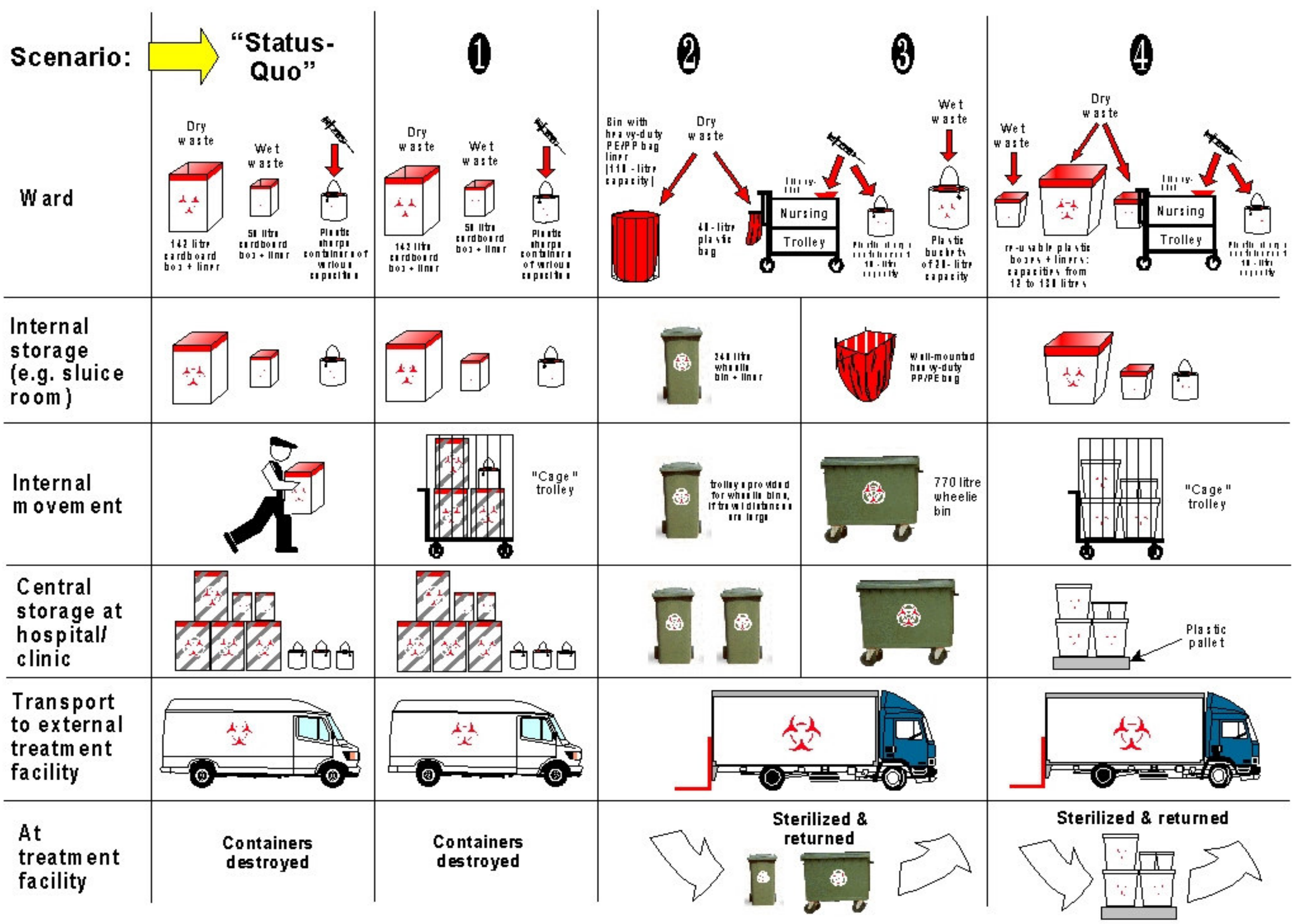
Table 7.1: *Selected options of the Status Quo Scenario and the three alternative scenarios*

Module	Scenarios				
	Status Quo	**1**	**2**	**3**	**4**
Containerisation	Disposable containers	Disposable containers	Heavy-duty plastic bags, buckets and sharps containers	Heavy-duty plastic bags, buckets and sharps containers	Various sizes of reusable plastic containers. Sharps container disposable
Intermediate storage (e.g. sluice room)	In the disposable containers	In the disposable containers	Reusable containers, 240 l wheelie bins or plastic bags	Heavy-duty plastic bags	Various sizes of reusable plastic containers.
Internal transport	Disposable containers carried manually	Disposable containers in cage trolleys	Reusable containers, 240 l wheelie bins	Heavy-duty plastic bags in cage trolleys	Various sizes of reusable plastic containers placed on trolleys.
Central storage at health care facility	In the disposable containers	In the disposable containers	Reusable 240 l wheelie bins	Reusable 770 l wheelie bins	Various sizes of reusable plastic containers.

Module	Scenarios				
	Status Quo	**1**	**2**	**3**	**4**
External transport	By truck	By truck	By truck with a lifting tailgate	By truck with a lifting tailgate	By truck with a lifting tailgate
Treatment technology	Non complying incineration or none	Complying incineration or non-burn technology	Complying incineration or non-burn technology	Complying incineration or non-burn technology	Complying incineration or non-burn technology
Management of containers after treatment	Containers destroyed	Containers destroyed	240 l bins disinfected and returned	770 l bins disinfected and returned	Containers disinfected and returned
Location	Few on-site incinerators and several regional ones	One or more central treatment plants	One or more regional treatment plants	One or more regional treatment plants	One or more regional treatment plants

Figure 7.1 below illustrates the containerisation and transport modes applied in the overall scenarios.

Figure 7.1: *Illustration of the Status Quo and the three alternative scenarios (1,2 & 3).*



For the purpose of calculating the environmental as well as the financial implications of the scenarios the four scenarios are sub-divided into three alternative treatment technologies, which further is divided into four different numbers of plants for covering the whole province. This will altogether generate 53 scenarios which numbering is shown in table 7.2 below.

Table 7.2: *Types of Assessment Carried Out and Numbering of the alternative scenarios and sub-scenarios*

Overall scenario	**Containerisation**	**Treatment**	**Number of Sites (units)**	**Financial Assessment** *Quantitative*	**Environmental Assessment** *Quantitative*	**Safety and Health Assessment** *Qualitative*	**Socio-economic Assessment** *Qualitative*	**Scenario No.**
Status Quo	Disposable cardboard boxes, manual internal transport	Incineration	58 on-site 2 (5) regional	✓	✓	✓	✓	0.1
Scenario 1	Disposable cardboard boxes, mechanical internal transport	Autoclaving	1	✓	✗	✓	✓	1.1.1
			3	✓	✓	✓	✓	1.1.2
			10	✓	✗	✓	✓	1.1.3
			20	✓	✓	✓	✓	1.1.4
		Incineration	1	✓	✗	✓	✓	1.2.1
			3	✓	✓	✓	✓	1.2.2
			10	✓	✗	✓	✓	1.2.3
			20	✓	✓	✓	✓	1.2.4
		Microwave	1	✓	✗	✓	✓	1.3.1
			3	✓	✓	✓	✓	1.3.2
			10	✓	✗	✓	✓	1.3.3
			20	✓	✓	✓	✓	1.3.4
		Mix	Mix	✓	✓	✓	✓	1.3.5
Scenario 2	Heavy-duty plastic bags, buckets and sharps containers, and reusable 240 l wheelie bins	Autoclaving	1	✓	✗	✓	✓	2.1.1
			3	✓	✓	✓	✓	2.1.2
			10	✓	✗	✓	✓	2.1.3
			20	✓	✓	✓	✓	2.1.4
		Incineration	1	✓	✗	✓	✓	2.2.1
			3	✓	✓	✓	✓	2.2.2
			10	✓	✗	✓	✓	2.2.3
			20	✓	✓	✓	✓	2.2.4
		Microwave	1	✓	✗	✓	✓	2.3.1
			3	✓	✓	✓	✓	2.3.2
			10	✓	✗	✓	✓	2.3.3
			20	✓	✓	✓	✓	2.3.4
		Mix	Mix	✓	✓	✓	✓	2.3.5
Scenario 3	Heavy-duty plastic bags, buckets and sharps containers, and reusable 770 l wheelie bins	Autoclaving	1	✓	✗	✓	✓	3.1.1
			3	✓	✓	✓	✓	3.1.2
			10	✓	✗	✓	✓	3.1.3
			20	✓	✓	✓	✓	3.1.4
		Incineration	1	✓	✗	✓	✓	3.2.1
			3	✓	✓	✓	✓	3.2.2
			10	✓	✗	✓	✓	3.2.3
			20	✓	✓	✓	✓	3.2.4
		Microwave	1	✓	✗	✓	✓	3.2.1
			3	✓	✓	✓	✓	3.2.2
			10	✓	✗	✓	✓	3.2.3
			20	✓	✓	✓	✓	3.2.4

Overall scenario	Containerisation	Treatment	Number of Sites (units)	Financial Assessment *Quantitative*	Environmental Assessment *Quantitative*	Safety and Health Assessment *Qualitative*	Socio-economic Assessment *Qualitative*	Scenario No.
		Mix	Mix	✓	✓	✓	✓	3.2.5
Scenario 4	Different sizes of reusable plastic containers	Autoclaving	1	✓	✗	✓	✓	4.1.1
			3	✓	✓	✓	✓	4.1.2
			10	✓	✗	✓	✓	4.1.3
			20	✓	✓	✓	✓	4.1.4
		Incineration	1	✓	✗	✓	✓	4.2.1
			3	✓	✓	✓	✓	4.2.2
			10	✓	✗	✓	✓	4.2.3
			20	✓	✓	✓	✓	4.2.4
		Microwave	1	✓	✗	✓	✓	4.2.1
			3	✓	✓	✓	✓	4.2.2
			10	✓	✗	✓	✓	4.2.3
			20	✓	✓	✓	✓	4.2.4
		Mix	Mix	✓	✓	✓	✓	4.2.5

The financial and the environmental impacts of the different scenarios have been quantified in detail using relatively elaborate modelling. However, as indicated in Table 7.2 above whereas the financial impacts have been determined in detail for all 53 scenarios the environmental impacts has only been determined for the key principle scenarios and the safety and socio-economic impacts have been determined in qualitative terms only.

7.2 General assumptions for the scenarios

It is a precondition that all the alternative scenarios, based on Scenario 1, 2, 3 and 4, comply with the Sustainable Health Care Waste Management Policy (ref. 3).

Furthermore, all the scenarios are based on the assumption that the present amount of HCRW generated will be treated, divided into dry infectious waste, wet infectious waste and sharps as shown in table 4.1 in chapter 4.

Below the various scenarios are described in further details.

7.3 Detailed description of the scenarios

7.3.1 Status Quo Scenario

This scenario represents the present situation. The most commonly applied containers and procedures for transport etc. are applied as described below.

Table 7.4: *Brief description of the Status Quo Scenario*

Status Quo Scenario	**Selected options for the different modules**
Containerisation	Containerisation is as per the Status-quo Scenario, viz.: • "Dry" waste: 142 L cardboard boxes + 50 micron plastic bag liner + cardboard lid

Status Quo Scenario	Selected options for the different modules
	• "Wet" waste: 50 L cardboard boxes or plastic buckets + lids (various capacities, e.g. 10 L, 20 L, 25 L) • Sharps: Plastic sharps containers of various capacities e.g. 2.5 L, 5 L, 7.5 L, 10 L, 20 L.
Intermediate storage	The waste is stored in same containers as enumerated above for intermediate storage, and in most cases the sluice rooms are used for this purpose.
Internal transport	During internal transport the waste containers are carried by hand, or transported on trolleys of various types.
Central storage	All the waste is brought to a central storage room, either for further transport to an external treatment facility or for treatment at the health care facility itself.
External transport	Where HCRW is moved to an external treatment facility it is transported by means of a trucks with a closed loading bays. Volumetric capacity of the truck is approximately 29 m^3, able to convey approximately 180 x 142 L cardboard boxes per load.
Treatment	HCRW is either treated (a) by means of on-site incinerators or (b) transported to off-site incinerators by contractors, or (c) a combination of (a) and (b). In all cases the ashes and flue gas cleaning residues will be disposed at a class H:h or H:H landfill.

7.3.2 Scenario 1: Disposable containers

This scenario is based on the following overall principles:

- The existing containerisation principle is applied, implying disposable containers
- Manual handling is minimised e.g. introducing cage trolleys for internal transport
- All HCRW is treated, and non-burn treatment technology is applied as an alternative to the existing.

Table 7.5: *Brief description of Scenario 1*

Scenario 1	Selected options for the different modules
Containerisation	Containerisation is as per the Status-quo Scenario, viz.: • "Dry" waste: 142 L cardboard boxes + 50 micron plastic bag liner + cardboard lid • "Wet" waste: 50 L cardboard boxes or plastic buckets + lids (various capacities, e.g. 10 L, 20 L, 25 L) • Sharps: Plastic sharps containers of various capacities e.g. 2.5 L, 5 L, 7.5 L, 10 L, 20 L.
Intermediate storage	Waste stored in same containers as enumerated above for intermediate storage, and in most cases it will be most appropriate to store the waste in the sluice room.
Internal transport	For internal transport the containers are loaded into "cage trolleys", having dimensions of approximately 140 cm long x 70 cm wide x 160 cm high (and therefore able to accommodate six 142 L cardboard

Scenario 1	Selected options for the different modules
	boxes).
Central storage	All the waste is brought to a central storage room, either for further transport to an external treatment facility or for treatment at the health care facility itself.
External transport	Where HCRW is moved to an external treatment facility it is transported by means of a truck with a closed loading bays. Volumetric capacity of the truck is approximately 29 m^3, able to convey approximately 180 x 142 L cardboard boxes per load.
Treatment	In this scenario – as in the other future scenarios – it is anticipated that the HCRW can be treated either by incineration, autoclaving or microwave sterilisation. Wheelie bins are disinfected at treatment facility and returned to generators. In all cases the ashes and flue gas cleaning residues will be disposed at a class H:h or H:H landfill and the residues from non-burn technologies will be disposed in a sanitary landfill for domestic waste, class GB+, (cf. DWAF Minimum Requirements).
Location of Treatment Facilities	In the scenario the following siting options are considered: • "On-site": Treatment takes place at 20 largest hospitals (those generating more than 12 tons/month of HCRW itself). HCRW from other (i.e. smaller) generators taken to closest "on-site" facility for treatment. • "Regionalised": Treatment takes place at between one and 10 facilities, located in accordance with the HCRW generation. HCRW from other generators taken to closest "regional" facility for treatment.

7.3.3 Scenario 2: Reusable containers, 240 l wheelie bins

This scenario is based on the following overall principles:

- Dry waste is initially containerised in plastic bags; wet waste in plastic buckets; sharps in plastic sharps containers
- The waste is transported and stored in reusable wheelie bins
- All HCRW is treated, and where appropriate non-burn treatment technology is applied as an alternative to incineration.

Table 7.6: *Brief description of Scenario 2*

Scenario 2	Selected options for the different modules
Containerisation	Containerisation is as follows: • "Dry" waste is placed in (a) 50 L plastic bags hanging from suitable bracket on nursing-trolleys or (b) 85 L plastic bags in suitable stands on floor. • "Wet" waste is placed in 20 L plastic buckets with lids. • Sharps are placed in plastic sharps containers of various capacities, e.g. 2.5 L, 5 L, 7.5 L, 10 L, 20 L.
Intermediate storage	Waste stored in 240 L wheelie bins in sluice room or wall mounted heavy-duty plastic PE/PP bags.
Internal transport	For internal transport the wheelie bins are used, or if long distances are

Scenario 2	Selected options for the different modules
	involved small trailers carrying approximately four wheelie bins.
Central storage	All the waste is brought – in the wheelie bins - to a central storage room, either for further transport to an external treatment facility or for treatment at the health care facility itself.
External transport	Where HCRW is moved to an external treatment facility the wheelie bins are transported by means of trucks with a closed loading bays and lifting tailgates. Volumetric capacity of approximately 32 m^3, able to convey approximately 40 x 240 L wheelie bins per load.
Treatment	In this scenario – as in the other alternative scenarios – it is anticipated that the waste can be treated either by incineration, autoclaving or microwave sterilisation. Wheelie bins are disinfected at treatment facilities and returned to generators. In all cases the ashes and flue gas cleaning residues will be disposed at a class H:h or H:H landfill and the residues from non-burn technologies will be disposed in a sanitary landfill for domestic waste, class GB+, (cf. DWAF Minimum Requirements).
Location of Treatment Facilities	In the scenario the following siting options are taken into consideration: • "On-site": Treatment takes place at 20 largest hospitals (those generating more than 12 tons/month of HCRW itself). HCRW from other (i.e. smaller) generators taken to closest "on-site" facility for treatment. • "Regionalised": Treatment takes place at between one and 10 facilities, located in accordance with HCRW generation. HCRW from other generators taken to closest "regional" facility for treatment.

7.3.4 Scenario 3: Reusable containers, 770 l wheelie bins

This scenario is based on the following overall principles:

- The waste is initially containerised like in Scenario 2
- The internal transport is taking place with cage trolleys, while the external transport takes place with wheelie bins
- All HCRW is treated, and where appropriate non-burn treatment technology is applied as an alternative to incineration.

Table 7.7: *Brief description of Scenario 3*

Scenario 3	Selected options for the different modules
Containerisation	Containerisation is the same as in Scenario 2.
Intermediate storage	The "Dry" waste, packed in plastic bags is stored in wall- or floor-mounted 85 L heavy-duty PP/PPE bags. "Wet" waste + sharps are kept in the containers as enumerated above.
Internal transport	For internal transport the bags and the other containers are loaded into "cage trolleys", having dimensions of approximately 140 cm long x 70 cm wide x 160 cm high (770 l wheelie bins).
Central storage	All the waste is stored in wheelie bins having a capacity of 770 L.

Scenario 3	**Selected options for the different modules**
External transport	Where HCRW is moved to an external treatment facility the wheelie bins are transported by means of trucks with a closed loading bays and lifting tailgates. The volumetric capacity of the trucks is approximately 32 m^3, being able to convey approximately 15 x 770 L wheelie bins per load.
Treatment	In this scenario – as in the other future scenarios – it is anticipated that the HCRW can be treated either by incineration, autoclaving or microwave sterilisation. Wheelie bins are disinfected at treatment facilities and returned to generators. In all instances the ashes and flue gas cleaning residues will be disposed at a class H:h or H:H landfill and the residues from non-burn technologies will be disposed in a sanitary landfill for domestic waste, class GB+, (cf. DWAF Minimum Requirements).
Location of Treatment Facilities	In the scenario the following siting options are taken into consideration: • "On-site": Treatment takes place at 20 largest hospitals (those generating more than 12 tonnes/month of HCRW itself). HCRW from other (i.e. smaller) generators taken to closest "on-site" facility for treatment. • "Regionalised": Treatment takes place at between one and 10 facilities, located in accordance with the HCRW generation. HCRW from other generators taken to closest "regional" facility for treatment.

7.3.5 Scenario 4: Reusable stackable containers

This scenario is based on the following overall principles:

- The waste is immediately containerised in the final container that will be closed safely thus making the further handling as safe as possible.
- The internal transport is taking place with cage trolleys or similar onto which the stackable reusable plastic boxes are stacked
- All HCRW is treated, and where appropriate non-burn treatment technology is applied as an alternative to incineration.

Table 7.8: *Brief description of Scenario 4*

Scenario 3	**Selected options for the different modules**
Containerisation	The waste is at source paced in its final container. There are three sizes of reusable plastic boxes: i) approx. 130 litre, ii) approx. 60 litre and iii) approx. 20 litre. Disposable sharps containers are used for sharps.
Intermediate storage	Filled reusable containers are closed safely and placed in the intermediate storage (Sluice room).
Internal transport	For internal transport the containers are loaded into "cage trolleys", having dimensions of approximately 140 cm long x 70 cm wide x 160 cm high
Central storage	The reusable boxes are placed on pallets for loading into the collection truck and further handling at the treatment plant.
External transport	Where HCRW is moved to an external treatment facility the wheelie bins

Scenario 3	**Selected options for the different modules**
	are transported by means of trucks with a closed loading bays and lifting tailgates.
Treatment	In this scenario – as in the other future scenarios – it is anticipated that the HCRW can be treated either by incineration, autoclaving or microwave sterilisation. Wheelie bins are disinfected at treatment facilities and returned to generators. In all instances the ashes and flue gas cleaning residues will be disposed at a class H:h or H:H landfill and the residues from non-burn technologies will be disposed in a sanitary landfill for domestic waste, class GB+, (cf. DWAF Minimum Requirements).
Location of Treatment Facilities	In the scenario the following siting options are taken into consideration: • "On-site": Treatment takes place at 20 largest hospitals (those generating more than 12 tonnes/month of HCRW itself). HCRW from other (i.e. smaller) generators taken to closest "on-site" facility for treatment. • "Regionalised": Treatment takes place at between one and 10 facilities, located in accordance with the HCRW generation. HCRW from other generators taken to closest "regional" facility for treatment.

8 Site requirements

8.1 Observed Siting Issues for Existing Incinerators Located in Gauteng

Currently a number of on-site incinerators are not being operated due to various complaints from both nearby residences and hospital staff.

In all cases the complaints are due to visible black smoke as well as occasional fall down of soot and particles, at times even recognisable pieces of waste. These problems are related to the old designs, as well as the poor maintenance and limited operator skills at the small incinerators installed at many hospitals in Gauteng.

There have been occasional complaints regarding the current three sites where there are commercially operated incinerators in Gauteng, as these plants occasionally emit visual pollutants to the atmosphere.

However, the many past and current incidents and complaints caused by the sub-standard incinerators has lead to a very negative public opinion of incinerators, and it is assumed that this legacy results in a popular association of the words "incinerators" with "black smoke" and "pollution" and is assumed to be the primary reason for much public concern in case of any location of future incinerators, disregarding the actual environmental performance that can be achieved by today's incineration and flue gas cleaning technology.

A number of non-burn treatment technologies for HCRW have emerged over the past one or two decades, as a consequence of increasing costs of incinerators, due to increasing environmental requirements. These non-burn technologies are in general more acceptable to the public, as there is no significant emissions to the atmosphere occurring on site.

One of the main principles of the Gauteng HCW Management Policy consulted and endorsed November 2001 is that environmental requirements for any HCRW treatment plants shall be sufficiently strict to, practically, allow location of such plants at any suitably accessible site, where unacceptable neighbourhood nuisances will not occur. Hence, emission to the atmosphere shall comply with the strict DEAT emission guidelines that in practice will result in performance similar to current EU requirements, and thus, pose fewer constraints in terms of possible location of future incinerators for HCRW or non-burn treatment plants for HCRW.

8.2 Overall Siting Considerations of Importance

The Policy does not accept the principle of polluting already compromised land or where no one will notice due to distance to dwellings or similar. Hence, for the table below it is therefore assumed that the Gauteng Policy will be adhered to.

Table 8.1 below summarises the main issues of relevance for locating treatment plants for HCRW.

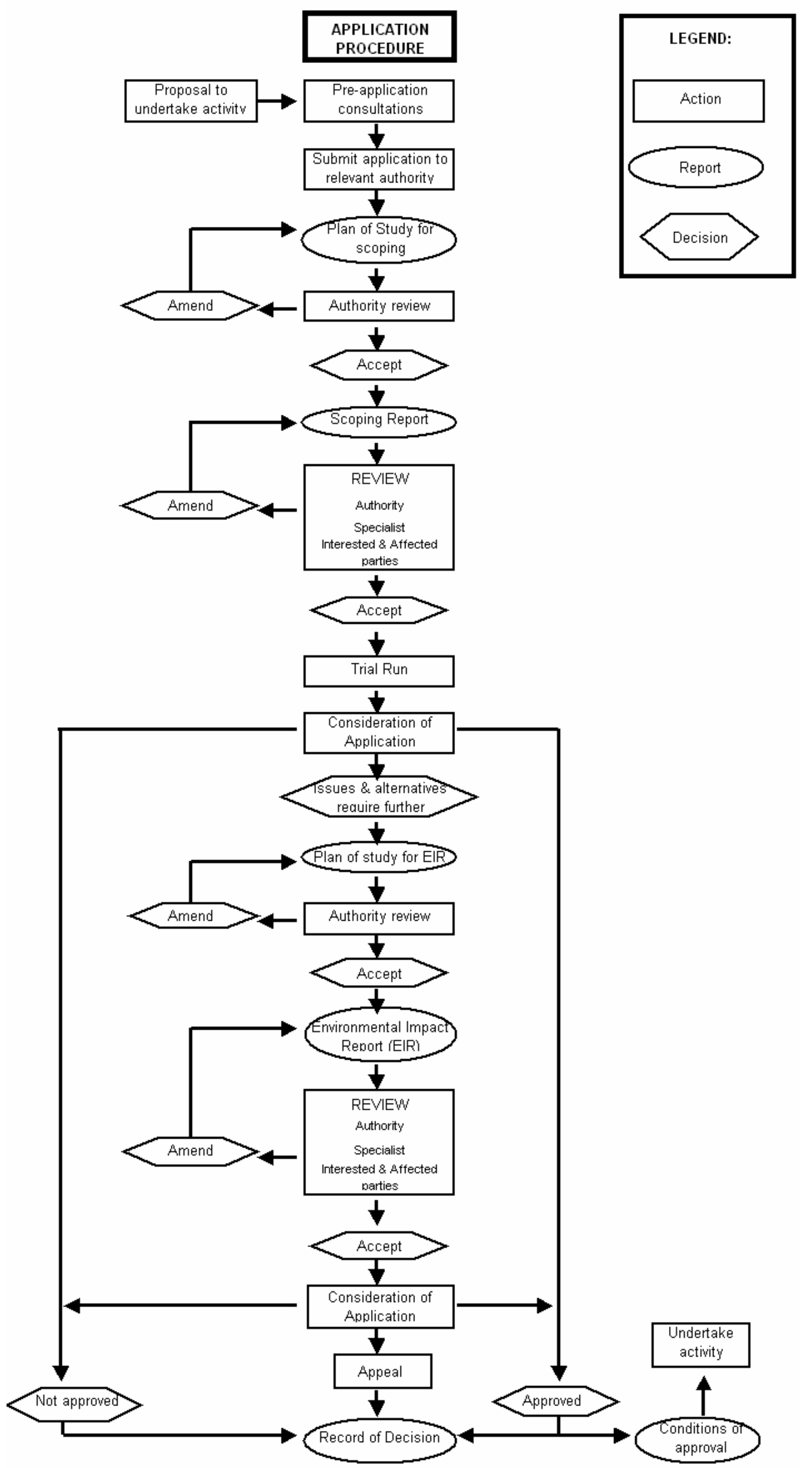
Table 8.1: *Main Issues of Relevance for Locating HCRW Treatment Plants*

Siting Issues	Incinerators	Non-burn treatment plants
NEMA		
Environmental justice	Very relevant	Very relevant
The vicinity:		
Distance to residences	Very relevant	Relevant
Existing ambient air challenges	Very relevant	Not relevant
Location in sensitive habitats/cultural areas	Not allowed	Not allowed
Location near sensitive habitats/cultural areas	Not desirable	Possible, but not desirable
Located near wetlands	Possible	Possible
Located near Permitted Disposal Facilities	Relevant	Very Relevant
Topography of the neighbouring terrain	Relevant (dispersion from stacks is highly influenced by the topography, especially location next to steep hills, in valleys etc. can be problematic)	Not relevant
Power and Energy Infrastructure		
Access to main power grid	Relevant	Relevant
Access to natural gas/piped gas infrastructure	Desirable	Can be relevant for some technologies
Nearby industrial consumers of steam, hot water or power	Relevant, to facilitate economic energy recovery from incinerators utilising the calorific value of waste and support fuel	Not relevant
Road Infrastructure:		
Availability of good road access	Very relevant	Very relevant
Traffic Loading:		
Loading due to transport to the plant	Relevant	Relevant
Traffic loading due to removal of residues	Not relevant	Relevant
Noise/Odour:		
Times of Transport	Relevant	Relevant
Time of plant operation	Not relevant (if properly engineered)	Not relevant (if properly engineered)
Odour problems for neighbours	Not relevant (if properly engineered)	Not relevant (if properly engineered)
Ambient Air Quality:		
Location in areas with poor ambient air quality	Not desirable, as the marginal increase may be unacceptable	Allowed
Visual impact:		
Location on prominent and highly visual locations	Not desirable	Not desirable

With the assumption that the environmental requirements of the Gauteng Policy will be adhered to, HCRW treatment plants can be located practically everywhere, where there is a suitable plot of land with good public infrastructure and where there will be limited neighbourhood nuisances in the form of, e.g., traffic loading, and where there are no sensitive habitats or culturally significant sites.

8.3 Requirements in terms of the EIA Regulations

Figure 8.2: *Permitting Activities according to the EIA Regulations (ref. Internal DACEL HCRW Treatment Manual)*



8.4 Conclusions on Siting Issues

As demonstrated above it is evident that due to the nature and environmental performance of plants complying to the Policy requirements the actual sites of any new plants would not have an impact on the general feasibility of any particular HCRW management scenario. However, it is clear that many of the existing incinerators, in particular the many on-site incinerators, are causing unacceptable impacts to the vicinity.

9 Ownership and Service Provision Options

This section briefly discusses the ownership and contractual options that may be relevant for the provincial government in planning the health care waste management system for Gauteng. Legal options and issues are discussed separately in chapter 10.

9.1 Current Service Provision Situation in Gauteng

It is important to see any proposed future service provision options in the light of the current HCRW service industry and service provision systems.

Table 9.1 below shows that on-site (mainly government owned)) and regionalised (privately owned) service provision co-exists at the moment, and that even though the regional facilities are unlikely to meet the new required environmental standards, the majority of the on-site treatment infrastructure is dilapidated and poorly performing. Given the draft Gauteng HCW Management Policy (ref 3) it is evident that the existing on-site incineration plants will have to be decommissioned and it is likely that this may also apply to most of the existing regionalised incinerators in Gauteng. However, it is evident that individual private sector companies are eagerly positioning themselves in the market and that a host of new treatment infrastructure is being planned.

The current private sector activities demonstrate that there is a significant commitment to invest in new and environmentally sound treatment plants and that the available treatment capacity in Gauteng may in this way develop from a situation with insufficient treatment capacity, to a significant over-capacity compared to the actual HCRW generation rate in Gauteng.

The current development of new non-burn treatment technologies around the world may also lead to a situation where larger health care facilities may invest in their own on-site treatment facilities, as some of the new technologies may also be more cost-effective at smaller capacities.

The current service provision situation in Gauteng for HCRW services appears to be as follows:

Table 9.1: *Current Estimated Service Provision Situation in Gauteng (September 2002)*

				Number	Amounts (T/months)
Waste Generators	In-adequate solutions	Large with no service	A few medium to large public and private institutions have no dedicated HCRW Management service	est. 1-5	5¤
		Small with no service	Many small health care practitioners institutions have no or inadequate disposal systems for HCRW	est. 500-5000	80¤
			Sub-total		85
	On site solutions	Self-sufficient institutions	A few public and private institutions maintain on-site incinerators and in-house management of HCRW	est.15-30?	15¤
	Combined solutions	Both own system and service contractors	A number of public and private health care institutions have functional on-site incinerators that treat part of the waste stream (e.g. placentas, pathological, sensitive documents etc,) only. Remainder off-site treatment	est. 15-30?	20¤
	Off site solutions	Large using contractors	The majority of medium to large public and private health care institutions have no on-site treatment plant or do not operate such plants any more, but are serviced by private service providers.	est. 450-550	1037¤
		Small being serviced indirectly	The majority of small health care institutions have no direct contracts with service companies but are serviced via laboratory services or similar	est. 1000-3000	15¤
		Sub-total		10600	**1172 T/m**
Service Providers, incl. on-site incinerator capacity	HCRW Collection Contractors	Companies currently providing HCRW collection services to generators (Q1, 2002)	**Name**	**No. Trucks**	**Collection**
			Buhle	6	257 T/m
			Phambili	4	> 130 (200) T/m♣
			SanuMed	8	210 T/mσ
			Pikitup	3	20 T/m
			ClinX	4	20 T/m
			Aids Safe	0	n.a.
			Waste Group	1	n.a.
			Evertrade	?	?
		Sub-total		26 + ?	**637 - ? T/m**
	HCRW Treatment Companies	Companies currently operating treatment plants commercially	**Name**	**No. Plants**	**Capacity**
			Evertrade (*) (EDT)	1	1500 T/m#
			Pikitup (Jhb Metro)❄ (Inc.)	1	80 T/m¤
			SanuMed, Roodepoort❄ (Inc.)	2(3)	295 T/m¤
			SanuMed, Rietfontein ❄ (Inc.)	2	165 T/m¤
		Sub-total		6 (7)	**2040 T/m**
	On-site incinerators	Various operational on-site incinerators for HCRW, of which many are not operated (nominal capacity)		58	**280 T/m**
	Proposed new treatment facilities (2002)	Proposed treatment plants (assuming that conditions are met and that plants comply with requirements)	Microwaste (*?) (Microwave)	1	250 T/m#
			ClinX (*?) (Inc.)	1	75 T/m#
			Clinical Waste Management (*?) (Inc.)	2 (Batch)	210-400 T/m 1 or 2 shift of 12h
			Aid Safe (*?) (Inc.)	1	220 T/m
		Sub-total		5	**755-9454 T/m**

Notes: Information gathered via various personal communications with industry and rough estimations. ¤: Estimated based on Status Quo and current conditions. #: Reported by proponents. σ: Assuming full capacity and estimated 250 quota used by other collectors. ♣: At least 50% of estimated 250 T/m quota at SanuMed. *: Registration Certificate issued based on Gauteng HCWM Policy November 2001. *?: Claimed by proponent to comply to Gauteng HCWM Policy November 2001 but no Record of Decision issued yet. ❄: Registration certificate issued before Policy was in put force, assumed *not* to comply to Gauteng HCWM Policy November 2001.

As the table 9.1 above illustrates there is currently insufficient treatment capacity in Gauteng as the combined nominal capacity of the commercial and the on-site incinerators totals 2320 tonnes/month, whereas there is an estimated generation of approximately 1200 tonnes/month and a collection of perhaps 800 tonnes/month.

Assuming that the numbers are representative of the actual situation, approximately 30% of the waste generation is currently being disposed of in the domestic waste stream at ordinary landfills or treated at plants located outside Gauteng.

In the first quarter of 2002, it is known that, amongst others, for financial reasons considerable amounts of HCRW was transported to treatment facilities in the neighbouring provinces, in particular, the North West Province. Assuming that the existing commercial incinerators can remain in service, the expected commissioning of new treatment plants will result in the HCRW treatment capacity in Gauteng exceeding the generated amount by a factor of two. Hence, the flow of waste is likely to turn toward a net import of HCRW from other provinces or alternatively result in under utilisation of the installed capacity.

It is assumed that most, if not all, of the existing incinerators will have to be up-graded to meet the environmental standards laid down in the Policy, if feasible, or alternatively decommissioned in accordance with the deadlines of the Gauteng HCW Management Policy that was adopted by the Provincial Government during November 2001.

In any event, it appears that sufficient treatment capacity may be in place some time during 2002 to deal with the actual HCRW generation in Gauteng, plus ample excess capacity to serve as backup, assuming that only modest quantities of HCRW will be brought into Gauteng from other provinces. It is also evident that there will be several commercial service providers in place to allow for reasonable competition on price and quality of service that could meet the needs of private and public HCRW generators.

9.2 Political Priorities in Gauteng and South Africa

There are some overall political priorities expressed by the Government of South Africa as well as the Provincial Government of Gauteng that impacts on the relevance of potential ownership and service delivery options.

It has consistently been national and provincial government policy to outsource (privatise) specialised services to the private sector, building the private sector service industry, among others with a view to allowing emerging businesses access to the market. The reasoning behind this outsourcing may comprise one or several of the following ways of thinking:

- Political decision to reduce the public sector's involvement in technical services;
- Political decision to let market forces provide cost-effective services to the public under competition and public guidance and control;
- Political decision to support the emerging businesses and providing access to the market for previously disadvantaged individuals;
- Political decision that health care institutions shall specialise on core business of health care only;
- Increasing environmental demands for HCRW treatment facilities require increasing capital investments that government is unable to prioritise over other capital demanding investments;

- Government may have difficulty in competing with the private sector for the required specialised professionals required for establishing, managing and operating advanced management and treatment systems for HCRW;
- Political desire to avoid bias in government's monitoring and enforcement of HCW treatment plants due to ownership, thus, defining government's role as referee only.

This Feasibility Study takes cognisance of the national and provincial policies and views the draft Gauteng HCW Management Policy (Ref. 3) to be in line with such overall national and provincial priorities.

9.3 Financial/Contractual Options for HCW Management Infrastructure

There are in principle the following financial options for ensuring sufficient and permitted HCRW treatment infrastructure in Gauteng:

Publicly financed HCW treatment infrastructure by
  - Drawing on cash balance
  - Public credit taking backed by public guarantees
  - Financing against issuing of (provincial) bonds
  - Establishment of Inter-Municipal Service Company, financed by deposits made by participating municipalities, e.g., based on populations, tax base, etc. for example in the form of a so-called Section 21-Company
- Privately financed
  - Infrastructure financed directly by preferred company method based on business plan assessment
  - Infrastructure financed by preferred company method based on public minimum turnover guarantee for a set period
  - Various versions of BOT/BOOT schemes resulting in eventual transfer of assets to the public
- Donor funded
  - Donations for all or part of the investments
  - Donor facilitated soft loans based on adequate government guarantees.

The return on any of the investments above can be by one or a combination of any of the following principle methods:

- *Market driven customer relations* based on customers (HCRW generators and/or transporters) making individual treatment agreements with particular treatment plants deemed suitable for, among others, financial, logistical and performance reasons.
- *Publicly managed concession system* requiring generators in certain areas to make use of particular concessioned plants for particular areas, thus ensuring reliable income. (Section 21 Company)
- Arrange *co-operative ownership* of treatment plants, thus motivating the group of owners to make use of the investments and, thus, ensuring reliable income.

- *Publicly managed payment schemes* such as levying the cost of HCRW treatment via an ad-on to billing for essential public supplies/services such as water, electricity, property tax, permit renewal fees or similar

General financial risks can be numerous but the most important risks may include:

- Currency exchange risk including changes to FOREX regulations in case of foreign investors or need for substantial imports for operation and maintenance;
- Political risk in particular in case of long-term contracts during which political priorities may change, thus, affecting repayment of credit;
- Interest rate changes affecting the viability of investment;
- Labour disputes;
- Significant change in operating costs (labour, fuel, power, disposal costs for residues, etc.)
- In case of the public, there may be a financial risk regarding clean-up of stored or inadequately disposed waste or seepage in case of the liable party being insolvent.

There are in principle the following contractual options:

Service contracts of short-term duration (2-5 years)

  - o Direct service provision agreements that includes the whole service of containerising, transporting and treatment/disposal
  - o Separate contracts for: i) supply of waste handling equipment/containers, ii) collection and transport of containerised HCRW, and iii) treatment and disposal of residue
  - o Operation and Maintenance contracts for publicly owned infrastructure

- Service contracts of long-term duration (8-15 years), including infrastructure provision
  - o Contracting of all collection and treatment services to a Privately owned and operated Utility having the license to carry out these services for all generators in a particular area.
  - o BOT/BOOT contracts similar to the Utility Model
  - o Turnkey contracts (supply and operate public owned equipment).

In conformity with various national government policies towards the development of the South African private service sector and in agreement with the draft Gauteng HCW Management Policy it appears that private sector is preferred as owners and operators of collection, transport and treatment infrastructure, with the authorities fulfilling the regulatory functions. However, within those frames there is much scope for discussing the advantages of:

- Short versus long service contract periods
- Concessions to particular service providers versus free market forces
- Co-operative ownership versus individual private ownership
- Direct billing versus compulsory payment via publicly controlled services.

Length of service contracts: If performance requirements, monitoring and penalties are not adequately defined in detail when contracting services the risks and possible negative impacts of outsourcing services increases significantly with the duration of the service agreement. However, and in particular for capital intensive infrastructure, the longer the duration of the service agreement the lower premiums investors must place on service fees, thus, reducing the overall cost of the service over a period of time. Assuming for instance for modern treatment plants that are capital intensive, there would be an immediate benefit in committing to long service agreements running over periods of 8-15 years Therefore, longer service contracts would be preferable but based on thoroughly detailed tender documents and subsequent contracts providing adequate performance monitoring and penalties/termination of agreement in case of breach.

Concessions is not required for the publicly owned health care facilities as both provincial and municipal health care facilities could be serviced via co-ordinated service agreements if adequately co-ordinated by the different public health facility operators, provided that municipal and provincial by-laws permit this. However, it may be necessary to establish a system of compulsory use of services of concession holders when addressing the private generators, especially, the numerous minor generators such as general practitioners, acupunctures etc. to ensure adequate and cost-effective service delivery to these small generators of HCRW.

Co-operative ownership of HCRW treatment infrastructure could be a viable option in a number of cases, including i) a group of local councils joining forces to be able to ensure service delivery to the small HCRW generators within their areas of jurisdiction, for example, in the form of a by-law supported concession holder, and ii) a group or association of private hospitals/clinics could join forces to secure cost effective joint ownership and operation of a treatment plant servicing primarily the members. In both cases, establishment of a co-operative structure would spread and reduce the financial liability and facilitate that particular performance requirements are being met.

Piggy backing on existing public payment structures for public supplies and taxes can be an effective way to avoid that especially minor generators, provided they are registered, cannot avoid paying for a needed service, whereby motivating especially smaller HCRW generators to make use of the service made available, as it is being paid for in any event. However, such payment structures are mostly suitable for the collection of flat rates or discreet rates that are easily determined and would not be suitable for larger generators where the payment should be generation specific, thus, motivating, improved segregation and waste minimisation where the largest potential for such environmental improvements are largest.

For small generators of HCRW particular payment systems could be considered such as i) up-front payment of deposits that are refundable via acceptable professional body on presentation of certificate of proper disposal, ii) prepayment of collection system, iii) prepayment of bring system with penalties if certificate of proper disposal are incomplete or similar systems and combinations of systems.

Therefore, it appears that the preferred principle options are:

- *Private financing (co-operative or individual) of HCRW treatment infrastructure*

- *Medium- to long-term service contracts (with individual clients or for concession areas) with comprehensive performance monitoring and penalties to ensure cost-efficient service*
- *Securing implementation of minimum service delivery to public sector via comprehensive tender and contracting arrangements*
- *Allowing larger private HCRW generators to select any service delivery model that complies with the provincial minimum requirements for HCRW Management.*
- *Possible use of compulsory flat rate collection directly by the public from minor HCRW generator, thus, making use and payment for a particular HCRW collection and treatment system for smaller generators possible and cost-efficient.*

9.4 Ownership and Service Options for HCRW Management in Gauteng

In South Africa, as well as in most other countries the services of collecting and treating HCRW were in the past predominantly carried out in-house, in case of larger health care institutions, or by the local councils/department for smaller or all generators of HCRW. Hence, in the past treatment plants were mostly located at the larger hospitals and wastes generated at other sources were either brought to the larger hospitals for treatment or were not being adequately treated.

Recent years have shown two worldwide tendencies. One towards outsourcing specialised services to professional private contractors, which is in line with the South African Government's policy. The other being increased environmental performance requirements resulting in fewer but larger treatment plants requiring increasing investments and operational costs, but having the benefit of economies of scale as well as less monitoring points.

There is, in principle, the following overall ownership and service provision options deemed of relevance for Gauteng:

Table 9.2: *Principle Service Provision Options for Gauteng*

Location	Principle Service Provision Options	Financing	Ownership	Operation
On-site treatment system at major hospitals only	1. **Traditional on-site System.** System financed, owned and operated by hospital	Hospital / Government	Hospital / Government	Hospital / Public Works
	2. **Outsourced Operation.** System financed and owned by hospital but operated by contractor	Hospital / Government	Hospital / Government	Contractor
	3. **Outsourced Financing and Operation.** System owned by hospital but financed and operated by contractor	Contractor	Hospital / Government	Contractor
	4. **Fully Outsourced On-site System.** System owned, financed and operated by contractor on-site	Contractor	Contractor	Contractor
Off site collection and treatment systems	5. **Publicly owned Utility.** System financed, owned and operated by public e.g. in the form of a Section 21 Company or a traditional municipal cleansing and landfill operation department. The utility has license to operate in specific area. Generators (in particular area) under obligation to make use of service	Public	Public	Public
	6. Co-operatively owned. Private institutions or association of institutions may form a co-operative or joint company that services the co-operation/association	Private/Co-operate	Private/Co-operate	Private/Co-operate

Location	Principle Service Provision Options	Financing	Ownership	Operation
	7. **Outsourced Operation.** System financed and owned by public but operated by contractor. Generators (in particular area) under obligation to make use of service	Public	Public	Contractor
	8. **Outsourced financing and Operation.** System owned by public but financed and operated by contractor. Generators (in particular area) under obligation to make use of service	Contractor	Public	Contractor
	9. **Market Driven Competition.** Competing Companies. System owned, financed and operated by contractor off-site. Generator has free choice of service provider.	Contractor	Contractor	Contractor
	10. Privately owned Utility. Utility has license to operate in specific area. Generators (in particular area) under obligation to make use of service	Contractor	Contractor	Contractor

In the Gauteng context it appears there is particular scope for discussing:

- On-site versus regionalised treatment of HCRW;
- Publicly owned versus outsourcing to private sector service providers;
- Establishment of public utilities having concessions for receiving HCRW from certain areas/generators.

On-site treatment facilities are clearly not cost-efficient compared to the regionalised plants, as well documented in Chapter 6 and further in Section 11.11. This is demonstrated in this report to be the case for both non-burn treatment technologies and especially for burn technologies (incinerators). Hence, regionalisation is clearly the preferred option.

Public ownership of HCRW treatment infrastructure, with the increasing capital demands, is clearly not preferably nor in line with current government policies, as this would tie up public funds that could be applied better in other sectors or addressing other needs, as there clearly is a well established and growing private service sector available to render the required service. For the same reason, publicly owned utilities are not deemed ideal for Gauteng and the preferred ownership option is clearly private sector ownership under public authority performance monitoring.

Concession holding companies being privately or publicly owned are discussed in the section above, where the conclusion was that such structures are in general not suitable, but could be required to provide cost-effective service delivery to the thousands of minor generators currently not being serviced and to a large extent not seeking the service. Hence, granting of concessions to particular service companies, for example under local or provincial bylaws, would only be applicable for minor generators.

In conclusion, it is evident that firstly regionalisation of the treatment infrastructure in Gauteng shall replace the current prevailing on-site treatment and secondly that the private sector shall be encouraged to provide capital for providing the necessary treatment infrastructure. It is thirdly assumed that market forces will be the driving force behind the private sector but that some concession systems could be relevant for small generators only.

9.5 Comparison of Advantages and Disadvantages of principle options

Table 9.3 below summarises the main ownership and service provision options for HCRW treatment in Gauteng.

Table 9.3: *Comparison of Ownership and Service Provision Scenarios*

Service Scenario	Invest/ finance	Ownership	Operation	Advantages	Disadvantages	Key Requirements
1. Traditional Government Service System. *Public Utility(or Sect. 21 Co.)*	Public	Public	Public	• Full public control • Easy to meet political requirements in fee structure, e.g. cross-subsidising based on affordability • Labour unions have more control than in the private sector	• Limited incentive for cost-efficiency (lack of competition) • Potential conflicts of interest between government departs. • Tying of public funds/debt limits in infrastructure • Generators must be obliged to use services in certain license areas or similar • Public sector seen as referee and player • Labour unions have more control than in the private sector	Efficient public administration
2. Private operation and maintenance contract on existing/old publicly owned infrastructure	Public	Public	Private	• Full public control by means of comprehensive operations contract • Incentives for efficient operations • Role of public limited to financing and monitoring (investor) • Contract periods can be relative short (2-4 years) • Public sector not seen as referee and player	• Potential conflicts of interest between government departs. • Tying of public funds/debt limits in infrastructure • Existing public staff to be transferred/re-trenched/re-trained • Generators must be obliged to use services in certain license areas or similar • Public owner does not retain operational experience • Public assets operated by outside party for short periods of time. Public operator may not have sufficient motivation for adequate maintenance of the public assets	Fail-proof performance and auditing system to guard against depletion of public assets and adequate service
3. Typical Build-Operate-Transfer (BOT) scheme	Private	Public	Private	• Incentives for efficient operations • Role of public limited to monitoring • Liberation of public funds/dept limits for other purposes • Full public control by means of comprehensive operations contract • Public sector not seen as referee and player	• Long contract periods required (10-15 years) • Public linked to one contractor for a long time • If applied to existing facilities, existing public staff to be transferred/re-trenched • Generators must be obliged to use services in certain license areas or similar • Public owner does not retain operational experience	Fail-proof performance and auditing system to guard against depletion of public assets and adequate service
4. Typical Build-Own-Operate-Transfer (BOOT) scheme	Private	Private being transferred to public	Private	• Incentives for efficient operations • Role of public limited to monitoring • Liberation of public funds/dept limits for other purposes • Public sector not seen as referee and player	• Long contract periods required (10-15 years) • Public linked to one contractor for a long time • If applied to existing facilities, existing public staff to be transferred/re-trenched • Generators must be obliged to use services in certain license areas or similar • Public owner does not retain operational experience	Well defined asset assessment system for the transfer of ownership after the end of the contract period
5. Typical fully outsourced service to a number of competing companies	Private	Private	Private	• Incentives for efficient operations • Role of public limited to contract monitoring • Liberation of public funds/dept limits for other purposes • Contract periods can be relative short (2-4 years) • Easy to change to other contractor, if desired	• If applied to existing facilities, existing public staff to be transferred/re-trenched • Unstable contracting situation due to frequent changes in contracts	Service performance monitoring system to ensure value for money
6. Private Utility. Fully outsourced service	Private	Private	Private	• Incentives for efficient operations if benefits of cost-efficiency are harvested by operator • Role of public limited to contract monitoring • Liberation of public funds/dept limits for other purposes • Easy to change to other contractor, if desired	• Existing public staff to be transferred/re-trenched • Contract periods must be relative long (10-15 years) • Generators must be obliged to use services in certain license areas or similar • Monopolies may be created if not competing with private sector on equal footing	Service performance monitoring system to ensure value for money. Generators must be obliged to use services in certain license areas or similar

For Gauteng, many combinations of the above could co-exist. For example, large generators of HCRW may wish to establish their own on-site treatment systems while regionalised systems exist for other smaller generators. Similarly, different regions of Gauteng could opt for different service provision principles, thus allowing for monitoring and comparison of the suitability and cost effectiveness of the different regional service provision models. Furthermore, different sets of service provision models could be used by e.g. provincial, municipal and privately managed generators throughout Gauteng, provided that there is uniformity in the approach for all facilities covered under a single contract, thus avoiding the risk of confusion whilst reaping the maximum benefits from economies of scale that can be achieved.

However, the following main options appears to be preferred for Gauteng:

- *When contracting, setting of firm provincial minimum requirements is important for the performance of the HCW service industry in terms of environment, health, safety, service delivery and adherence to legislated reporting and monitoring systems, thus, securing implementation of minimum service delivery to public sector by means of comprehensive tender and contracting arrangements;*
- *Private financing (co-operative or individual) of HCRW collection and treatment infrastructure;*
- *Medium- to long-term service contracts (with individual clients or for concession areas) with comprehensive performance monitoring and penalties to ensure cost-effective service;*
- *Possible use of compulsory flat rate collection directly by the public from minor HCRW generators, thus, making use and payment for a particular HCRW collection and treatment system for smaller generators possible and cost-effective.*

In summary, it is evident that regionalisation of the treatment infrastructure in Gauteng should replace the current prevailing on-site treatment facilities and that the private sector shall be encouraged to provide capital for providing the necessary collection and treatment infrastructure. It is assumed that market forces will be the driving force behind the private sector, but that some concession systems could be relevant for small generators only.

10 Current Legal Framework and Shortcomings

10.1 Introduction

It is evident that there is, in South Africa compared to especially developed counties, a less developed regulatory framework for Health Care Waste Management. This is, among others, the case regarding i) emission standards for incinerators, ii) standards for microbial inactivation to be achieved by non-burn technologies, iii) definition and de-facto role and function of the three tiers of government, iv) level of compliance, and v) public capacity to plan, monitor and take action for improved HCW Management.

This section includes a brief introduction to the major current regulations of relevance to HCW Management as well as a preliminary assessment of the current regulatory framework and some of the identified needs for regulatory strengthening.

10.2 List of Current Relevant Legislation and Guidelines

The following regulations etc. have been reviewed by the Legal Consultants to assess the current status of the legal framework for HCW Management in South Africa and in Gauteng:

- The Constitution of the Republic of South Africa, Act 108 of 1996
- Future Developments
    - White Paper on Integrated Pollution and Waste Management for South Africa
    - The National Waste Management Strategy
    - Draft Regulations for the Control of Environmental Conditions Constituting a Danger to Health or Nuisance
- National Legislation
    - Atmospheric Pollution Prevention Act 45 of 1965
    - Environment Conservation Act 73 of 1989
    - Hazardous Substances Act 15 of 1973
    - Health Act 63 of 1977
    - Human Tissue Act 65 of 1983
    - National Environmental Management Act 107 of 1998
    - National Nuclear Regulator Act 47 of 1999
    - National Road Traffic Act 93 of 1996
    - National Water Act 36 of 1998
    - Nuclear Energy Act 46 of 1999
    - Occupational Health and Safety Act 85 of 1993
    - Medicines and Related Substances Control Act, 1965 (Act 101 of 1965);
    - National Nuclear Regulator Act, 1999 (Act 47 of 1999);
- Provincial Legislation
    - Local Government Ordinance
- Local Government
    - Solid Waste By-laws of Johannesburg, Tswane etc.
- The Common Law of Nuisance

In addition to the various Acts etc. referred to above, there are a number of Internal Policy Documents in use at present. Although the latter does not have any legal standing, it will form an integral part of the Gauteng Provincial Policy an act as minimum requirements, which will not only advance uniformity in the standards set, but it will also support the training and awareness initiatives taken to date:

- Environmental Policy on Waste Disposal
- US Centre for Disease Control Standards
- Internal Circular 47 of 1997 – Medical
- Health and Safety Policy 1.24 – Medical Waste Control
- Infection Control Policy No 24 – Disposal of medical waste
- Infection Control Policy No 33 – Disposal of Human Tissue
- Infection Control Policy – How to deal with a blood spill
- Health and Safety Policy – Recycling Policy
- Health and Safety Policy – Hazardous Chemical Spill
- SABS Code of Practice on Hazardous Substances Code 0228
- SABS Code of Practice for the Handling and Disposal of Waste Materials within Health Care Facilities – SABS 0248:1993; (being revised 2002)
- Department of Water Affairs and Forestry (DWAF) Policy on the Disposal of Medical Waste
- “Minimum Requirements for Handling, Classification and Disposal of Hazardous Waste”
- “Minimum Requirements for Waste Disposal by Landfill”
- Netcare Infection Control Standards
- Presmed Infection Control Policy – G4.1

Although the “Minimum Requirements for Handling, Classification and Disposal of Hazardous Waste” as well as the “Minimum Requirements for Waste Disposal by Landfill” are not in themselves Acts, adherence thereto is enforced through the “Environmental Conservation Act, 1989 (Act 73 of 1989)”. For this reason the Minimum Requirements will also be evaluated as if they are Acts.

In the context of future South African legislation, it is likely that national legislation will be the framework legislation setting minimum norms and standards which must be complied with by all spheres of government, while Provincial and Municipal legislation will address specific and technical issues pertinent to regional and local requirements, respectively.

10.3 Analyses of Current Legislation and Guidelines

Waste management and specifically HCW is controlled in South African legislation in a somewhat fragmented and uncoordinated manner. Although South Africa has a plethora of environmental legislation, these laws are often described as controlling environmental pollution and waste management in a “haphazard and uncoordinated manner”.[1] Furthermore, such legislation does not provide sufficient guidance on the management

[1] MA Rabie, RS Fuggle, Environmental Management in South Africa (RS Fuggle and MA Rabie, eds, Juta and Co. 1991, page 511).

of HCW. The following analysis of legislation, regulations and guidelines that impact on the management of HCW shall illustrate the fragmented and uncoordinated manner within which HCW is currently regulated in South Africa.

10.3.1 Analyses of Legislation and other Regulations

The analysis below confines itself to legislation that is critical (or key) to the regulation of HCW.

Overview of the applicable key legislation

The Atmospheric Pollution Prevention Act 45 of 1965 ("the Atmospheric Pollution Prevention Act") sets out the procedure for the registration of, what is referred to in the Act, as "Scheduled Processes". A Scheduled Process is defined under Section 1 of the Act to mean any works or processes specified in the Second Schedule to the Act. For the purposes of the Atmospheric Pollution Prevention Act, waste incineration is considered a Scheduled Process. That is to say processes for the destruction by incineration of waste that contains chemically bonded halogens, nitrogen, phosphorus, sulphur or metal, or any waste that can give rise to noxious or offensive gases. Accordingly, the incineration of Health Care Risk Waste ("HCRW") is a process that is controlled under the Atmospheric Pollution Prevention Act. The effect of this is that any person carrying out a Scheduled Process in or on any premises is prohibited from so doing unless that person (including a company) is the holder of a current Registration Certificate issued under the Act. In addition, there are emission guidelines for medical waste incinerators that are developed by the Directorate: Air Pollution Control, Department of Environmental Affairs and Tourism. In addition, the Minister of Environmental Affairs and Tourism has identified certain activities that may have a substantial detrimental effect on the environment. Such activities include Scheduled Processes listed in the Schedule to the Atmospheric Pollution Prevention Act. Accordingly, a written authorisation issued by the Minister or an authority designed by notice in the Government Gazette is required where HCRW is treated and disposed of by incineration. This authorisation will only be issued after the consideration of reports concerning the impact of the proposed activity and of alternative proposed activities on the environment. This means that an environmental impact assessment is required to be undertaken.

HCRW may include chemical waste, such as all types of discarded chemicals, including pharmaceuticals and cytotoxic substances that may pose a special risk to human health and the environment. The object of the Hazardous Substances Act 15 of 1973 ("the Hazardous Substances Act") is to provide for the control of substances which may cause injury or ill-health to or death of human beings by reason of the toxic, corrosive, irritant, strongly sensitising or flammable nature or a generation of pressure in certain circumstances and for the control of certain electronic products. The Hazardous Substances Act categorises certain groups of hazardous substances. Groups I and II relate to substances of a toxic, corrosive, irritant, strongly sensitising or flammable nature. Group III relates to electronic products and Group IV relates to radioactive materials. The Hazardous Substances Act and Regulations promulgated thereunder should be considered relevant to Hazardous Chemical Substances management "(HCS"), particularly, those regulations relating to the disposal and transportation of such substances.

The Health Act 63 of 1977 (“the Health Act”) provides that the local government is obliged to take measures to maintain its district in a clean and hygienic condition and to prevent the occurrence of any nuisance, unhygienic or offensive condition or other condition that could be of danger to the health of any person. Where such a nuisance or a condition has occurred, the local government will be obliged to abate the nuisance or remedy the condition. It is possible that HCW if incorrectly disposed of may amount to such nuisance or unhygienic or offensive conditions. In addition, the Minister is empowered in terms of the Health Act to make regulations relating to conditions that are dangerous to health. These may include regulations relating to the disposal of waste to prevent the development of conditions dangerous to health and the removal from premises of waste.

The Human Tissue Act 65 of 1983 (“the Human Tissue Act”) provides that the Minister of Health may make regulations regarding the disposal of human bodies and tissue no longer required for any of these purposes. The Human Tissue Act does not expressly provide for the disposal of HCW.

The National Environmental Management Act 107 of 1998 (“the National Environmental Management Act”) requires that waste is avoided or minimised or reused and recycled where possible or otherwise disposed of in a responsible manner. The National Environmental Management Act provides that environmental management must be integrated. In terms of the National Environmental Management Act, a duty of care is placed on every person who causes, has caused or may cause significant pollution or degradation of the environment to take reasonable measures to prevent such pollution or degradation from occurring, continuing or recurring. These measures may include ceasing, modifying or controlling any act, activity or any process causing the pollution or degradation; containing or preventing the movement of pollutants or cause of the degradation; and eliminating any source of the pollution or degradation. It is possible that if incorrectly managed HCW may cause such pollution or degradation of the environment. It should be highlighted that for the purposes of the National Environmental Management Act, “environment” includes the surroundings within which humans exist and that are made up of properties and conditions that influence human health and well-being. In addition, the definition of “pollution” in the Act includes a change in the environment caused by amongst others, substances emitted from any activity including the storage and treatment of waste or substances where that change has an adverse effect on human health or well-being. Similar ‘duty of care’ provisions are provided for in the National Water Act 36 of 1998 where certain activities may impact on water resources.

The Occupational Health and Safety Act 85 of 1993 (“the Occupational Health and Safety Act”) provides for the health and safety of persons at work and for the health and safety of persons in connection with the use of plant and machinery and the protection of persons other than persons at work against hazards to health and safety arriving out of or in connection with activities of persons at work. Regulations promulgated under the Occupational Health and Safety Act for Hazardous Biological Agents apply to every employer and self-employed person at a workplace where Hazardous Biological Agents are deliberately produced, processed, used, handled, stored or transported at the workplace or an incident that may result in such persons being exposed to Hazardous Biological Agents while performing his or her work. For the purposes of these Regulations Hazardous Biological Agents means hazardous biological agents which are micro-organisms, including those that have been a genetically modified, pathogens, cells, cell cultures and human endoparasites that have the potential to provoke an infectious toxic effect. These Hazardous Biological Agents are sub-divided into certain groups. The Regulations provide for the disposal of Hazardous Biological Agents providing that an employer or self-employed person shall lay down procedures for appropriate decontamination and disinfection; implement written procedures enabling infectious waste to be handled and disposed of without risk; ensure that all fixture and equipment which have been in contact with hazardous biological waste are disinfected and decontaminated and ensuring that all hazardous biological waste that can cause exposure is disposed of only in sites especially designed for this purpose in terms of the Environment Conservation Act 73 of 1989 ("the Environment Conservation Act"). Also promulgated under the Occupational Health and Safety Act are the Hazardous Chemical Substances Regulations. These regulations are applicable to an employer or self-employed person who carries out work at a workplace that may expose any person to the intake of a hazardous chemical substance at that workplace. In terms of these Regulations, an employer shall, as far as reasonably practicable, recycle all hazardous chemical substance waste and where disposal of such substances may take place, that this only happens on sites specifically designated for that purpose in terms of the Environment Conservation Act and in such a manner that it does not cause a hazard inside or outside the site.

The handling, storage and transportation of HCW follow the same principles and requirements as those that relate to dangerous goods in general. In South Africa, the United Nations Recommendations for the Transportation of Dangerous Goods (as incorporated in the International Maritime Organisation's Dangerous Goods Code) and the International Civil Aviation Organisation's Regulations (as given in their technical notes) are implemented as legislation through Department of Transport's Merchant Shipping Act 57 of 1951 and the Aviation Act 72 of 1962 respectively. SABS Codes of Practice dealing, inter alia, with vehicle inspection requirements, operational requirements, emergency response information, packaging details and labelling and transportation of bulk substances are also relevant to the transportation of waste. Acts of Parliament such as the Occupational Health and Safety Act (including the Regulations made thereunder and Regulations made under the Machinery and Occupational Safety Act 6 of 1983 which remain in force) pertaining to worker health and safety, the Health Act insofar as nuisances and health issues are concerned, and the National Road Traffic Act 93 of 1996 insofar as transportation requirements are concerned, are further examples of statutes which have a direct effect on waste generated, waste transportation and a waste disposer's activities. For example, under the Regulations for Hazardous Chemical Substances ("the HCS Regulations") made under the Occupational Health and Safety Act, Regulation 15 deals with the disposal of hazardous chemical substances (which includes HCW).

In terms of Regulation 1of the HCS Regulations, HCS are defined as follows:

"any toxic, harmful, corrosive, irritant or asphyxiant substance, or a mixture of such substances for which –

- an occupational exposure limit is prescribed; or
- an occupational exposure limit is not prescribed, but which creates a hazard to health".

Regulation 15 of the HCS Regulations provides the following:

"an employer shall, as far as is reasonably practicable, –

- recycle all HCS waste;
- ensure that all collected HCS waste is placed into containers that will prevent the likelihood of exposure during handling;
- ensure that all vehicles, re-useable containers and covers which have been in contact with HCS waste are cleaned and decontaminated after use in such a way that the vehicles, containers or covers do not cause a hazard inside or outside the premises concerned;
- ensure that all HCS waste which can cause exposure, is disposed of only on sites specifically designated for this purpose in terms of the Environment Conservation Act, in such a manner that it does not cause a hazard inside or outside the site concerned;
- ensure that all employees occupied in the collection, transport and disposal of HCS waste, who may be exposed to that waste, are provided with suitable personal protective equipment; and
- ensure that if the services of a waste disposal contractor are used, provision is incorporated into the contract stating that the contractor shall also comply with the provisions of these regulations".

It is pointed out that the HCS Regulations require that if a waste disposal contractor is used by an employer, then a provision must be incorporated into the contract with the waste disposal contractor stating that the contractor shall comply with the provisions of the HCS Regulations. Regulation 14 of the HCS Regulations is also important in that it provides detailed labelling, packaging, transportation and storage requirements.

Regulation 14 of the HCS Regulations provides that:

"an employer shall, in order to avoid the spread of contamination of an HCS, take steps, as far as is reasonably practicable, to ensure –

- that the HCS in storage or distributed are properly identified, classified and handled in accordance with SABS 072 and SABS 0228;
- that a container or a vehicle in which an HCS is transported, is clearly identified, classified and packed in accordance with SABS 0228 and SABS 0229; and
- that any container into which an HCS is decanted, is clearly labelled with regard to the contents thereof".

It is submitted that the provisions of Regulation 14 will apply to the labelling of containers filled with a HCS waste, the packaging of HCS waste, the transportation and storage of a HCS waste. Regulation 14 also incorporates SABS Codes 072, 0228 and 0229 thereby giving these SABS Codes of Practice the force of law.

<u>Overview of governance issues and institutional arrangements for HCW</u>

In order to properly understand the powers of the National, Provincial and Local spheres of Government pertaining to HCW in relation to the Constitution if the Republic of South Africa Act 108 of 1996 ("the Constitution"), then we must understand the underlying constitutional principles.

Constitutionalism is the notion that government should derive its powers from a written constitution and that its powers should be limited to only those powers set out in the written constitution. Very closely associated with the notion of constitutionalism are three principles of law, without which constitutionalism will have very little effect on ensuring that governments do not violate any guaranteed fundamental human right. These are: – constitutional supremacy, justiciability, and entrenchment.

- Constitutional supremacy

  This principle dictates that the rules or provisions of the constitution are binding on all branches of the State and all other rules, policies and laws must comply with the rules set out under the constitution. If any State conduct, rule, policy or law is in conflict with the rules set out under the constitution, then such conduct, rule, policy or law is unconstitutional and unenforceable.

- Justiciability

  Justiciability is the principle that a court must be able to enforce those provisions so as to ensure that the State and private persons do not infringe the rules of the constitution. The principle of justiciability provides that an order or decision of a court binds all persons to whom and organs of state to which it applies.

- Entrenchment

  Unlike any other law or statute, the constitution prevents Parliament from amending the constitution. Section 74 of the Constitution sets out in detail the procedures to be followed should Parliament wish to amend a provision of the Constitution.

The Constitution expressly entrenches the “rule of law” as a “founding value” of the South African constitutional state. The very essence of this principle is that, firstly, the State, as well as every other person in South Africa, must obey the law, and secondly, the State may not exercise a power unless a law permits it to do so.

The Constitution states that the Constitution is adopted by the people of South Africa so as to establish a society based on democratic values, social justice and fundamental human rights and lay the foundations for a democratic and open society in which government is based on the will of the people.

The principle of democracy is considered to be the underpinning principle of South Africa’s constitutional statehood. The principle of democracy requires that government can only be legitimate in so far as it rests on the will of the people it governs.

The final principle to be discussed is that of the separation of powers. The doctrine requires that the functions of government be divided between the executive (execution and enforcement of law), the legislatures, whether National, Provincial or Local (law-making) and the judiciary - our courts - (dispute resolution). The Constitution recognises the doctrine of separation of powers. Section 43 vests the law making authority of South

Africa at the National sphere of Government in Parliament and at the Provincial sphere in the nine separate provincial legislatures.

In the past, the administration of laws pertaining to waste management generally has been fragmented and without any co-ordination amongst various departments at the National sphere of Government, as well as amongst Provincial and Local Government.

The difficulty in co-ordination arises because environmental management encompasses the broad array of concerns, including natural and cultural resources, pollution control and HCW, general and hazardous waste management, as well as land-use planning and development and by nature is cross-sectoral.

Section 40 of the Constitution introduces 3 spheres of government – National, Provincial and Local.

Chapter 3 of the Constitution introduces the concept of “co-operative governance” and requires all organs of state (and all 3 spheres of government) to work harmoniously together by, for example, co-ordinating their actions and legislation with one another. Section 40 therefore refers to the various spheres of government as being interrelated, interdependent and yet distinctive.

In determining the respective legislative competencies or jurisdictions of National, Provincial and Local spheres of government to legislate and administer particular environmental matters (such as HCW), regard must be had to Schedules 4 and 5 of the Constitution. These two schedules are of fundamental importance in determining the functional legislative competencies of the three spheres of government.

Schedule 4 lists the functional areas of concurrent National and Provincial legislative competence. The areas listed under Schedule 4, Part A, may be legislated upon by both the provinces and National government. The areas under Part B may be legislated upon by Local government as well.

Schedule 5 lists the exclusive areas of functional Provincial legislative competence. The areas listed under Schedule 5, Part A, may be legislated upon only by the provinces. The areas under Part B may be legislated upon by Local government as well. Under Schedule 5 the Provincial and Local governments may legislate on refuse removal, refuse dumps and solid waste disposal.

Within the National sphere, Parliament may legislate on any area, except those listed under Schedule 5 of the Constitution. Nonetheless, Section 44(2) stipulates that Parliament may intervene by passing legislation pertaining to a matter falling within a functional area listed under Schedule 5 when it is necessary –

- to maintain national security;
- to maintain economic unity;
- to maintain essential national standards;
- to establish minimum standards required for the rendering of services; or
- to prevent unreasonable action taken by a province which is prejudicial to the interests of another province or to the country as a whole.

Further, Section 44(3) provides that –

> "Legislation with regard to a matter that is reasonably necessary for, or incidental to, the effective exercise of a power concerning any matter listed in Schedule 4 is, for all purposes, legislation with regard to a matter listed in Schedule 4."

Within the Provincial sphere Section 104(1) sets out the legislative powers of the provinces. These include the power to pass legislation for its province with regard to –

- any matter within a functional area listed in Schedule 4;
- any matter within a functional area listed in Schedule 5;
- any matter outside those functional areas, and that is expressly assigned to the province by national legislation; and
- any matter for which a provision of the Constitution envisages the enactment of provincial legislation.

A provincial legislature is bound only by the Constitution and if it has passed a constitution for its province, also by that constitution, and must act in accordance with, and within the limits of the Constitution and that provincial constitution.

Section 104(4) of the Constitution provides that provincial legislation with regard to a matter that is reasonably necessary for, or incidental to, the effective exercise of a power concerning any matter listed in Schedule 4, is for all purposes legislation with regard to a matter listed in Schedule 4. Section 156(5) provides that a municipality has the right to exercise any power concerning a matter reasonably necessary for, or incidental to, the effective performance of its functions. In Ex Parte President of the Republic of South Africa: In Re Constitutionality of The Liquor Bill[2] the Constitutional Court took the view that the phrase 'reasonably necessary for, or incidental to' should be interpreted as meaning 'reasonably necessary for and reasonably incidental to'. The Constitutional Court held further that since the possibility of overlap is inevitable, it will on occasion be necessary to determine the main substance of legislation and hence to ascertain in what field of competence its substance falls; and, this having been done, what it incidentally accomplishes. This entails that a Court determining compliance by a legislative scheme with the competencies enumerated in Schedule 4 and 5 must at some stage determine the character of the legislation. It seems apparent that the substance of a particular piece of legislation may not be capable of a single characterisation only and that a single statute may have more than one substantial character.

A provincial legislature may assign any of its legislative powers to a Municipal Council in that province. Under Section 151(2) of the Constitution, the executive and legislative authority of a municipality vests in its municipal council. Section 151(4) prohibits either the National Government or a Provincial Government from compromising or impeding upon a municipality's ability or right to exercise its powers or perform its functions.

<u>Understanding the legal nature and rights and duties of municipalities in relation to HCW</u>

Chapter 7 of the Constitution deals with local government and provides for the establishment of municipalities.

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[2] 2000 (1) SA 732 (CC) at para 81.

A municipality is an organ of state within the local sphere of government exercising legislative(law making) and executive(law enforcement) authority within an area determined in terms of the Local Government: Municipal Demarcation Act, 1998.

Municipalities must exercise their executive and legislative authority within the constitutional system of co-operative government envisaged in Section 41 of the Constitution.

In addition, the national and provincial spheres of government must, within the constitutional system of co-operative government envisaged in Section 41 of the Constitution, exercise their executive and legislative authority in a manner that does not compromise or impede a municipality's ability or right to exercise its executive and legislative authority.

Section 4 of the Municipal Systems Act 32 of 2000 ("the MSA") provides for the rights and duties of municipal councils. The council of a municipality has the right to:

- govern on its own initiative the local government affairs of the local community;
- exercise the municipality's executive and legislative authority, and to do so without improper interference; and
- finance the affairs of the municipality by charging fees for services and imposing surcharges on fees, rates on property and, to the extent authorised by national legislation, other taxes, levies and duties.

The council of a municipality has the following duties:

- exercise the municipality's executive and legislative authority and use the resources of the municipality in the best interests of the local community;
- provide, without favour or prejudice, democratic and accountable government;
- strive to ensure that municipal services are provided to the local community in a financially and environmentally sustainable manner;
- consult the local community about the level, quality, range and impact of municipal services provided by the municipality, either directly or through another service provider;
- give members of the local community equitable access to the municipal services to which they are entitled;
- promote and undertake development in the municipality;
- promote gender equity in the exercise of the municipality's executive and legislative authority;
- promote a safe and healthy environment in the municipality; and
- contribute, together with all organs of state, to the progressive realisation of the fundamental rights contained in Sections 24, 25, 26, 27 and 29 of the Constitution.

Integrated Development Planning (IDP) is a vital concept in understanding the role of municipalities, their IDP obligations and how they relate to an HCW management strategy as well as the National Waste Management Strategy (discussed below).

An IDP is a plan devised by the Municipality in order to meet the various goals of local government. The Constitution determines the various objects and duties of local government are set out. The IDP's must give effect to those objects. Also, the fundamental rights set out in the Constitution (particularly the environmental right) must be given effect to by the IDPs.

The objects of an IDP are as follows, it :

- strives to achieve the objects of local government set out in Section 152 of the Constitution;
- gives effect to its developmental duties as required by Section 153 of the Constitution; and
- together with other organs of state, contributes to the progressive realisation of the fundamental rights contained in Sections 24, 25, 26, 27 and 29 of the Constitution.

Section 24 of the MSA provides that the municipal planning undertaken by a municipality must be aligned with, and compliment, the development plans and strategies of other affected municipalities and other organs of state so as to give effect to the principles of co-operative government contained in Section 41 of the Constitution.

In terms of Section 26, IDP's must reflect:

- the municipal council's vision for the long term development of the municipality with special emphasis on the municipality's most critical development and internal transformation needs;
- an assessment of the existing level of development in the municipality, which must include an identification of communities which do not have access to basic municipal services;
- the council's development priorities and objectives for its elected term, including its local economic development aims and its internal transformation needs;
- the councils development strategies which must be aligned with any national or provincial sectoral plans and planning requirements binding on the municipality in terms of legislation;
- applicable disaster management plans; and
- a financial plan.

In addition to Schedule 5, Part B of the Constitution (discussed above) municipal councils also derive their power to make by-laws on HCRW from the Local Government Ordinance 17 of 1939. For Example, in 1975 the City of Johannesburg promulgated By-laws [Refuse (Solid Waste By-laws of Johannesburg (AN 1047 of 18 June 1975)]. These By-laws provide that a person engaged in an activity which causes special industrial, hazardous, medical or infectious refuse to be generated, shall notify the Council within 7 days of such generation of the composition thereof, the quantity generated, method of storage, the proposed duration of storage, and the manner in which it will be removed. Special medical or infectious refuse stored on the premises shall be stored in such a manner that it cannot become a nuisance, safety hazard or pollute the environment. In addition, hazardous, medical or infectious refuse shall be stored in a container approved by the Executive Director: Health and Housing and such container shall be kept in an approved storage area for a period not exceeding the maximum period to be stipulated by the Executive Director. Furthermore, the by-laws provide that no person shall dispose of any infectious refuse other than by incinerating it at the Council's incinerator facility, unless the Executive Director: Water and Waste's prior written permission has been given to incinerate such refuse at another facility. These By-laws will in due course be replaced by new Waste Management By-laws whilst the municipal councils have constitutional (and other) legislative powers to make by-laws, on HCW, the legal position is that this does not prohibit the Gauteng Provincial Legislature from legislating on HCW management and HCWR management. What is important is that such legislation, in the spirit of co-operative governance, should be co-ordinated with the municipal councils in the interests of sustainability and the environment.

Policy initiatives relevant to HCW

The Constitution states that the people of South Africa have the right to an environment that is not detrimental to human health, and imposes a duty on the state to promulgate legislation and to implement policies to ensure that this right is upheld. Steps taken to date to ensure the environmental right include: the publication of the Environmental Management Policy for South Africa (1998); the preparation of the Draft White Paper on Integrated Pollution and Waste Management (1998); the National Water Act (1998); as well as the promulgation of the National Environmental Management Act (1998). A further step is the development of this National Waste Management Strategy for South Africa.

During 1997, the Department of Water Affairs and Forestry (DWAF) and the Department of Environmental Affairs and Tourism (DEAT), with financial support from the Danish Co-operation for Environment and Development (Danced), initiated a project for the development of a National Waste Management Strategy (NWMS) for South Africa. The overall objective of this strategy is to reduce the generation of waste and the environmental impact of all forms of waste and thereby ensure that the socio-economic development of South Africa, the health of the people and the quality of its environmental resources are no longer adversely affected by uncontrolled and uncoordinated waste management.

In order to achieve this objective the following goals were agreed for the NWMS project:

- The development of strategies for integrated waste management.
- The development of action plans to implement the identified strategies.
- Capacity building within DWAF and DEAT to implement the action plans.

Consultation with a wide range of stakeholders on the waste management situation in South Africa (1997/8) identified the following as key issues and needs that had to be addressed by this National Waste Management Strategy:

- To bring about a paradigm shift from end-of-pipe control to waste prevention and minimisation.
- To provide basic waste management services for those sections of the population who do not have access to waste collection services or who do not receive adequate services.
- To ensure that public health and occupational health issues receive due consideration in all waste management practices.
- To initiate a system of integrated waste management through the implementation of instruments such as legislation, capacity building, institutional arrangements and funding mechanisms.

- To ensure integration of waste management initiatives with other governmental initiatives, programmes and administrative systems, e.g. Integrated Development Forums (IDFs) and Land Development Objectives (LDOs), the Masakhane campaign and job creation projects.
- To integrate waste management with the over-arching process of environmental planning, management and protection.

Conclusion

The principles derived from the Constitution and other environmental statutes applicable to HCW will guide and influence the activities of all parties involved in the process to bring about sustainable health care waste management in Gauteng. The holistic nature of environmental concerns in general is mirrored in the fragmented manner in which environmental issues, and HCW in particular, is dealt with in legislation. Currently, there is no legislation either at the National, Provincial or Local level that specifically addresses the regulation of HCW. Having regard to the Province's obligations in relation to Local Government, an integrated and consultative approach is therefore required to develop and implement a sustainable health care waste management strategy in Gauteng and thus achieve its ultimate goals.

10.3.2 Analyses of Guidelines and Standards

Based on discussion with various stakeholders there appears to be a perceived lack of national and provincial guidance, as to the most appropriate management of HCW. In particular the health care facilities appear to have no guidance as to the practical implementation, supervision and operation of a HCW management system, including requirements for sharps' containers, waste receptacles, their placement, internal collection and storage as well as requirements for disposal and treatment and performance of service contractors. The existing and proposed draft SABS guidelines do not appear to meet the health care facilities' detailed need for concrete guidance, but provides general guidance for good practices and pertinent issues to be considered as well as some guidance as to the preferred colour coding, marking and handling of HCRW.

The DWAF minimum requirements appear to be difficult to apply due to the need for elaborate chemical and leachate tests for the classification of waste before landfilling. Hence, there is scope for confusion as to the suitable type of landfill to be used for particular types of waste. There could be a need for a more operational practical version of the Minimum Requirements, thus for example, reducing the need for elaborate and expensive tests for typical standards types of residues and waste.

With the emergence of various non-burn treatment technologies for HCRW in South Africa it has become apparent that there exists no South African guidelines or regulations for the level of microbial inactivation that must be achieved by these emerging technologies. In Gauteng it has been decided to apply the STAATT I /II (ref. 9 and 10) level of inactivation in the absence of national guidance.

Most private hospital associations have developed standard clinical procedures or Clinical Codes of Practice that also describes the procedures for handling HCW. However, most public hospitals and clinics have yet to develop such procedures or codes of practice to ensure safe and environmentally acceptable sorting, packaging, handling and disposal.

There is currently a general SABS Code 0248 for HCW Management (Ref. 11) but there are no practical guidelines or national policies issued by DEAT, DWAF or NDoH that meets the current needs of information of the HCRW generators or HCRW service providers adequately.

10.4 Identified Need for Legislation and Regulatory Tools

The following needs for additional or improved regulatory tools have been identified:

- Legislation to regulate HCW management, HCRW management, HCRW treatment technology, and HCWIS;
- Performance standards;
- Licensing mechanisms (in co-operation with the municipal councils); and
- Guidelines for decision-making.

10.5 Conclusions

There is a crucial need for appropriate regulation of HCW (including HCRW) in the Gauteng Province. The existing legislation at the provincial level (i.e. the 1939 Local Government Ordinance) is outdated and does not take sufficient cognisance of the legislative scheme envisaged in the Constitution. While national government legislation on HCW (generally) is anticipated, this is likely to be framework legislation only. This is a further basis for the need for regulation on HCW and HCRW management in the Gauteng Province on a regional basis and one that takes into account regional circumstances. The development of legislation is a detailed process and one that should be highly consultative – especially in the interests of ensuring that the constitutional obligation of co-operative governance is fulfilled in the context of the constitutional legislative powers of the municipal sphere of government.

11 Assessment of the Selected Scenarios

This chapter includes an estimate of the environmental, safety, financial and socio-economic implications of implementing the scenarios specified in chapter 7. To the extend possible the implications have been quantified in order to make the comparison of the implication of the different scenarios as clear as possible. However, some of the environmental, safety and socio-economic aspects have been difficult to quantify. Hence, some aspects are briefly discussed in qualitative terms.

11.1 Environmental implication

In principle, there are environmental impacts from cradle-to-grave for the entire system, starting from mining of raw materials and manufacturing of equipment, goods and services, all the way through to the final disposal of either HCW, or the equipment that was used for the management thereof. In practical terms, there are some major contributing factors that cause by far the greatest environmental impact.
In this study it is assumed that the following key aspects within the feasibility study determines the major environmental impact:

- Green procurement and substitutions of undesirable products;
- Improved segregation;
- Reusable vs. disposable containers for HCRW;
- On-site HCRW treatment vs. regionalised HCRW treatment;
- Incineration vs. non-burn HCRW treatment technologies.

In all instances, considerable environmental (and in most cases financial and safety) benefits can be achieved by introducing a rigorous segregation system aimed at minimising the amounts of HCW requiring dedicated HCRW containerisation, transport, treatment and disposal.

This section on environmental impact is structured in the following way:

- The main environmental impact categories are identified and their character is determined
- The impact categories to be included in the further calculations are selected
- The main assumptions and omissions are presented
- Emission rates for the various impact categories are presented
- Environmental impact of the various impact categories are calculated
- The results are interpreted and conclusions are drawn.

It should be noted that the four main scenarios (Status Quo, 1, 2, 3 and 4) are defined based on the principles of containerisation only, whereas for example the type of treatment plant used varies for each of the Scenarios 1, 2, 3 and 4.

The table 11.1 below indicates the major environmental impacts and differences for the different scenarios.

In brief, there are the following main differences in the impact and conclusions:

Table 11.1: *Main Differences in the Environmental Impact of the Scenarios*

Environmental Key Issue	Main assumptions concerning environmental impact
1. Green procurement and substitutions of undesirable products	• *Disposable items:* The health care sector has traditionally been a major consumer of disposable items such as syringes, needles, scalpels, gloves, linen savers, plastic bags, tubes, gowns, pillows, bedpans, nappies, kidney dishes, etc. Some of the items are produced from compounds that, from an environmental point of view, are undesirable. By substitution of, for example, i) PVC products, ii) metal containing dies and paints, iii) halogenated and chlorinated compounds via the introduction of green procurement procedures, there is scope for considerable reduction of the environmental impacts during treatment and disposal of waste products. There is especially scope for reduction of the emission of dioxins/furans, acid gases, and heavy metals as well as reduced leaching to the aquatic environments and soil. • *Study the use, contents and disposal of special items:* In particular the following items should be studied i) mercury containing equipment, ii) PVC plastics. • *Avoid excess packaging:* A number of items procured in general as well as for the health care sector are excessively packaged for various reasons. This can be addressed via the manufactures and suppliers to minimise the environmental impact while observing adequate hygiene and safety standards. • *Use of reusable instead of disposable products:* There could in many instances be scope for investigating the potential environmental benefits of moving away from, e.g., i) disposable linen and gowns, ii) disposable paper towels, iii) disposable cups, cutlery and plates, iv) single use batteries, etc. With due consideration of the potential health impact through infection, it may be justified to consider the sterilisation and re-use rather than single use and disposal of some products being used, even though it may initially require the purchase of more durable products. *(Not quantified in the assessment of environmental impacts below)*
2. Improved segregation	• From many visits, in particular to public health care institutions in Gauteng, it became evident that there is considerable occurrence of poor segregation of waste taking place at present. It is evident that much of the waste currently containerised, transported and treated as HCRW is in fact not infections and could be classified as domestic waste, for example: i) beverage containers, ii) food waste, iii) packaging material from sterile consumables, iv) other packaging materials (cardboard, plastic bags, wrappers etc.), v) office papers, vi) flowers etc. A segregation survey in 2002 shows that approx. 25% of the current volume being handled as HCRW, could in fact be managed via the HCGW system. • Classifying HCRW as HCGW result in untreated HCRW, including sharps, chemicals and pharmaceuticals, being disposed of at general waste landfills, which creates a risk to people as well as pollution of both the surface and the subsurface water resources. *(Not quantified in the assessment of environmental impacts below)*
3. Reusable vs. disposable receptacles for HCRW	• The current disposable containers are manufactured from cardboard (infectious waste) and plastic (sharps and some wet HCRW). It is assumed that the reusable non-sharp, dry infectious containers would be produced from glass fibre and/or polymeric materials. • The current use of cardboard boxes and plastic bags etc. result in environmental impact through their manufacturing, distribution and disposal in terms of incineration. • The use of reusable plastic wheelie bins similarly result in environmental impacts through their manufacturing and distribution. However, this environmental impact should be divided into the number of times the bins are used. On the other hand wastewater is generated each times the bins are returned, as they have to be disinfected.

Environmental Key Issue	Main assumptions concerning environmental impact
	(Included in the assessment of environmental impacts below)
4. Incineration vs. non-burn technologies	*Emission to Air:* Incineration results in immediate conversion of waste to mainly carbon dioxide and the production of inert residues, whereas, non-burn technologies result in a much slower conversion (e.g. 1-50 years) to a combination of methane and carbon dioxide at the landfill. The conversion to gases is, however, inevitable irrespective of the technology used. Methane is generally considered to have a negative greenhouse gas impact, approximately 25 times worse than carbon dioxide. With a given carbon content of the waste, in practical terms, the option is either to covert to CH_4 or CO_2. The ratio of methane and carbon dioxide formation depends, among others, on the aerobic/anaerobic conditions in the landfill body, temperature, availability of water and the biological activity of top cover (if any). In general, the better a landfill is managed and covered with biologically active topsoil the less methane will be emitted. Biologically active topsoil may, if adequately engineered to obtain an even diffusion of landfill gas, to a large extent convert methane produced in the landfill body to carbon dioxide. If deliberate or unintentional burning of waste at the landfill site takes place, the actual emission of pollutants, in particular dioxin/furan, CO and other problematic pollutants will be several magnitudes higher (e.g. 50-1000 times) than when the same waste had been combusted in a controlled environment by means of well-engineered incinerators. Non-burn technologies generally do not emit any pollutants to the air on site, as the energy used in most cases is power, where the pollution takes place at the power plant. All non-burn technologies have system to contain particles and vapour that may carry pathogens to the ambient air. Normally HEPA filters and mostly in combination with a condensation of vapours. If such filters do not work as intended there is a risk of unacceptable emissions to the air. • *Leaching from residues:* Residues from incineration consist of slag/bottom ash and a flue gas-cleaning residue. The bottom ash may leach metals and the flue gas-cleaning residue may leach salts (NaCl, $CaCl_2$ etc.) as well as metals and dioxin/furan that may have to be removed from the flue gas. If bottom ash and flue gas cleaning residues are managed separately, parts of the bottom ash can, after sieving, be used as road base etc. On the other hand residues from non-burn technologies are in essence the same as the input, except for having been size reduced and sterilised. Hence, such residues may leach both nutrients and heavy metals, whereas dioxins/furans are unlikely to be present. Therefore, in addition to the heavy metal load, leachate with nutrients (BOD/COD) will have to be managed at the landfill. *(Included in the assessment of environmental impacts below)*
5 On-site treatment vs. regionalised treatment	• *Emissions from vehicles:* • Regionalised treatment requires most transportation of waste. Hence most pollution from transport is generated in the regionalised scenarios, including emission of CO_2, NO_x, SO_2, particles etc. to the atmosphere. The amount of emissions depends on the size and weight of the vehicle, the distances driven and the weight of the load. • With on-site treatment there is only limited need for the transport of residues for which the volume is significantly reduced, thus eliminating emissions from vehicles to a minimum. • Higher risk of pollution through spillage during accidents etc. due to off site transport, which is not required for on-site scenarios *(Included in the assessment of environmental impacts below)*

Table 11.2 below shows the principle environmental impact categories that have been included in this report during the assessment of scenarios for each step required to produce an integrated HCW management system.

Table 11.2: *Principle Environmental Impact caused by Principle Treatment Scenarios*

Environmental	Status Quo	On-site Incineration	On-site Sterilisation	Off-site Incineration	Off-site Non-burn treatment	Assumptions/Principle Differences
Impacts	**Status Quo Scenario**	**Scenario 1-4 (many inc.)**	**Scenario 1-4 (many NB)**	**Scenario 1-4 (few inc.)**	**Scenario 1-4 (few NB)**	
Manufacturing and distribution of treatment supplies and equipment	• Emission from mining, manufacturing, transport and installation • Emission from final decommissioning • Use of natural energy resources	• Emission from mining, manufacturing, transport and installation • Emission from final decommissioning • Use of natural energy resources	• Emission from mining, manufacturing, transport and installation • Emission from final decommissioning • Use of natural energy resources	• Emission from mining, manufacturing, transport and installation • Emission from final decommissioning • Use of natural energy resources	• Emission from mining, manufacturing, transport and installation • Emission from final decommissioning • Use of natural energy resources	• The same for all scenarios. Hence, will not be quantified in this report
Impacts at health care facility	• Poor placement and handling logistics result in, among others, poor segregation.	• Limited	• Limited	• Limited	• Limited	• The same for all scenarios (except Status Quo).
Impacts during transport	• Use of fuel • Emission from vehicles • Noise impact (non-tangible) • Traffic loading (non-tangible) • Use of water for washing	• No transport needed	• No transport needed	• Use of fuel • Emission from vehicles • Noise impact (non-tangible) • Traffic loading (non-tangible) • Use of water for washing	• Use of fuel • Emission from vehicles • Noise impact (non-tangible) • Traffic loading (non-tangible) • Use of water for washing	• On-site require less transport than regional treatment
Impacts during treatment	• Use of fuel • Use of electricity • Emission from power production • Emissions from plant	• Use of fuel • Use of electricity • Emission from power production • Emissions from plant	• Use of electricity • Emission from power production • Emissions from plant	• Use of fuel • Use of electricity • Emission from power production • Emissions from plant • (Energy recovery not assumed viable)	• • Use of electricity • Emission from power production • Emissions from plant	• More emissions to air from incinerators • Significantly more use of power for non-burn • Regional incinerators can, in principle, recover energy saving fuel or power
Impacts during transport of residues	• Use of fuel • Emission from vehicles • Noise impact (non-tangible) • Traffic loading (non-tangible) • Use of water for washing	• Use of fuel • Emission from vehicles • Noise impact (non-tangible) • Traffic loading (non-tangible) • Use of water for washing	• Use of fuel • Emission from vehicles • Noise impact (non-tangible) • Traffic (non-tangible) • Use of water for washing	• Use of fuel • Emission from vehicles • Noise impact (non-tangible) • Traffic loading (non-tangible) • Use of water for washing	• Use of fuel • Emission from vehicles • Noise impact (non-tangible) • Traffic loading (non-tangible) • Use of water for washing	• Less residue to transport from incinerators compared to non-burn resulting in more emissions from transport (despite compaction)
Impacts at landfill receiving residues	• Leachate production with metals • Loss of land opportunity	• Leachate production with metals • Loss of land opportunity	• Leachate production with nutrients • Leachate production with metals • Emission of Methane • Emission of Carbon dioxide • Risk of fire (non-tangible) • Loss of land opportunity	• • Leachate production with metals • Loss of land opportunity	• Leachate production with nutrients • Leachate production with metals • Emission of Methane • Emission of Carbon dioxide (CO_2/kg) • Risk of fire (non-tangible) • Loss of land opportunity	• Higher greenhouse gas impact of non-burn • More nutrient loading from non-burn residues • Concentration of metals & salts in residues from incinerators • Higher loss of land opportunities (landfill volume) for non-burn technologies

11.1.1 Calculation of the Environmental Impacts of Scenarios

The environmental impact for the selected scenarios has been calculated below based on the indicated unit emissions. The unit emission rates have been determined based on various literatures with some adaptation to assumed South African conditions (e.g. sulphur level of South Africa diesel, etc.).

Naturally, a number of assumptions have been made for the determination of the above emission rates for various treatment technologies, vehicles, etc. The emission rates are shown in the tables below. Thus, allowing for re-calculation should other emission rates prove more suitable in the future. The calculation of the monthly figures is based on the estimated emission rates and usual conversion figures for energy, number of units, calorific value, etc.

Only the most significant impacts have been included, hence, the following assumptions and considerations for omissions are made:

Table 11.3: *Main Assumptions and Considerations for Omissions from the Estimation of Environmental Impact.*

- *Included:* Direct emissions from: i) off-site transport to treatment plant, ii) emission caused by operation of on-site and of-site treatment plants, making appropriate allowance for the alternative treatment technologies, iii) emissions from external transport of waste and residues, iv) emission from degradation and leaching of residues in landfill
- *Included:* emissions from manufacturing of consumables. For the purpose of the modelling it is assumed that all waste in Gauteng is either i) disposed in 140 litre cardboard boxes with a liner or ii) in wheelie bins (240 or 770 litre). Sharps containers are not modelled separately, and assumed to be equal in terms of manufacturing impacts for all scenarios.
- *Excluded:* i) emission caused by manufacturing (other than waste containers described above) and distribution of equipment (consumables, machinery and structures), land development, etc. ii) supplanted emissions saved due to saved fossil fuel consumption due to recovery of energy, iii) emission from machinery used for landfill operation, iv) any other type of emission not mentioned above
- For the purpose of including the energy recovery potential calculations have been made with and without energy recovery. It is assumed that only 33% of the calorific value can viably be recovered as *energy from regionalised incineration plants only*.
- In calculation of energy consumed, it is assumed that the fuel used for transport is South African quality diesel (high sulphur)
- 17% (w/w) bottom ash and air pollution control residues are assumed from incinerators
- 100% (w/w) residue is assumed from non-burn technologies
- It is assumed that all residues generated are landfilled (no recycling)
- For all incinerators it is assumed that the DEAT Emission Guidelines are complied with and equal to the average monthly emissions
- It is assumed that Methane contributes 25 times more towards global warming (green house gas impact) than carbon dioxide
- It is assumed that 50% of degradable carbon deposited in landfills is emitted as methane based on current landfill practises.
- Assuming 14 Nm^3 wet flue gas per kg waste; 15% moisture; 9.5% CO_2 in dry gas.
- Emission of dioxins/furans from vehicles is not well investigated literature review has resulted in an assumption of 2.5 pg TEQ-I Dioxin per kilometre driven for non-leaded petrol and diesel vehicles. In reality diesel vehicles may emit somewhat less dioxin/furan but there is little reliable data to substantiate that.

Table 11.4: *Assumed Emission Rates for Incinerators (complying and non-complying)*

Type	DEAT Emission Guidelines (Sch 2, Pro 39 APP Act 1965)	Assumed for Complying Incinerators (Future Scenarios)	Assumed for Non-complying incinerators (Status Quo)	Emissions per kg of HCRW (complying)	Emissions per kg of HCRW (non-complying)
Units	**mg/Nm^3**	**mg/Nm^3**	**mg/Nm^3**	**mg/kg waste**	**mg/kg waste**
PM/dust	180.00	35	180	417	2,142
CO2		187,815	187,815	2,234,999	2,234,999
CO	-	50	250	595	2,975
TOC	-			-	-
Dioxin/furan (ng) TEQ	0.20	0.20	1.00	2.38	11.90
HCl	30.00	30	150	357	1,785
HF	-			-	-
SO_2	25.00	25	250	298	2,975
NO_x	-	200	300	2,380	3,570
NH_3	-			-	-
Pb, (same for Cr, Be, Ar, As, Sb, Ba, Ag, Co, Cu, Mn, Sn, V, Ni)	0.50	0.50	1.00	5.95	11.90
Cd (same for Tl)	0.05			-	-
Hg	0.05	0.05	0.20	0.60	2.38
Dry flue gas amount (Nm3/kg waste)					11.9
Ref. Cond.	11% O2, 273 Kelvin, 101.3 kPa				

Table 11.5 below indicates the assumed amounts of waste being treated in various on-site and off-site incinerators and non-burn technologies for the different scenarios.

Table 11.5: *Assumptions for Treatment Capacity in the Scenarios (per month)*

		Sc. 0	**Scenarios 1, 2, 3 and 4**					
ASSUMPTIONS	**Unit**	**Status Quo**	**Regional Incineration**	**Regional Non-burn**	**On-site Incineration**	**On-site Non-burn**	**Mix regional treatment**	**Mix all**
Waste Treatment			-	-	-	-	-	-
On-site inc	tonne/m	632	-	-	1,172			293
On-site non-burn	tonne/m		-	-		1,172		293
Regional Inc	tonne/m	540	1,172	-			586	293
Regional Non-burn	tonne/m		-	1,172			586	293
total waste	**T/m**	1,172	1,172	1,172	1,172	1,172	1,172	1,172
Amounts of residues								
Residue from Inc on-site	tonne/m	107	-	-	199	-	-	50
Residue from NB on-site	tonne/m	-	-	-	-	1,172	-	293
Residue from Inc Regional	tonne/m	92	199	-	-	-	100	50
Residue from NB Regional	tonne/m	-	-	1,172	-	-	586	293
Total residue	**T/m**	199	199	1,172	199	1,172	686	686

Table 11.6 below shows an estimated emission caused by the manufacturing of receptacles used in the different scenarios (card board boxes or different sizes of wheelie bins).

Table 11.6: *Monthly Impacts from manufacturing of Cardboard boxes, 240 litre, 770 litre wheelie bins or reusable bins for all of Gauteng.*

Impact from container manufacturing		**Status Quo**	**Scenario 1**	**Scenario 2**	**Scenario 3**	**Scenario 4**
Impact prod. cardboard boxes/wheelie bins		**Status Quo**	**Scenario 1**	**Scenario 2**	**Scenario 3**	**Scenario 4**
Total Energy	MJ	3,347,493	3,347,493	365,372	294,601	308,146
Water	kg water	6,500,265	6,500,265	641,582	360,737	317,127
Waste	kg waste	8,743	8,743	6,146	5,268	7,684
Loss of land	m2 land	1.2	1.2	0.9	0.7	1.1
CO	kgCO	87.8	87.8	2.6	2.2	0.7
CO2	kgCO2	121,628	121,628	16,795	12,229	28,657
Dust	kgDust	157	157	10	8	14
HF	kgHF	0.0200	0.0200	0.0054	0.0046	0.0015
Hg	kgHG	0.0054	0.0054	0.0014	0.0012	0.0004
NOx	kgNOx	375	375	51	40	54
SO2	kgSO2	802	802	71	55	77
COD	kgCOD	1,370	1,370	22	14	21
HCl	kgHCl	0.4	0.4	0.1	0.1	0.0
CH4	kgCH4	79	79	22	19	6

Note: For details refer to annexure 5.

Table 11.7: *Relative Impact from Manufacturing of Receptacles in Percentage of the Largest Value of Each Parameter (ref. Table 11.6)*

Impact from container manufacturing	**Status Quo**	**Scenario 1**	**Scenario 2**	**Scenario 3**	**Scenario 4**
Prod. cardboard box/reusable bin	**Status Quo**	**Scenario 1**	**Scenario 2**	**Scenario 3**	**Scenario 4**
Total Energy	100%	100%	11%	9%	9%
Water	100%	100%	10%	6%	5%
Waste	100%	100%	70%	60%	88%
Loss of land	100%	100%	70%	60%	88%
CO	100%	100%	3%	3%	1%
CO2	100%	100%	14%	10%	24%
Dust	100%	100%	6%	5%	9%
HF	100%	100%	27%	23%	8%
Hg	100%	100%	26%	23%	7%
NOx	100%	100%	14%	11%	15%
SO2	100%	100%	9%	7%	10%
COD	100%	100%	2%	1%	2%
HCl	100%	100%	28%	24%	8%
CH4	100%	100%	28%	24%	8%

Note: For details refer to annexure 5.

Table 11.8 below shows the unit emission rates assumed per kilogram of waste to the left and the result of the calculations based on the assumptions above to the right.

Table 11.8: *Standard Unit Emission Rates and Result of Calculations of Emissions (per month)*

				Status Quo	Scenarios 1, 2, 3 and 4					
Impact Transport HCRW from Institutions				**Status Quo**	**Regional Incineration**	**Regional Non-burn**	**On-site Incineration**	**On-site Non-burn**	**Mix regional treatment**	**Mix all**
NOx	2.1	mg/kg	kgNOx	1.16	2.51	2.51			2.51	1.25
SO2	0.8	mg/kg	kgSO2	0.45	0.98	0.98			0.98	0.49
CO	1.8	mg/kg	kgCO	0.98	2.13	2.13			2.13	1.07
Dust	0.4	mg/kg	kgDust	0.24	0.52	0.52			0.52	0.26
Hg		mg/kg	kgHg							
Dioxin (TEQ-I) (diesel)	0.0025	ngDioxin/km	gDioxin (TE	0.0002	0.0003	0.0003			0.0003	0.0001
Liter fuel/kg	0.010	l/kg	liter	6,318	11,720	11,720			11,720	5,860
Impact Treatment Plants				**Status Quo**	**Regional Incineration**	**Regional Non-burn**	**On-site Incineration**	**On-site Non-burn**	**Mix regional treatment**	**Mix all**
Non-burn										
Use of Power (non-burn)	0.15	kWh/kg	MJ			632,880		632,880	316,440	316,440
Use of water	0.08	l/kg	Litre			93,760		93,760	46,880	46,880
Incineration Non-complying	Complying									
HCl (incineration) 1,785.0	357.0	mg/kg	kgHCl	2,092	418		418		209	209
NOx 3,570.0	2,380.0	mg/kg	kgNOx	4,184	2,789		2,789		1,395	1,395
CO 2,975.0	595.0	mg/kg	kgCO	3,487	697		697		349	349
SO2 2,975.0	297.5	mg/kg	kgSO2	3,487	349		349		174	174
Dust 2,142.0	416.5	mg/kg	kgDust	2,510	488		488		244	244
Hg 2.38	0.60	mg/kg	kgHg	2.79	0.70		0.70		0.35	0.35
Dioxin (TEQ-I) 11.90	2.38	ng/kg	mgTEQ	0.0139	0.0028		0.0028		0.0014	0.0014
CO2 2,234,999	2,234,999	mg/kg	kgCO2	2,619,418	2,619,418		2,619,418		1,309,709	1,309,709
Use of Power 108.0	108.0	kJ/kg	MJ	126,576	126,576		126,576		63,288	63,288
Use of Fuel 216.0	216.0	kJ/kg	MJ	253,152	253,152		253,152		126,576	126,576
Supplanted energy	700.0	kJ/kg	MJ		-820,392				-410,196	-205,098
Impact Transport of Residues				**Status Quo**	**Regional Incineration**	**Regional Non-burn**	**On-site Incineration**	**On-site Non-burn**	**Mix regional treatment**	**Mix all**
NOx	1.4	mg/kg	kgNOx	0.27	0.27	**1.62**	0.27	**1.62**	0.95	0.95
SO2	0.4	mg/kg	kgSO2	0.08	0.08	**0.49**	0.08	**0.49**	0.29	0.29
CO	0.9	mg/kg	kgCO	0.18	0.18	**1.05**	0.18	**1.05**	0.62	0.62
Dust	0.2	mg/kg	kgDust	0.05	0.05	**0.28**	0.05	**0.28**	0.16	0.16
Dioxin (TEQ-I) (diesel)	0.00252	ng/km	gDioxin(TE	0.00003	0.00003	0.00015	0.00003	0.00015	0.00009	0.00009
Liter fuel/kg	0.005	l/kg	liter	996	996	**5,860**	996	**5,860**	3,428	3,428
Impact at Power Plants (Coal -> Power)				**Status Quo**	**Regional Incineration**	**Regional Non-burn**	**On-site Incineration**	**On-site Non-burn**	**Mix regional treatment**	**Mix all**
Power	-		kWh/month	35,160	35,160	175,800	35,160	175,800	105,480	105,480
CO2	420.0	g/kWh	kgCO2	14,767	14,767	73,836	14,767	73,836	44,302	44,302
SO2	1.0	g/kWh	kgSO2	35	35	176	35	176	105	105
NOx	0.7	g/kWh	kgNOx	25	25	123	25	123	74	74
Dust	0.2	g/kWh	kgDust	7.0	7.0	35.2	7.0	35.2	21.1	21.1
Impact at Landfill				**Status Quo**	**Regional Incineration**	**Regional Non-burn**	**On-site Incineration**	**On-site Non-burn**	**Mix regional treatment**	**Mix all**
Non-burn										
Leachate	0.01	l/kg	liter			11,720		11,720	5,860	5,860
COD	1,100	mgCOD/kg	kgCOD			1,289		1,289	645	645
Hg	0.005	mgHg/kg	kgHg			0.01		0.01	0.00	0.00
CH4	310,000	mgCH4/kg	kgCH4			363,320		363,320	181,660	181,660
CO2	850,000	mgCO2/kg	kgCO2			996,200		996,200	498,100	498,100
Loss of land	0.00014	m2/kg	m2			**164**		**164**	**82**	**82**
Incineration										
Leachate	0.01	l/kg	liter	1,992	1,992		1,992		996	996
Hg	0.1	mgHg/kg	kgHg	0.02	0.02		0.02		0.01	0.01
Loss of land	0.000024	m2/kg	m2	4.74	4.74		4.74		2.37	2.37

11.1.2 Results of the Assessment of Environmental Impact

Table 11.9 and 11.10 below summarise the environmental impacts calculated in Table 11.6 and 11.7 above, based on the stated assumptions and modelling.

Table 11.9: *Total Emissions Calculated (per month) (Scenario Numbers refer to Table 7.6)*

TOTAL Incl. Manufacturing of containers				**Status Quo**	**Scenario 1 (Cardboard boxes)**						**Scenario 2 (240 litre wheelie bins)**				
			Scenario Number:	*0.1*	*1.2.2*	*1.1.2&1.3.2*	*1.2.4*	*1.1.4&1.3.4*	*1.3.5*	*1.3.5*	*2.2.2*	*2.1.3 & 2.3.2*	*2.2.4*	*2.1.4&2.3.4*	*2.3.5*
Total Impact				**Status Quo**	**Regional Incin.**	**Regional Non-burn**	**On-site Incin.**	**On-site Non-burn**	**Mix regional treatment**	**Mix all**	**Regional Incin.**	**Regional Non-burn**	**On-site Incin.**	**On-site Non-burn**	**Mix regional treatment**
CH4		Air	kgCH4	79	79	363,399	79	363,399	181,739	181,739	22	363,342	22	363,342	181,682
CO		Air	kgCO	3,576	787	91	785	89	439	438	702	6	700	4	354
CO2		Air	kgCO2	2,755,813	2,755,813	1,191,664	2,755,813	1,191,664	1,973,738	1,973,738	2,650,980	1,086,831	2,650,980	1,086,831	1,868,906
COD		Water	kgCOD	1,370	1,370	2,659	1,370	2,659	2,014	2,014	22	1,311	22	1,311	666
Dust		Air	kgDust	2,675	653	193	652	192	423	423	506	46	505	46	276
HCl		Air	kgHCl	2,092	418		418		209	209	419	0	419	0	209
Hg		Air	kgHg	3	0.72	0.01	0.72	0.01	0.36	0.36	0.71	0.00	0.71	0.00	0.36
NOx		Air	kgNOx	4,585	3,191	502	3,189	499	1,846	1,845	2,868	179	2,866	176	1,523
SO2		Air	kgSO2	4,325	1,187	980	1,186	979	1,084	1,083	456	248	455	247	352
Dioxin (TEQ-I)		Air	mgTEQ	0.014	0.0031	0.0004	0.0028	0.0001	0.0018	0.0016	0.0031	0.0004	0.0028	0.0001	0.0018
Green-house gas (as CO2)		Air	kgCO2	2,757,786	2,757,786	10,276,636	2,757,786	10,276,636	6,517,211	6,517,211	2,651,528	10,170,378	2,651,528	10,170,378	6,410,953
Land/Waste Impacts															
Leachate production		Water	liter	1,992	1,992	11,720	1,992	11,720	6,856	6,856	1,992	11,720	1,992	11,720	6,856
Liter fuel/kg		Resource	liter	7,314	12,716	17,580	996	5,860	15,148	9,288	12,716	17,580	996	5,860	15,148
Loss of land		Resource	m2	5	6.0	165.3	6.0	165.3	85.6	85.6	5.6	164.9	5.6	164.9	85.3
Energy Impacts															
Brut Energy (excl diesel)		Resource	MJ	3,727,221	3,727,221	3,980,373	3,727,221	3,980,373	3,853,797	3,853,797	745,100	998,252	745,100	998,252	871,676
Use of diesel		Resource	Liter	7,314	12,716	17,580	996	5,860	15,148	9,288	12,716	17,580	996	5,860	15,148
Total energy (excl. Suppla)		Resource	MJ	3,988,338	4,181,189	4,607,979	3,762,785	4,189,575	4,394,584	4,185,382	1,199,069	1,625,858	780,665	1,207,454	1,412,463

TOTAL Incl. Manufacturing of containers			Scenario 3 (770 litre wheelie bins)						Scenario 4 (resuable bins)					
		Scenario Number:	*3.2.2*	*3.1.2&3.3.2*	*3.2.4*	*3.1.4&3.3.4*	*3.3.5*	*3.3.5*	*4.2.2*	*4.1.2&4.3.2*	*4.2.4*	*4.1.4&4.3.4*	*4.3.5*	*4.3.5*
Total Impact			**Regional Incin.**	**Regional Non-burn**	**On-site Incin.**	**On-site Non-burn**	**Mix regional treatment**	**Mix all**	**Regional Incin.**	**Regional Non-burn**	**On-site Incin.**	**On-site Non-burn**	**Mix regional treatment**	**Mix all**
CH4	Air	kgCH4	19	363,339	19	363,339	181,679	181,679	6	363,326	6	363,326	181,666	181,666
CO	Air	kgCO	702	5	700	3	354	353	706	9	704	7	357	356
CO2	Air	kgCO2	2,646,414	1,082,265	2,646,414	1,082,265	1,864,339	1,864,339	2,634,191	1,070,042	2,634,191	1,070,042	1,852,117	1,852,117
COD	Water	kgCOD	14	1,304	14	1,304	659	659	6	1,295	6	1,295	651	651
Dust	Air	kgDust	503	44	503	43	274	273	502	42	501	41	272	272
HCl	Air	kgHCl	419	0	419	0	209	209	424	6	424	6	215	215
Hg	Air	kgHg	0.71	0.00	0.71	0.00	0.36	0.36	7	6	7	6	6	6
NOx	Air	kgNOx	2,857	168	2,855	165	1,512	1,511	2,823	133	2,820	131	1,478	1,477
SO2	Air	kgSO2	440	233	439	232	336	336	391	183	390	182	287	287
Dioxin (TEQ-I)	Air	mgTEQ	0.0031	0.0004	0.0028	0.0001	0.0018	0.0016	0.0031	0.0004	0.0028	0.0001	0.0018	0.0016
Green-house gas (as C(	Air	kgCO2	2,646,883	10,165,734	2,646,883	10,165,734	6,406,308	6,406,308	2,634,336	10,153,187	2,634,336	10,153,187	6,393,761	6,393,761
Land/Waste Impacts														
Leachate production	Water	liter	1,992	11,720	1,992	11,720	6,856	6,856	1,992	11,720	1,992	11,720	6,856	6,856
Liter fuel/kg	Resource	liter	12,716	17,580	996	5,860	15,148	9,288	12,716	17,580	996	5,860	15,148	9,288
Loss of land	Resource	m2	5.5	164.8	5.5	164.8	85.1	85.1	5.8	165.2	5.8	165.2	85.5	85.5
Energy Impacts														
Brut Energy (excl diese	Resource	MJ	674,329	927,481	674,329	927,481	800,905	800,905	687,874	941,026	687,874	941,026	814,450	814,450
Use of diesel	Resource	Liter	12,716	17,580	996	5,860	15,148	9,288	12,716	17,580	996	5,860	15,148	9,288
Total energy (excl. Sup	Resource	MJ	1,128,297	1,555,087	709,893	1,136,683	1,341,692	1,132,490	1,141,842	1,568,632	723,438	1,150,228	1,355,237	1,146,035

Table 11.10: *Totals for Emissions Calculated Expressed in Percent of Highest Value of each Parameter*

TOTAL Incl. Manufacturing of containers			**Status Quo**	**Scenario 1 (Cardboard boxes)**							**Scenario 2 (240 litre wheelie bins)**				
		Scenario Number:	*0.1*	*1.2.2*	*1.1.2&1.3.2*	*1.2.4*	*1.1.4&1.3.4*	*1.3.5*	*1.3.5*	*2.2.2*	*2.1.3 & 2.3.2*	*2.2.4*	*2.1.4&2.3.4*	*2.3.5*
Total Impact			**Status Quo**	**Regional Incin.**	**Regional Non-burn**	**On-site Incin.**	**On-site Non-burn**	**Mix regional treatment**	**Mix all**	**Regional Incin.**	**Regional Non-burn**	**On-site Incin.**	**On-site Non-burn**	**Mix regional treatment**
CH4	Air	kgCH4	0%	0%	100%	0%	100%	50%	50%	0%	100%	0%	100%	50%
CO	Air	kgCO	100%	22%	3%	22%	2%	12%	12%	20%	0%	20%	0%	10%
CO2	Air	kgCO2	100%	100%	43%	100%	43%	72%	72%	96%	39%	96%	39%	68%
COD	Water	kgCOD	52%	52%	100%	52%	100%	76%	76%	1%	49%	1%	49%	25%
Dust	Air	kgDust	100%	24%	7%	24%	7%	16%	16%	19%	2%	19%	2%	10%
HCl	Air	kgHCl	100%	20%		20%		10%	10%	20%	0%	20%	0%	10%
Hg	Air	kgHg	100%	26%	0%	26%	0%	13%	13%	25%	0%	25%	0%	13%
NOx	Air	kgNOx	100%	70%	11%	70%	11%	40%	40%	63%	4%	63%	4%	33%
SO2	Air	kgSO2	100%	27%	23%	27%	23%	25%	25%	11%	6%	11%	6%	8%
Dioxin (TEQ-I)	Air	mgTEQ	100%	22%	3%	20%	1%	13%	12%	22%	3%	20%	1%	13%
Green-house gas (as CO2)	Air	kgCO2	27%	27%	100%	27%	100%	63%	63%	26%	99%	26%	99%	62%
Land/Waste Impacts														
Leachate production	Water	liter	17%	17%	100%	17%	100%	59%	59%	17%	100%	17%	100%	59%
Liter fuel/kg	Resource	liter	42%	72%	100%	6%	33%	86%	53%	72%	100%	6%	33%	86%
Loss of land	Resource	m2	3%	4%	100%	4%	100%	52%	52%	3%	100%	3%	100%	52%
Energy Impacts														
Brut Energy (excl diesel)	Resource	MJ	94%	94%	100%	94%	100%	97%	97%	19%	25%	19%	25%	22%
Use of diesel	Resource	Liter	42%	72%	100%	6%	33%	86%	53%	72%	100%	6%	33%	86%
Total energy (excl. Suppla)	Resource	MJ	87%	91%	100%	82%	91%	95%	91%	26%	35%	17%	26%	31%

TOTAL Incl. Manufacturing of containers			Scenario 3 770 litre wheelie bins)						Scenario 4 (resuable bins)					
		Scenario Number:	*3.2.2*	*3.1.2&3.3.2*	*3.2.4*	*3.1.4&3.3.4*	*3.3.5*	*3.3.5*	*4.2.2*	*4.1.2&4.3.2*	*4.2.4*	*4.1.4&4.3.4*	*4.3.5*	*4.3.5*
Total Impact			**Regional Incin.**	**Regional Non-burn**	**On-site Incin.**	**On-site Non-burn**	**Mix regional treatment**	**Mix all**	**Regional Incin.**	**Regional Non-burn**	**On-site Incin.**	**On-site Non-burn**	**Mix regional treatment**	**Mix all**
CH4	Air	kgCH4	0%	100%	0%	100%	50%	50%	0%	100%	0%	100%	50%	50%
CO	Air	kgCO	20%	0%	20%	0%	10%	10%	20%	0%	20%	0%	10%	10%
CO2	Air	kgCO2	96%	39%	96%	39%	68%	68%	96%	39%	96%	39%	67%	67%
COD	Water	kgCOD	1%	49%	1%	49%	25%	25%	0%	49%	0%	49%	24%	24%
Dust	Air	kgDust	19%	2%	19%	2%	10%	10%	19%	2%	19%	2%	10%	10%
HCl	Air	kgHCl	20%	0%	20%	0%	10%	10%	20%	0%	20%	0%	10%	10%
Hg	Air	kgHg	25%	0%	25%	0%	13%	13%	239%	213%	239%	213%	226%	226%
NOx	Air	kgNOx	62%	4%	62%	4%	33%	33%	62%	3%	62%	3%	32%	32%
SO2	Air	kgSO2	10%	5%	10%	5%	8%	8%	9%	4%	9%	4%	7%	7%
Dioxin (TEQ-I)	Air	mgTEQ	22%	3%	20%	1%	13%	12%	22%	3%	20%	1%	13%	12%
Green-house gas (as C(	Air	kgCO2	26%	99%	26%	99%	62%	62%	26%	99%	26%	99%	62%	62%
Land/Waste Impacts														
Leachate production	Water	liter	17%	100%	17%	100%	59%	59%	17%	100%	17%	100%	59%	59%
Liter fuel/kg	Resource	liter	72%	100%	6%	33%	86%	53%	72%	100%	6%	33%	86%	53%
Loss of land	Resource	m2	3%	100%	3%	100%	52%	52%	4%	100%	4%	100%	52%	52%
Energy Impacts														
Brut Energy (excl diese	Resource	MJ	17%	23%	17%	23%	20%	20%	17%	24%	17%	24%	20%	20%
Use of diesel	Resource	Liter	72%	100%	6%	33%	86%	53%	72%	100%	6%	33%	86%	53%
Total energy (excl. Sup	Resource	MJ	24%	34%	15%	25%	29%	25%	25%	34%	16%	25%	29%	25%

Table 11.10 shows the relative percentage of the values in table 11.7 compared to the highest value for each parameter.

Tables 11.9 and 11.10 above contain numerous data that can be used for various conclusions. The main conclusions of the environmental impact analysis includes:

Table 11.11 *Conclusions from the Environmental Assessment of Alternatives*

No.	Element	Conclusion
1.	Packaging – emissions	Use of disposable cardboard boxes causes a significantly higher environmental impact from i) use of energy, ii) greenhouse gases, iii) use of water, iv) COD, v) NO_x, vi) SO_2, and vii) dust compared to use of reusable wheelie bins Especially in terms of energy used for manufacturing cardboard boxes requires 9 times more energy and reusable bins
2.	Packaging – use of material and water	Use of disposable cardboard boxes results in the consumption of 1100 tonnes of cardboard and 160 tonnes of polypropylene per years. Even though water is required for washing of reusable bins the water consumed in the manufacturing of cardboard is still 10 times higher that using reusable containers requiring washing.
3.	Transport from institutions	For obvious reasons the use of on-site treatment plants results in the lowest environmental impact from transportation, whereas the use of regional non-burn treatment plants result in the highest impact as the entire waste generation must be transported of-site for further treatment. In the on-site scenarios only residues are to be transported for final disposal.
4.	Treatment plants	Incineration results in immediate transformation of waste into gaseous compounds whereas the non-burn technologies sterilises and compacts the waste for subsequent transformation in a landfill. Hence, the emissions to the air from incineration are a significant environmental impact and a similar impact does not occur at the non-burn plants. However, when including subsequent emissions at landfills receiving both ashes and flue gas cleaning products or residues from non-burn plants there is significant emission caused by using non-burn technologies also (see below). Furthermore, the majority of energy used by non-burn plants is electricity, which in SA is produced among others at coal-fired power plants equipped with limited flue gas cleaning. When including the emissions caused during the electricity production (but excluding the emissions at the landfill), non-burn treatment still leads to less (half) but comparable emissions than incineration due to the quality of coal and power plants in SA whereas incineration leads to 14 times more dust and 22 times more NO_x as well is a very significant CO_2 emission compared to non-burn. Of particular concern is the emission of NO_x, HCl, SO_2, dust, Hg, and Dioxin from incineration. In terms of energy, the non-burn plants use 30% more energy for treatment than incinerators. Energy recovery from incinerators is not assumed feasible at this scale.
5.	Transport of residues	Transport of residues requires 6 times more fuel for non-burn treatment than if incineration is used because of the larger volumes of waste to be transported.
6.	Impact at landfill	Because of the difference in pollution parameters generated by deposited residues from incineration and non-burn plants, the main difference between the two principle treatment methods is: i) need for landfill area is 30 times higher if using non-burn than for incineration, ii) there is 6 times more leachate generation but there is a considerable difference in the leachate quality.
7.	Assessment of total impact of scenarios compared to Status	Practically, the Status Quo scenario is for all parameters worse than any of the proposed scenarios. For example, the following relative environmental impacts are calculated: CH4 $4 \times$ the best alternative CO $1100 \times$ the best alternative CO_2 $2.5 \times$ the best alternative

No.	Element	Conclusion
	Quo	COD 1 × the best alternative Dust 14 × the best alternative Hg 2300 × the best alternative NO_x 9 × the best alternative SO_2 4 × the best alternative Dioxin (TEQ-I) 100 × the best alternative Green-house gas (as CO_2) 1 × the best alternative Litre fuel/kg 7 × the best alternative Loss of land 1 × the best alternative Brut Energy (excl diesel) 6 × the best alternative Use of diesel 7 × the best alternative Total energy 6 × the best alternative
8.	Assessment of total impact of proposed new scenarios	In general the following statements can be made based on the environmental impact assessment calculations: 1. Non-burn plants causes the highest "greenhouse" gas emission (×4) 2. Use of incineration causes more dioxin (×7), dust, HCl, Hg, NO_x, than use of non-burn 3. Need for landfill volume is much higher when using non-burn equal to a 25 times high need for landfill area compared to incineration. 4. Manufacturing of cardboard boxes leads to much higher use of water (×10) and energy (×10) as well as much higher emission of dust, COD, acid gases etc. compared to reusable PP containers
9.	General conclusions	1. It is not completely clear if non-burn or incineration is the environmentally best options as the types of impacts and emissions caused are very different. 2. It is clearly environmentally better to use reusable wheelie bins that to continue using disposable cardboard boxes. 3. In environmental terms, and assuming that the same environmental standards are being up-held, there is no significant difference in impacts using on-site or regionalised treatment plants. However, it is expected to have a significant negative financial impact to introduce high environmental standards for on-site treatment plants. 4. Dioxin emissions from transportation are 10% of the total dioxin emission in case of regional incineration. In the Status Quo scenario there is 5 times higher dioxin emission than in the scenarios with compliant regionalised incinerators. In the non-burn scenarios there is assumed to be dioxin generation from transportation only. 5. Non-burn scenarios lead to approximately double nutrient loading of the aquatic and soil environment compared to incineration scenarios.

11.2 Assessment of Health and Safety Implications

Health and safety risks and impacts are often closely linked for HCRW management. One of the main reasons for investigating other types of containers for sharps and HCRW, in general, is to address the safety problems currently being experienced with, in particular, needle stick injuries, but also injuries due to heavy and awkward lifts.

The main health and safety implications of the HCRW management, and hence, the selected scenarios are assumed to be those presented in table 11.12a below.

Table 11.12a: *Assessment of the Main Health and Safety Impacts of the Selected Scenarios.*

Issue	Status Quo	Scenario 1	Scenario 2	Scenario 3	Scenario 4
Description of Scenario:	**Present System**	**Improved Environmental Performance of Present System**	**Improved Environmental Performance and New Containers (240 litre)**	**Improved Environmental Performance and New Containers (770 litre)**	**Improved Environmental Performance and New Reusable platic boxes**
1. Needle stick injuries in wards	Relative high risk and occurrence of injuries	Reduced risk due to training	Reduced risk due to training	Reduced risk due to training	Reduced risk due to training and provision of puncture proof containers in wards
2. Needle stick injuries during internal collection and internal storage	Relative high risk and occurrence of injuries	Reduced risk due to training	Reduced as the wheelie bin is puncture proof	Potential higher risk, if sharps are not separated correctly	Reduced considerable due to puncture proof primary containers
3. Needle stick injuries during internal and external transport and treatment	Relative high risk and occurrence of injuries	Reduced risk due to training	Considerably reduced due to new containers	Considerably reduced due to new containers	Eliminated due to puncture proof primary containers
4. Injuries due to heavy and awkward lifts	Relative high risk and occurrence of injuries	Reduced risk due to training	Considerably reduced due to new containers	Considerably reduced due to new containers	Moderately reduced by use of trolleys, but needs to be lifted
5. Impact of spills at institutional level	Relative high risk and occurrence of injuries	Reduced risk due to training	Reduced risk due to training and new containers	Reduced risk due to training and new containers	Very reduced risk due to training and new containers
6. Impact of spills off site	Relative high risk and occurrence of injuries	Reduced risk due to training	Considerably reduced due to training and new containers	Considerably reduced due to training and new containers	Very reduced risk due to training and new containers
7. Health and Safety for patients and visitors	Relative high risk and occurrence of injuries	Reduced risk due to training and less accessible containers.	Reduced risk due to training and less accessible containers.	Reduced risk due to training and less accessible containers.	Reduced risk due to training and less accessible containers.
8. Health and Safety for waste reclaimers at landfills	Relative high risk and occurrence of injuries	Reduced risk due to training	Reduced risk due to training	Reduced risk due to training	Reduced risk due to training
9. Health and Safety for general public	Air pollution and water pollution risk Illegal disposal occurs posing a significant health and safety risk to	Limited risk. Illegal disposal should be minimised with the envisaged licensing and reporting in a	Limited risk. Illegal disposal should be minimised with the envisaged licensing and reporting in a	Limited risk. Illegal disposal should be minimised with the envisaged licensing and reporting in a	Limited risk. Illegal disposal should be minimised with the envisaged licensing and reporting in a

Issue	Status Quo	Scenario 1	Scenario 2	Scenario 3	Scenario 4
Description of Scenario:	**Present System**	**Improved Environmental Performance of Present System**	**Improved Environmental Performance and New Containers (240 litre)**	**Improved Environmental Performance and New Containers (770 litre)**	**Improved Environmental Performance and New Reusable platic boxes**
	the community	HCW Information System	HCW Information System	HCW Information System	HCW Information System

In the assessment presented in Table 11.12 above it is assume that specialised training and awareness activities are launched throughout Gauteng's health care sector, while improved receptacles are introduced in the Provincial sector, possibly followed by the private sector also.

It appears that training and awareness is perhaps the most important factor to improve the occupational as well as public health and safety impacts of HCRW management, with provision and adequate placement of more efficient HCRW containers as another key issue.

A subjective assessment of the perceived risk level and importance of risk parameter was conducted among the Consultants that resulted in the subjective assessment of risks for the scenarios presented in table 11.12b. The subjective assessment, *which merely reflects the average perception of a number of health care waste specialists*, show that the Status Quo (Scenario 0) is considered the most risky scenario whereas Scenario 4 (reusable containers) is considered the safes scenario closely followed by the 240 litre wheelie bin (Scenario 2) and the 770 litre wheelie bin (Scenario 3). The scenario based on the improved manual handling of cardboard boxes (Scenario 1) is not considered significantly safer than the Status Quo (Scenario 0).

Table 11.12b: *Subjective Assessment of Risk Level and Importance of Risk Factor Conducted amount the Project Consultants (averages of the individual judgements)*

Risk factors (e.g. needle stick, egonomic, accidents, spills, fire, etc.)	Weight	Subjective assessment of risk level (0-5)				
		Scenario 0	Scenario 1	Scenario 2	Scenario 3	Scenario 4
	(0-5)	Status Quo	Improved Cardboard Box System	240 litre Wheelie Bin	770 litre Wheelie Bin	Reusable Plastic Box System
Distribution and supply of waste equipment	1.0	1.3	1.3	1.0	1.3	2.0
Use and design of sharps' container	5.0	4.5	4.5	2.8	2.8	2.8
Use of primary container for HCRW (e.g. pedal bin, bag on nurse trolley, box etc.)	3.3	3.3	3.3	3.5	3.5	2.3
Transfer from primary to secondary container (from primary to larger container, e.g. in sluice)	4.3	2.5	2.5	3.5	3.8	0.3
Use of secondary container for HCRW (e.g. placed in sluice or box in ward)	3.5	3.3	3.3	3.0	3.8	1.3
Transfer from Secondary container to final container (if applicable or from secondary to reusable container/wheelie bin)	4.3	-	-	2.5	3.3	-
Collection and internal transport of final container (Box, wheelie bin, reusable box)	3.5	4.0	3.5	1.0	1.0	1.8
Storage at central on-site storage	2.5	3.8	3.3	1.0	1.0	1.5
Collection from on-site storage	3.3	3.8	3.3	1.3	1.3	1.8
Transport on public roads	2.3	2.3	2.3	1.5	1.5	1.5
Unloading and temporary placement at treatment plant	3.8	4.0	3.0	1.3	1.3	2.0
Feeding into treatment plant	3.8	4.0	4.0	1.8	1.8	2.3
Final Weighed Score		**10.6**	**9.9**	**7.2**	**7.8**	**5.3**

Weighing factor	
Not relevant	0
Not important	1
Somewhat important	2
Important	3
Very important	4
Extremely important	5

Risk Level	
No risk	0
Very little risk	1
Little risk	2
Acceptable risk	3
High risk	4
Unacceptable Risk	5

11.3 Assessment of Socio-Economic Implications

In terms of the social and socio-economic impact on the different scenarios, only limited differences are expected. However, the following most prominent issues have been identified:

Table 11.13: *Assessment of Main Social and Socio-economic Impacts*

Issue	Status Quo	Scenario 1	Scenario 2	Scenario 3	Scenario 4
Description of Scenario:	**Present System**	**Improved Environmental Performance of Present System**	**Improved Environmental Performance and New Receptacles (240 litre)**	**Improved Environmental Performance and New Receptacles (770 litre)**	**Improved Environmental Performance and New Reusable platic boxes**
1. Job opportunities	Many job opportunities due to low degree of mechanisation and some inefficiency.	Reduced number of job opportunities due to more effective systems	Reduced number of job opportunities due to more effective systems	Reduced number of job opportunities due to more effective systems	Reduced number of job opportunities due to more effective systems
2. Skills development	No skills development, fixation of unskilled labour in unsafe and unattractive positions	Movement from unskilled to semi skilled and skilled labour	Movement from unskilled to semi skilled and skilled labour	Movement from unskilled to semi skilled and skilled labour	Movement from unskilled to semi skilled and skilled labour
3. Private Sector Development	Limited private sector development due to some public on site treatment.	Improved private sector development due to more effective outsourcing of full HCRW management service	Improved private sector development due to more effective outsourcing of full HCRW management service	Improved private sector development due to more effective outsourcing of full HCRW management service	Improved private sector development due to more effective outsourcing of full HCRW management service
4. Affirmative development	In-house solutions facilitate affirmative initiatives as well as the establishment of relative many smaller service contracts.	Regionalisation may require the development of well-established contractors, thus requiring enterprises operated by PDI with limited financial capacity and technical skills to team up with other parties to provide financial and technical backing. New opportunities created for smaller contractors to deal with small HCRW generators.	Regionalisation may require the development of well-established contractors, thus requiring enterprises operated by PDI with limited financial capacity and technical skills to team up with other parties to provide financial and technical backing. New opportunities created for smaller contractors to deal with small HCRW generators.	Regionalisation may require the development of well-established contractors, thus requiring enterprises operated by PDI with limited financial capacity and technical skills to team up with other parties to provide financial and technical backing. New opportunities created for smaller contractors to deal with small HCRW generators.	Regionalisation may require the development of well-established contractors, thus requiring enterprises operated by PDI with limited financial capacity and technical skills to team up with other parties to provide financial and technical backing. New opportunities created for smaller contractors to deal with small HCRW generators.

Issue	Status Quo	Scenario 1	Scenario 2	Scenario 3	Scenario 4
5. Emerging contractor's development	Limited performance requirements allow for low capital entrepreneurs to enter market	Increasing performance requirements creates requirement for emerging contractors with limited financial capacity to become sustainable companies.	Increasing performance requirements pose creates requirement for emerging contractors with limited financial capacity to become sustainable companies.	Increasing performance requirements pose creates requirement for emerging contractors with limited financial capacity to become sustainable companies.	Increasing performance requirements and proprietary rights over boxes pose creates requirement for emerging contractors with limited financial capacity to become sustainable companies.
6. Socio-economic benefits/costs	Occurrence of illness and death due to exposure to pathogens, esp. HIV and Hepatitis B	Reduced risk of infection for both staff, general public and waste reclaimers	Reduced risk of infection for both staff, general public and waste reclaimers	Reduced risk of infection for both staff, general public and waste reclaimers	Reduced risk of infection for both staff, general public and waste reclaimers
7. Application of public capital resources. Public Credit taking / Indebtedness	Public capital fixed in treatment infrastructure	Outsourcing of services allows for liberation of public capital for priority uses	Outsourcing of services allows for liberation of public capital for priority uses	Outsourcing of services allows for liberation of public capital for priority uses	Outsourcing of services allows for liberation of public capital for priority uses
8. Cost-effectiveness and use of resources	Limited cost effectiveness due to unnecessary duplication and excessive use of material and labour resources.	Liberation of resources for other tasks	Liberation of resources for other tasks	Liberation of resources for other tasks	Liberation of resources for other tasks
9. Good governance	Public is both operating and monitoring performance of most treatment plants	Separation of executing and monitoring bodies	Separation of executing and monitoring bodies	Separation of executing and monitoring bodies	Separation of executing and monitoring bodies
10. Religious practices for pathological waste	Allows for religious groups' practices for disposal of pathological waste	Allows for religious groups' practices for disposal of pathological waste	Allows for religious groups' practices for disposal of pathological waste	Allows for religious groups' practices for disposal of pathological waste	Allows for religious groups' practices for disposal of pathological waste
11. Traditional practices for pathological waste	Occurrences of unsafe and unlawful use of pathological waste	Possibility of unsafe and unlawful use of pathological waste, with reduced risk where effective HCRW tracking	Possibility of unsafe and unlawful use of pathological waste, with reduced risk where effective HCRW tracking	Possibility of unsafe and unlawful use of pathological waste, with reduced risk where effective HCRW tracking	Possibility of unsafe and unlawful use of pathological waste, with reduced risk where effective HCRW tracking

Issue	Status Quo	Scenario 1	Scenario 2	Scenario 3	Scenario 4
		system is introduced.	system is introduced.	system is introduced.	system is introduced.
12. Illegal use and distribution of expired pharmaceuticals.	Occurrences of illegal use and distribution of expired pharmaceuticals.	Possibility of illegal use and distribution of expired pharmaceuticals, with reduced risk where effective HCRW tracking system is introduced.	Possibility of illegal use and distribution of expired pharmaceuticals, with reduced risk where effective HCRW tracking system is introduced.	Possibility of illegal use and distribution of expired pharmaceuticals, with reduced risk where effective HCRW tracking system is introduced.	Possibility of illegal use and distribution of expired pharmaceuticals, with reduced risk where effective HCRW tracking system is introduced.
13. Socio-economic impact of public health conditions	Loss of earning opportunities and increased economic costs due to adverse public and occupational impacts	Improved earning opportunities and reduced economic costs due to reduced level of disease and occupational impact	Improved earning opportunities and reduced economic costs due to reduced level of disease and occupational impact	Improved earning opportunities and reduced economic costs due to reduced level of disease and occupational impact	Improved earning opportunities and reduced economic costs due to reduced level of disease and occupational impact

The assessment presented in Table 11.13 above is based on the current conditions in Gauteng and assuming that regionalisation will lead to a consolidation of the market players to only a few, for example 4-6, contractors providing HCRW collection services from large generators and 4-6 providing HCRW treatment services.

It appears that whereas the Status Quo Scenario is relatively more labour intensive, that this is mainly as a result of a number of inefficiencies in the present HCW management systems. The potential alternative scenarios could in turn provide increased skills development with increased private sector development that will, at the same time, liberate public resources for priority activities in other sectors. On the other hand improved occupational and public health will lead to reduced absence of work and less loss of earning opportunities contributing to an improved socio-economic situation.

11.4 Financial Implications

The principal assumptions made applied for calculating the financial implications are shown in table 11.14 below.

Table 11.14: *Principal Assumptions made in the Cost Model*

Assumption	Source/Reference	Details

Assumption	Source/Reference	Details	
Mass of HCRW collected/treated	DACEL 2000 study	**Total** HCRW for Province: includes public & private hospitals + clinics, and "small" sources (GP's, Dentists, laboratories, pharmaceutical companies, etc.): 1,175 tonnes/month.	Provincial facilities **only**: includes public hospitals + clinics only: 574 tonnes/month.
Split: dry waste, wet waste, sharps	Deduced from DACEL 2000 study data	Hospitals (by mass): Dry: 88.5% Wet: 7.5% Sharps: 4.0%	Clinics (by mass): Dry: 89.5% Wet: 0.5% Sharps: 10.0%
Average mass of HCRW plus container	DACEL 2000 study data	142 L cardboard box: 9.0 kg; 50 L cardboard box: 8.0 kg; 20 L bucket: 10.4 kg; 85 L plastic bag: 4.1 kg; 7.5 L sharps container: 1.9 kg	
Average mass of HCRW plus container	Extrapolated from DACEL 2000 study data	50 L plastic bag: 2.4 kg; 10 L sharps container: 2.5 kg	
In-house HCRW workers	WHO Report "Safe Mgmt. of wastes from health-care activities", 1999 *	Institutions generating less than 200 kg HCRW/day: nil Institutions generating more than 200 kg HCRW/day: one worker per 200 kg HCRW/day * As adapted: WHO Report mentions one worker per approx. 525 kg of HCW /day	
Disposable containers	Present Study	Prices are as listed in 'Scenario Costs: All Facilities' sheet of *Excel* model. No stock-holding costs included in model.	
Wheelie-bins and re-usable plastic containers	Present Study	Prices as listed in 'Scenario Costs: All Facilities' sheet of *Excel* model. HCRW capacities assumed: 240 L wheelie-bin : 20 kg; 770 L wheelie-bin : 70 kg; 130 L plastic container (dry waste): 8.5 kg; 50 L and 12 L plastic containers (wet waste): 8kg and 6 kg, respectively.	
Number & location of treatment facilities	Present Study	Alternatives investigated are: one facility at "centre" of HCRW generation in province; three facilities, located at 'top' three HCRW generators; 10 facilities, located at 'top' 10 generators; 20 facilities, located at 'top' 20 generators	
Vehicle description	Present Study	Rigid-chassis trucks with closed van bodies, capacity 18 to 32 cubic metres, max. load mass 3,000 to 5,000 kg; vehicles for wheelie-bin transport have lifting tailgates.	
Transport scenarios	Present Study	HCRW transported to & treated at nearest facility; average round-trip distance between major generators and nearest treatment facility calculated for each alternative described above, and applied to all loads.	
Truck loading & unloading times	Present Study	Load plus unload times: 140 L boxes = 21 mins (fixed) + 0.9 mins/box; 240 L wheelie-binsbins = 25 mins + 1.88 min/bin 770 L bins = 27 mins + 4.5 min/bin 130 L plastic containers: 25 min + 0.9 min/container (assumes that containers are palletised, with 12 x 130 L containers or equivalent per pallet.)	

Assumption	Source/Reference	Details
Interest & Depreciation charges	Present Study	User-defined in model.
Maintenance costs	Present Study	User-defined in model, except as follows: trucks: 52 – 76 cents/km, depending on vehicle; treatment facilities: plant, other equipment & infrastructure: 5% of capital cost p.a., **except for incinerators**, where 10% of capital cost p.a. is provided.
Profit markup	Present Study	User-defined in model.

The estimate of the financial implication is carried out by calculating the cost per kg for handling the HCRW in the Status Quo as well as the three alternative scenarios. The costs are calculated for each of the following cost elements and then finally added up to the total costs. The major cost elements are:

- Containerisation
- Transport
- Treatment and disposal

The calculations of each of the cost elements are summarised below. Detailed background data are found in Annexure 3.

11.4.1 Financial Implications of Containerisation

The calculation of the cost of containerisation is based on a number of the assumptions with regard to volume of containers, the mass of HCRW it can contain and the prices of the containers, as detailed in table 11.15 below.

Table 11.15: *Assumptions concerning weight of containers, mass it can contain and prices*

Container	Empty mass (kg)		HCRW capacity (kg)	240 L wheelie bin	660 L wheelie bin	Cost (incl.VAT)
142 L cardboard box	0.70		9.0	n/a	n/a	R 11.50
50 L cardboard box	0.35		8.0	n/a	n/a	R 6.20
50 L bag			2.4	8.3	29.2	R 0.82
85 L bag			4.1	4.9	17.1	R 1.15
20 L bucket			10.4	1.9	6.7	R 26.22
10 L sharps			2.5	8.0	28.0	R 14.70
240 L w/b	15.0		20.0			R 300.00
770 L w/b	50.0		70.0			R 1,825.00
130 L plastic box	4.5		8.5	n/a	n/a	R 300.00
50 L plastic box	2.7		8.0	n/a	n/a	R 170.00
12L plastic box			6.0	n/a	n/a	R 60.00
130 L PE liner				n/a	n/a	R 1.27
240 L liner for w/b				n/a	n/a	R 1.50
Diesel cost per litre						R 3.99
Brackets on nursing trolleys: one per				4	50 L bags/day	R 200
Scenario 2: Wall-mounted bag-holders: one per				8	85 L bags/day	R 600
Scenario 3: Wall-mounted bag-holders: one per				4	85 L bags/day	R 600
Bins for dry waste: one per				4	85 L bags/day	R 300
Cage-trolleys: one per				20	142 L boxes/day	R 1,200
Cage-trolleys: one per				18	165 L boxes/day	R 1,200
Cage-trolleys: one per				60	bags/day	R 1,200
Pallets for cardboard/plastic boxes: TWO per				18	boxes/day	R 250
Pallet-trucks for above:one per				100	boxes/day	R 3,500
Trolleys for 4x 240L w/bins: one per				20	240 L bins/day	R 2,500
Waste workers (hospitals only): one per				200	kgs HCRW/day	R 3,000
Annual finance cost: percent per annum						12%

Note: The estimated content of container has been made for calculation purposes only. In reality the larger containers will contain a mix of all. The cost of 770 litre containers is relative high because it must be imported. If substantial local demand was created the price could most likely be reduced to half.

Based on this the daily and the monthly quantity of waste that the container can contain is calculated, as it appears from table 11.16 below.

Table 11.16 Cost of containerisation – Monthly Figures.

	Scenario 1 "Disposable Containers"			Scenario 2 "Re-usable 240 L w/bins"			Scenario 3 "Re-usable 770 L w/bins"			Scenario 4 "Re-usable plastic boxes"		
CONTAINERS OF HCRW GENERATED	**Type**	**Daily quantity**	**Monthly quantity**	**Type**	**Daily quantity**	**Monthly quantity**	**Type**	**Daily quantity**	**Monthly quantity**	**Type**	**Daily quantity**	**Monthly quantity**
Dry waste	142 L box	5,795	115,900	85 L bags	7,650	153,000	85 L bags	12,700	254,000	130 L box	6,135	122,700
	50 L bags	8,700	174,000	50 L bags	8,700	174,000	50 L bags	8,700	174,000	50 L bags	8,700	174,000
Wet waste	50 L box	425	8,500	20 L buckets	330	6,600	20 L buckets	330	6,600	50 L box	320	6,400
										12 L box	140	2,800
Sharps	10 L sharps	1,280	25,600	10 L sharps	1,280	25,600	10 L sharps	1,280	25,600	10 L sharps	1,280	25,600
				240 L bins	2,940	58,800	770 L bins	840	16,800			
				average gross bin mass =		35 kg	average gross bin mass =		120 kg			
				waste density in w/bins =		0.08 kg/litre	waste density in w/bins =		0.09 kg/litre			

CONTAINERISATION

		Scenario 1 Quantity	Unit cost	Total cost	Scenario 2 Quantity	Unit cost	Total cost	Scenario 3 Quantity	Unit cost	Total cost	Scenario 4 Quantity	Unit cost	Total cost
Capital cost													
Brackets to nursing trolleys		2,200	R 200.00	R 440,000	2,200	R 200	R 440,000	2,200	R 200	R 440,000	2,200	R 200.00	R 440,000
Bag holders		n/a		n/a	1,000	R 600	R 600,000	3,200	R 600	R 1,920,000	n/a		n/a
Bins for dry waste		n/a		n/a	2,000	R 300	R 600,000	3,200	R 300	R 960,000	n/a		n/a
Cage trolleys		310	R 1,200	R 372,000	n/a		n/a	n/a		n/a	360	R 1,200	R 432,000
Trolley for 4 x 240 L w/bins		n/a		n/a	147	R 2,500	R 367,500	n/a		n/a	n/a		n/a
Pallets for cardboard/plastic boxes		650	R 250	R 162,500	n/a		n/a	n/a		n/a	710	R 250	R 177,500
Patllet trucks for above		60	R 3,500	R 210,000	n/a		n/a	n/a		n/a	70	R 3,500	R 245,000
	Sets provided:												
240 L wheelie bins	4	n/a		n/a	11,760	R 300	R 3,528,000	n/a		n/a	n/a		n/a
770 L wheelie bins	3	n/a		n/a	n/a		n/a	2,520	R 1,825	R 4,599,000	n/a		n/a
165 L plastic boxes	6	n/a		n/a							36,800	R 300.00	R 11,040,000
50 L plastic boxes											1,920	R 170.00	R 326,400
20 L plastic boxes		n/a		n/a							840	R 60.00	R 50,400
TOTAL				**R 1,184,500**			**R 5,535,500**			**R 7,919,000**			**R 12,711,300**
Monthly costs													
Finance cost	(Rate as set abov	Rate =	**12%**	R 11,800		12%	R 55,000		12%	R 79,000		**12%**	R 127,000
Depreciation of equipment (other than re-usable containers): straight line over (number of years) :	10	Factor =	0.10	R 9,900			R 16,700			R 27,700			R 10,800
Depreciation of re-usable containers based on estimated life (usage cycles) :	150	Factor =				0.53	R 156,800		0.53	R 204,400		0.27	R 253,700
Labour cost (at HCRW source)		220	R 3,000	R 660,000	220	R 3,000	R 660,000	220	R 3,000	R 660,000	220	R 3,000	R 660,000
Consumable costs													
Disposable boxes 142 L		115,900	R 11.50	R 1,333,000							n/a		n/a
Disposable boxes 50 L		8,500	R 6.20	R 53,000							n/a		n/a
20 L plastic buckets		n/a		n/a	6,600	R 26.22	R 173,000	6,600	R 26.22	R 173,000	n/a		n/a
10 L Sharps containers		25,600	R 14.70	R 376,000	25,600	R 14.70	R 376,000	25,600	R 14.70	R 376,000	25,600	R 14.70	R 376,000
50 L PE bags 40 micron		n/a		n/a	174,000	R 0.82	R 143,000	174,000	R 0.82	R 143,000	183,200	R 0.82	R 150,000
85 L PE bags 100 micron		n/a		n/a	153,000	R 1.15	R 176,000	254,000	R 1.15	R 292,000	n/a		n/a
130 L PE liners 80 micron		n/a		n/a	n/a		n/a	n/a		n/a	122,700	R 1.27	R 156,000
240 L liner 40 mic for w/b		n/a		n/a	58,800	R 1.50	R 88,000	n/a		n/a	n/a		n/a
Maintenance of equipment (other than re-usable containers) @ % p.a.:		**5.0%**		R 4,900			R 8,400			R 13,800			R 5,400
Total monthly containerisation cost				**R 2,448,600**			**R 1,852,900**			**R 1,968,900**			**R 1,738,900**

As it appears from the table that Scenario 1 requires lowest capital cost, while Scenario 4 by far is the most expensive, and Scenario 2 and 3 are in between. This is due to the considerable investment in the reusable containers in Scenario 2-4. With regard to the monthly cost Scenario 1 is the most expensive, due to the considerable turnover of the disposable containers.

11.4.2 Financial Implications of Transport

Based on the amounts of waste and the weight of the containers together with cost figures on transport as well as estimated transport distances the transport costs are calculated, taking four different numbers of treatment facilities into consideration. The figures are summarised in table 11.17 below.

Table 11.17: *Transport costs in the three scenarios, taking four different numbers of treatment facilities into consideration.*

		Scenario 1 "Disposable Containers"			Scenario 2 "Re-usable 240 L w/bins"			Scenario 3 "Re-usable 770 L w/bins"			Scenario 4 "Re-usable plastic boxes"		
TRANSPORTATION (including return of wheelie bins + plastic boxes)													
Number of treatment facilities	Average round-trip distance	Price per container	Total transportation cost	No. of trucks	Price per container	Total transportation cost	No. of trucks	Price per container	Total transportation cost	No. of trucks	Price per container	Total transportation cost	No. of trucks
1	80	4.95	R 595,000		15.30	R 900,000		45.48	R 764,000	#	6.61	R 837,000	39
3	57	4.19	R 503,000		12.79	R 752,000		37.43	R 629,000	#	5.46	R 692,000	33
10	28	3.30	R 396,000		9.75	R 573,000		28.46	R 478,000	#	4.14	R 524,000	27
20	15	2.89	R 347,000		8.28	R 487,000		24.25	R 407,000	#	3.51	R 445,000	24
CLEANING AND DISINFECTION OF WHEELIE BINS/PLASTIC BOXES													
Total monthly cleaning and disinfection cost			R 0			R 153,000			R 131,000			R 221,000	

As it appears from table 11.17 the more plants that are established the lower total transport cost per kg HCRW as a result of shorter transport distances. Furthermore, it is seen that Scenario 2 represent the most expensive scenario in terms of transport cost, while scenario 1 is the cheapest. The reason why scenario 2, 3 and 4 have higher transport cost is that the cardboard boxes can be loaded more cost-effectively to take up the available storage capacity in Scenario 1.

In addition, cost for disinfecting and returning the reusable is included in Scenarios 2 and 3, see table 11.17 above.

11.4.3 Financial Implications of Treatment

Table 11.18 below summarises the cost calculations of treatment for Scenario 1, 2 and 3 under condition of various numbers of treatment facilities and divided on the three main types of treatment technology. The detailed assumptions that the calculations are based on appear from chapter 6 and annexure 3.

Table 11.18: *Monthly treatment cost for various types of treatment technology in Scenario 1-4.*

TREATMENT			Scenario 1 "Disposable Containers"			Scenario 2 "Re-usable 240 L w/bins"			Scenario 3 "Re-usable 770 L w/bins"			Scenario 4 "Re-usable plastic boxes"		
Treatment scenario:			Autoclave	Incinerator	Microwave	Autoclave	Incinerator	Microwave	Autoclave	Incinerator	Microwave	Autoclave	Incinerator	Microwave
Number of treatment facilities	Average capacity of treatment facility/facilities facility (tons HCRW /year)	Design capacity of treatment facility/facilities (tons /year)	Treatment cost per kg			Treatment cost per kg			Treatment cost per kg			Treatment cost per kg		
1	14,100	28,200	R 0.76	R 0.84	R 1.63	R 0.76	R 0.84	R 1.63	R 0.76	R 0.84	R 1.63	R 0.76	R 0.84	R 1.63
3	4,700	6,300	R 1.14	R 1.21	R 1.53	R 1.14	R 1.21	R 1.53	R 1.14	R 1.21	R 1.53	R 1.14	R 1.21	R 1.53
10	1,400	1,800	R 2.26	R 2.36	R 2.40	R 2.26	R 2.36	R 2.40	R 2.26	R 2.36	R 2.40	R 2.26	R 2.36	R 2.40
20	710	900	R 3.55	R 3.81	R 3.62	R 3.55	R 3.81	R 3.62	R 3.55	R 3.81	R 3.62	R 3.55	R 3.81	R 3.62
			Total monthly treatment cost			Total monthly treatment cost			Total monthly treatment cost			Total monthly treatment cost		
1			R 957,000	R 1,058,000	R 2,052,000	R 893,000	R 987,000	R 1,915,000	R 893,000	R 987,000	R 1,915,000	R 893,000	R 987,000	R 1,915,000
3			R 1,435,000	R 1,524,000	R 1,926,000	R 1,340,000	R 1,422,000	R 1,798,000	R 1,340,000	R 1,422,000	R 1,798,000	R 1,340,000	R 1,422,000	R 1,798,000
10			R 2,846,000	R 2,971,000	R 3,022,000	R 2,656,000	R 2,773,000	R 2,820,000	R 2,656,000	R 2,773,000	R 2,820,000	R 2,656,000	R 2,773,000	R 2,820,000
20			R 4,470,000	R 4,797,000	R 4,558,000	R 4,171,000	R 4,477,000	R 4,254,000	R 4,171,000	R 4,477,000	R 4,254,000	R 4,171,000	R 4,477,000	R 4,254,000

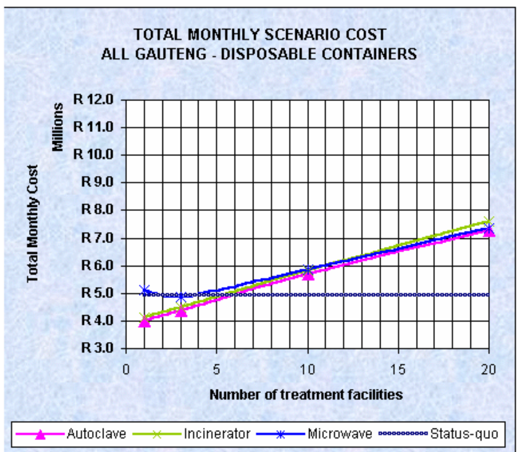
As it appears from table 11.18 above the cost of treatment for any of the investigated treatment technologies are of the same magnitude for the same size of plant. However, autoclaving represent the cheapest option in all cases closely followed by incineration whereas microwaving appears to more expensive for the larger capacities of plant but becomes cheaper or equal to incineration as the plant capacity falls. This is due to the fact that microwave plants currently are not produced for large throughputs, thus requiring several parallel plants to achieve the larger total throughputs.

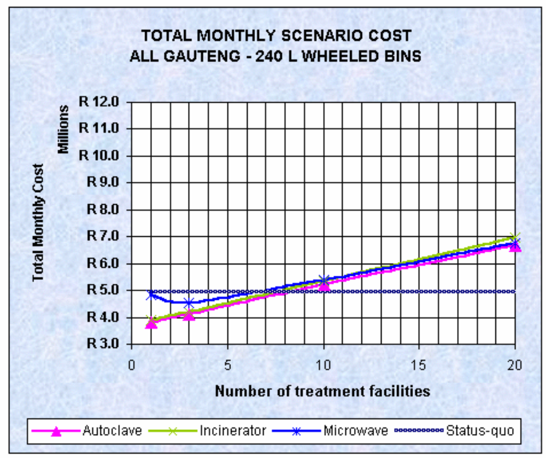
11.4.4 Total Financial Implications of the Scenarios

In table 11.19 below the total costs of handling HCRW according to Scenario 1, 2, 3 and 4 are summaries.

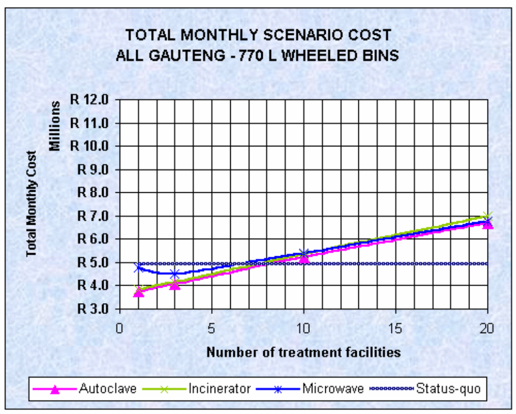
Table 11.19: *Total monthly cost for handling HCRW in Scenario 1 and 2, under different treatment technologies and different number of treatment facilities for all of Gauteng.*

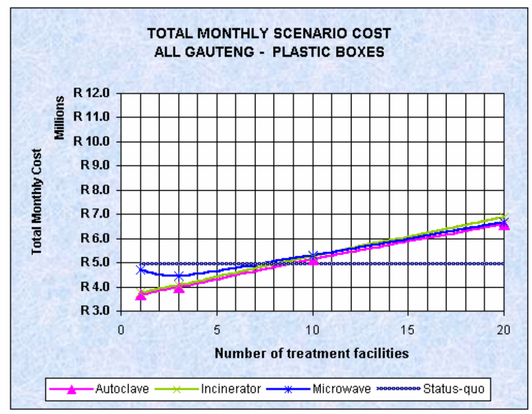
TOTAL MONTHLY SCENARIO COSTS	Scenario 1 "Disposable Containers"			Scenario 2 "Re-usable 240 L w/bins"		
Number of treatment facilities	Autoclave	Incinerator	Microwave	Autoclave	Incinerator	Microwave
1	R 4,001,000	R 4,102,000	R 5,096,000	R 3,799,000	R 3,893,000	R 4,821,000
3	R 4,387,000	R 4,476,000	R 4,878,000	R 4,098,000	R 4,180,000	R 4,556,000
10	R 5,691,000	R 5,816,000	R 5,867,000	R 5,235,000	R 5,352,000	R 5,399,000
20	R 7,266,000	R 7,593,000	R 7,354,000	R 6,664,000	R 6,970,000	R 6,747,000





	Scenario 3 "Re-usable 770 L w/bins"			Scenario 4 "Re-usable plastic boxes"		
TOTAL MONTHLY SCENARIO COSTS Number of treatment facilities	Autoclave	Incinerator	Microwave	Autoclave	Incinerator	Microwave
1	R 3,757,000	R 3,851,000	R 4,779,000	R 3,690,000	R 3,784,000	R 4,712,000
3	R 4,069,000	R 4,151,000	R 4,527,000	R 3,992,000	R 4,074,000	R 4,450,000
10	R 5,234,000	R 5,351,000	R 5,398,000	R 5,140,000	R 5,257,000	R 5,304,000
20	R 6,678,000	R 6,984,000	R 6,761,000	R 6,576,000	R 6,882,000	R 6,659,000

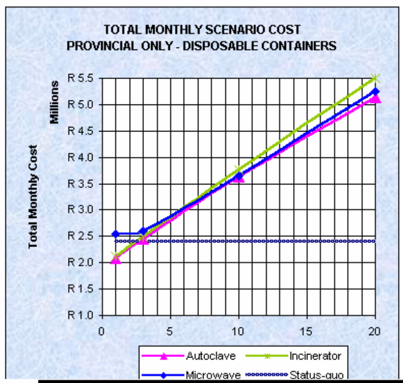


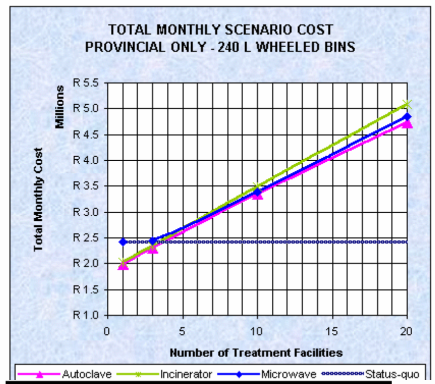


The figures above show both the estimated current cost of HCRW services in Gauteng and the estimated cost for the proposed three scenarios. It appears that the current HCRW Service cost are or the same magnitude as an efficiently run system complying with higher performance standards provided that few large regionalised treatment plants are being used only.

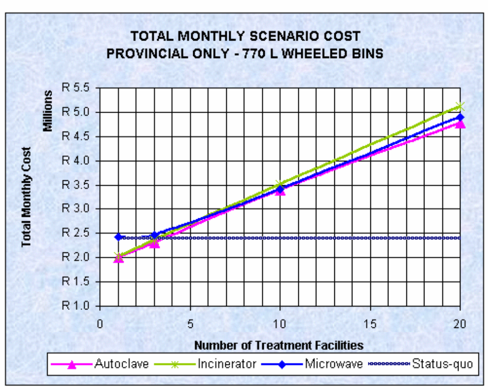
Table 11.20: *Total monthly cost for handling HCRW in Scenario 1, 2, 3 and 4, under different treatment technologies and different number of treatment facilities for Provincial Health Care Institutions Only.*

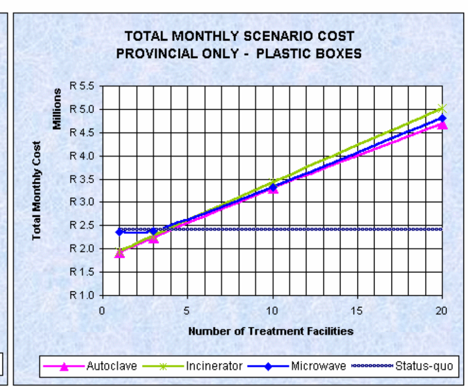
TOTAL MONTHLY SCENARIO	Scenario 1 "Disposable Containers"			Scenario 2 "Re-usable 240 L w/bins"		
Number of treatment facilities	Autoclave	Incinerator	Microwave	Autoclave	Incinerator	Microwave
1	R 2,091,000	R 2,116,000	R 2,546,000	R 1,994,000	R 2,017,000	R 2,419,000
3	R 2,447,000	R 2,496,000	R 2,607,000	R 2,296,000	R 2,342,000	R 2,445,000
10	R 3,619,000	R 3,767,000	R 3,650,000	R 3,351,000	R 3,489,000	R 3,380,000
20	R 5,126,000	R 5,495,000	R 5,255,000	R 4,737,000	R 5,082,000	R 4,858,000





TOTAL MONTHLY SCENARIO COSTS (INCLUDING	Scenario 3 "Re-usable 770 L w/bins"			Scenario 4 "Re-usable plastic boxes"		
Number of treatment facilities	Autoclave	Incinerator	Microwave	Autoclave	Incinerator	Microwave
1	R 2,006,000	R 2,029,000	R 2,431,000	R 1,929,000	R 1,952,000	R 2,354,000
3	R 2,314,000	R 2,360,000	R 2,463,000	R 2,232,000	R 2,278,000	R 2,381,000
10	R 3,382,000	R 3,520,000	R 3,411,000	R 3,292,000	R 3,430,000	R 3,321,000
20	R 4,777,000	R 5,122,000	R 4,898,000	R 4,682,000	R 5,027,000	R 4,803,000





When regarding the provincial generators of HCRW the estimated total cost of the proposed scenarios only become similar to the current estimated costs in case of one central plant used under the assumptions made for all of Gauteng. It is clear that the economies of scale are important to ensure that improved HCRW services can be achieved at a price similar to the current price (under the assumptions made).

As is the case for the whole of Gauteng, it is also clear that for the Provincial Hospitals and Clinics only the scenarios based on better performing burn or non-burn treatment technologies performing are only comparable to today's total costs of HCRW service if highly centralised treatment capacity (e.g. 1-3 plants only) treats all waste generated, thus, securing sufficient scale of economics.

12 Conclusions and Recommendations

The conclusions below are presented separate for the Environmental, Safety, Socio-economic and the Financial Impacts followed by a final conclusion and recommendation.

12.1 Environmental Conclusions

The above Environmental Analyses show that:

1. Use of disposable cardboard boxes causes a significantly higher environmental impact from i) use of energy, ii) greenhouse gases, iii) use of water, iv) COD, v) NO_x, vi) SO_2, and vii) dust compared to use of reusable wheelie bins Especially in terms of energy used for manufacturing cardboard boxes requires 9 times more energy than reusable bins
2. Use of disposable cardboard boxes results in the consumption of 1100 tonnes of cardboard and 160 tonnes of polypropylene per years. Even though water is required for washing of reusable wheelie bins manufacturing of cardboard boxes leads to much higher use of water (×10) and energy (×10) as well as much higher emission of dust, COD, acid gases etc. compared to reusable PP containers
3. For obvious reasons the use of on-site treatment plants results in the lowest environmental impact from transportation, whereas the use of regional non-burn treatment plants result in the highest impact as the entire waste generation must be transported of-site for further treatment. In the on-site scenarios only residues are to be transported for final disposal.
4. When including the emissions from treatment plants caused by the electricity production (but excluding the emissions at the landfill), non-burn treatment still leads to less (half) but comparable emissions than incineration due to the quality of coal and power plants in SA whereas incineration leads to 14 times more dust and 22 times more NO_x as well is a very significant CO_2 emission compared to non-burn.
5. Of particular concern is the emission of NO_x, HCl, SO_2, dust, Hg, and Dioxin from incineration.
6. In terms of energy, the non-burn plants use 30% more energy for treatment than incinerators. Energy recovery from incinerators is not assumed financially or practically at this scale.
7. Transport of residues requires 6 times more fuel for non-burn treatment than if incineration is used because of the larger volumes of waste to be transported.
8. Because of the difference in pollution parameters generated by deposited residues from incineration and non-burn plants, the main difference between the two principle treatment methods is: i) need for landfill area is 30 times higher if using non-burn than for incineration, ii) there is 6 times more leachate generation but there is a considerable difference in the leachate quality.
9. Practically, the Status Quo scenario is for all parameters significantly worse than any of the proposed scenarios
10. Non-burn plants cause the highest "greenhouse" gas emission (×4)

11. Use of incineration causes more dioxin (×7), dust, HCl, Hg, NO_x, than use of non-burn
12. It is not completely clear if non-burn or incineration is the environmentally best options as the types of impacts and emissions caused are very different.
13. It is clearly environmentally better to use reusable wheelie bins than to continue using disposable cardboard boxes.
14. In environmental terms, and assuming that the same environmental standards are being up-held, there is no significant difference in impacts using on-site or regionalised treatment plants. However, it is expected to have a significant negative financial impact to introduce high environmental standards for on-site treatment plants.
15. Dioxin emissions from transportation are 10% of the total dioxin emission in case of regional incineration. In the Status Quo scenario there is 5 times higher dioxin emission than in the scenarios with compliant regionalised incinerators. In the non-burn scenarios there is assumed to be dioxin generation from transportation only.
16. Non-burn scenarios lead to approximately double nutrient loading of the aquatic and soil environment compared to incineration scenarios.
17. Considerable emissions resulting from the manufacturing and transport of HCRW receptacles as well as from subsequent emissions during transport and treatment of filled HCRW could be prevented by applying a more rigorous waste segregation system aimed at minimising the amounts of waste requiring specialised treatment.
18. Across all scenarios there is a considerable scope for environmental improvements in applying green procurement procedures and self-assessment of current use and disposal of problematic items.
19. Residues from both incinerators and non-burn technologies may leach heavy metals depending on the original input, however, the residues from incinerators are more concentrated resulting in a more concentrated leaching as well as additional contents of salts and possibly dioxins/furans, whereas non-burn technologies in addition to heavy metals will leach nutrients than may also be problematic.
20. Residues from Incinerators will normally have to be deposited in a hazardous waste landfill whereas residues from non-burn technologies are normally suitable for landfilling with domestic waste, assuming separate management of pharmaceuticals and chemicals. Non-burn technologies avoid the concentration of pollutants in residues compared to the more condensed residues from incinerators

In summary, it is not possible, to select or calculate the value of one common indicator that could be used to determine the absolute comparative environmental impact of any scenarios. Hence, a final determination of the environmentally most suitable scenario is to be based on political priorities placed on the sensitivity of the various environmental media being impacted upon under local conditions.

Considerations could for instance be whether regional air pollution is more critical when compared to land opportunity or whether global warming or energy consumption should be prioritised. Furthermore, concerning incinerators, air dispersion models, especially in areas with existing compromised ambient air quality, may demonstrate particular problems, requiring erection of tall stacks or finding another site with more favourable topography and/or lower buildings near by.

Based on the current environmental, climatic and demographic conditions in Gauteng, it appears that there is no basis for preferring either incineration or non-burn technologies, assuming that the environmental performance criteria of the HCW Management Policy (ref. 3) are complied with. However, it appears that any of the proposed scenarios would be significantly better than the current situations (Status Quo).

12.2 Health and Safety Conclusions

From Table 11.12 above it appears that the proposed scenarios 2 and 3 may result in increased risk of needle stick injuries at the wards if not supported and implemented with an effective training and awareness programme, this is especially the case of the bag holder is not a reusable hard bin but a metal bag holder with open sides. This is due to the replacement of cardboard boxes with the much cheaper plastic bags within the wards, thus making poor segregation of sharps more critical than at present.

On the other hand the introduction of plastic bags and reusable wheelie bins provides a significantly safer working situation during internal storage, collection, transport and treatment.

Hence, there are no clear conclusions as to which scenario will have the most desirable health and safety impact, but it appears that any of the proposed scenarios would be more or less equally advantageous compared to the current situation.

12.3 Conclusions on the Socio-Economic Implications

It appears that whereas the Status Quo Scenario is relatively more labour intensive, this is mainly as a result of a number of inefficiencies in the present HCW management systems. The potential alternative scenarios could in turn provide increased skills development with increased private sector development that will, at the same time, liberate public resources for priority activities in other sectors as well as result in improved public health resulting in an overall improved socio-economic impact.

Hence, there are no clear conclusions as to which scenario will have the most desirable socio-economic impact, but it appears that any of the proposed scenarios would be more or less equally advantageous compared to the current situation.

12.4 Financial Conclusions

12.4.1 Introduction

Results from the Scenario Cost Model are presented and discussed below, under the headings ‘Treatment Technology’, ‘Centralised vs. Decentralised Treatment Facilities’ and ‘Containerisation’. Under each heading, the optimum (i.e. least-cost) scenario is identified and then sensitivity analyses are presented which illustrate the effect on the optimum scenario of changes in key assumptions.

The ‘Base-Line’ assumptions are presented first; in the absence of specific indication, the values reflected in the ‘base-line’ apply in the sections that follow.

12.4.2 Base-line Assumptions

HCRW: ALL GAUTENG (Quantity as for 2000)		INTEREST RATE: 12 %
TREATMENT PLANT	**TRUCKS**	**RE-USABLE CONTAINERS**
Depreciation Period: 12 yrs	Depreciation Period: 5 yrs	Useful life: 150 ‘cycles’
	No. of floors (for w-bins): 2	No. of ‘sets’ provided: 770 L wheelie-bins: 3 240 L wheelie-bins: 4 re-usable plastic containers: 6
	No. of shifts/day: 1	Maintenance charge on ancillary equipment: 5 % p.a.
Profit mark-up on cost: 25 %	Profit mark-up on cost: 25 %	Time-penalty on bin loading/unloading times (multiple floors in trucks): 25%

12.4.3 Treatment Technology

Autoclaving offers the lowest-cost solution, irrespective of the number of treatment facilities (1,3,10 or 20). Within each mode of containerisation, and irrespective of the number of treatment facilities, autoclaving offers a lower-cost solution than incineration or microwave treatment. The above holds true for **all** Gauteng HCRW, and for **provincial** HCRW.

Incineration is only marginally more expensive than autoclaving, particularly when the number of treatment facilities is 10 or less.

The above still holds true if the interest rate is increased from 12% to 16% p.a.

Microwave treatment is more expensive than autoclaving is all cases, but is marginally cheaper than incineration in certain scenarios when the number of facilities is > 10 (all Gauteng HCRW) and when the number of facilities is > approx. 5 (provincial HCRW only).

All of the above still holds true if the depreciation period is reduced from 12 years to 10 years, or increased to 15 years.

12.4.4 Number of Treatment Facilities

Under the 'base-line' assumptions, the fewer the number of treatment facilities, the lower the cost, in all cases. For autoclaving, for example, costs increase by 8% between 1 and 3 facilities, by 29% between 3 and 10 facilities, and by 26% between 10 and 20 facilities. (**All** Gauteng HCRW; for **provincial** HCRW only, percentage increases are higher.)

Even if **transport prices are doubled** (i.e. if the percentage mark-up on cost is increased from 25% to 150%), overall scenario costs reduce as the number of treatment facilities reduces.

(**Note**: the above takes no account of 'cartel-type' pricing policies, which could conceivably come into being if there was only a small number of treatment facilities, and which would counter the natural 'economy-of-scale' effect.)

12.4.5 Mode of Containerisation

Under the 'base-line' assumptions, re-usable plastic containers offer the lowest-cost solution. This holds true in the case of **all** Gauteng HCRW, and in the case of **provincial** HCRW only.

The cost-advantage of the re-usable plastic containers over 240 L and 770 L wheelie-bin scenarios is, however, small, particularly in the case of **provincial** HCRW only.

All of the above still holds true if the useful life of re-usable plastic containers and wheelie-bins is reduced from 150 to 100 'cycles'.

The above also holds true if the number of '**sets**' of re-usable plastic containers required is increased from 6 to 8.

There is minimal difference in overall cost between the 240 L and 770 L wheelie-bin scenarios in all cases. This remains true if the number of 'sets' of 240 L wheelie-bins provided is increased from 4 to 5.

If the trucks transporting wheelie-bins only have **one floor/layer of bins**, as opposed to the two floors/layers in the 'base-line' assumption, the wheelie-bin scenario costs increase by up to 10%, and even fall behind the cardboard-box scenario in cases where the number of treatment facilities is less than 10.

As might be expected, the model is sensitive to the mass-density figures assumed for HCRW in the various containers. If the actual average mass of HCRW in the wheelie-bins were of the order of 20% higher than that assumed (20 kg and 70 kg for the 240 L and 770 L units respectively), the wheelie-bin scenarios would become cheaper than the re-usable plastic container scenario.

12.4.6 General Financial Conclusions

It is clear that the more plants that are established the lower the total transport cost per kg HCRW as a result of the shorter transport distances. On the other hand the cost of treatment per kilogram increases.

It appears that the current HCRW Service cost are of the same magnitude or higher compared to an efficiently run system complying with higher performance standards provided that few large regionalised treatment plants are being used only.

It is clear that the economies of scale are important to ensure that improved HCRW services can be achieved at a price similar to the current price (under the assumptions made).

Several discussions with the health care sector have revealed that there is periodical inconsistency in the supply of waste handling equipment to some or all provincial health care institutions. This leads to excess stock taking in the institutions to ensure that there are always sufficient card board boxes, sharps containers, plastic liners etc. An analyses based of today's costs of equipment has found that one months of HCRW containerisation supply, which includes collection and disposal, has a value of approx. 2.1 million Rand.

Hence, for each month of excess stocktaking, and assuming and interest rate of 12% p.a., there is an additional capital cost of the Department of Health of approx. R 252,000 per year, or approximately R 21,000 per month cause by inconsistent supply only. This relative high capital cost is in particular caused by the fact that each container today includes a significant cost of collection and disposal that exceeds that actual cost of the container itself.

12.5 Final Conclusion and Recommendations

There Feasibility Report is based on a number of assumptions and the particular Gauteng and South African conditions. However, it appears that the following clear conclusions can be made:

1. It appears possible to introduce new HCRW service concepts that while complying to improved performance standards, cf. the Policy, will have the same budgetary impact as the current sub-standard HCRW services, provided
2. Regionalisation is clearly preferable compared to onsite solutions
3. 2-4 regionalised treatment plants appear to result in the lowest overall costs due to economics of scale
4. Use of reusable wheelie bins of the is slightly more cost efficient than use of disposable cardboard boxes, even when including the increased costs of transportation and disinfection of reusable containers
5. Cost of transportation increased when using reusable containers, but the increase does not exceed the savings due to elimination of disposable cardboard boxes.
6. The estimated cost of the existing HCRW collection and treatment services in Gauteng appears high compared to the estimated cost of improved efficient treatment system
7. Implementation of the environmental performance requirements stated in the Gauteng Policy (Nov. 2001) will significantly reduce the environmental impact of HCRW management in Gauteng
8. The existing incinerators in Gauteng are emitting very significant amounts of pollutants compared to internationally available state-of-the-art incinerators.
9. Incineration has compared to non-burn technologies the most adverse impact in terms of release of acid gases and dioxins/furans, whereas non-burn technologies has the most adverse impact on the emission of green house gases leading to global warming. Furthermore, the use of non-burn technologies increased the transportation of materials in the province compared to the use of incinerators. Hence, it is not clear if incinerators or non-burn technologies are overall (globally) most preferred environmentally.

Hence, in general it is recommended that:

1. The use of on-site treatment plants, in particular on-site incinerators should be discontinued over a period of time
2. There should be a move towards fewer and larger HCRW treatment facilities in Gauteng.
3. Internal and external handling of HCRW receptacles should be mechanised and the manual handling should be reduced
4. It is not clear if incineration or non-burn treatment is environmentally significantly better than the other. Hence, both technologies are recommended for use provided that the stringent emission standards are enforced.

For the Pilot Projects to be implemented at selected health care institutions in Gauteng it is, in particular, recommended that:

1. The suitability of using various types of trolleys for reducing internal manual handling is tested to improve occupational health
2. The suitability of applying wheelie bins (e.g. waste carts of the size of approx. 240 – 770 litre) is tested as an alternative to cardboard boxes.

13 Annex 1: List of references

1. Feasibility Study into the Possible Regionalisation of Health Care Risk Waste Treatment / Disposal Facilities in Gauteng (The Status Quo Report), DACEL, Nov. 2000.

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5. Stats SA. Mid-year estimates 2001, Population Estimates, PO302, Embargo 13:0, Date, 2 July 2001

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12. “Sources of Dioxin pollution and occurrence of dioxin in the environment”, 1995 Report of Work No. 81, Danish EPA, (In Danish: “Kilder til dioxinforurening og forekomst af dioxin i miljøet”. Arbejdsrapport nr. 81, 1995, Miljøstyrelsen, 1995.) www.mst.dk

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15. Gauteng Non-burn HCRW Treatment Efficiacy Validation Protocol, Gauteng DACEL 2002.

16. Safe management of wastes from health-care activities/edited by A. Prüss, E. Giroult, P. Rushbrook, World Health Organization, Geneva, 1999, ISBN 92 4 154525 9

14 Annex 2: Abbreviations

BOOT	Build-Own-Operate-Transfer
BOT	Build-Operate-Transfer
BSE	Bovine Spongiform Encephalopathy
CJD	Creutzfeldt Jakob Disease
Cd	Cadmium
CO	Carbon monoxide
CO_2	Carbon dioxide
DACEL	Department of Agriculture Conservation Environment and Land
DANCED	Danish Co-operation for Environment and Development
DEAT	Department of Environmental Affairs and Tourism
DoH	Department of Health
DPTR&W	Department of Public Transport, Roads and Works
DTPW	Department of Transport and Public Works
DWAF	Department of Water Affairs and Forestry
EIA	Environmental Impact Assessment
EPA	Environmental Protection Agency
ETD	Electro-thermal deactivation
EU	European Union
GDACEL	Gauteng Department of Agriculture Conservation Environment and Land Affairs
GDoH	Gauteng Department of Health
HCF	Health care facility
HCGW	Health care general waste
HCl	Hydrochloric acid
HCRW	Health care risk waste
HCS	Hazardous chemical substance
HCW	Health care waste
HCWIS	Health care waste information system
HCWM	Health Care Waste Management
HF	Hydrogen fluoride
Hg	Mercury
HIV	Human Immune Deficiency Syndrome
IDP	Integrated Development Planning
inc.	Incineration
IPD	Integrated policy document
LDO	Land Development Objectives
mg	milli-gram (10^{-3} gram)
MSA	Municipal Systems Act
MSW	Municipal solid waste
NB	Non-burn treatment technologies
NDoH	National Department of Health
NEMA	National Environmental Management Act
ng	nano-gram (10^{-9} gram)
NGO	Non-Governmental Organisation
NH3	Ammonia

NO_x	Nitrogen oxides
NWMS	National Waste Management Strategy
OHS	Occupational Health and Safety
p.a.	per annum (per year)
Pb	Lead
PE	Polyethylene
pg	pico-gram (10^{-12} gram)
PM	Particulate matter
PP	Polypropylene
PPE	Personal Protective equipment
PPE	Personal Protective Equipment
PVC	Polyvinyl chloride
REL	Rear End Loader
RSA	Republic of South Africa
SA	South Africa / South African
SO_2	Sulphur dioxide
TEQ	Total Eco-toxicity Equivalents
TOC	Total Organic Carbon
US	United States
USA	United States of America
WHO	World Health Organisation
ZAR	South African Rand

15 Annex 3: Cost Model Methodology and Assumptions

(**Note**: Box 6.11 and Table 11.14 in the body of the Feasibility Study Report provide summaries of the main assumptions used in the treatment cost module and the Scenario Cost Model as a whole, respectively.)

PURPOSE

The purpose of the model is to facilitate the comparison of costs associated with alternative modes of:
containerisation of HCRW (i.e. disposable, plastic-lined cardboard boxes of 142 L capacity; 240 L and 770 L wheelie bins; and re-usable plastic boxes of 130, 50 and 12 L capacity)
treatment of HCRW (viz. incineration, autoclaving and microwave treatment)
centralisation vs. de-centralisation of HCRW treatment facilities

The model has been set up in a manner that allows cost-comparison in respect of HCRW generated by provincial health-care facilities **only**, and in respect of HCRW generated by **all** health-care facilities in Gauteng, viz. provincial and private (including 'small' HCRW sources, such as GP's, pharmacies, etc.).

OVERVIEW

The model comprises a number of modules (on separate sheets of the *Excel* workbook), each of which allows determination of costs which are later fed into the '**Scenario Costs**' sheets on the workbook. The principal modules are '**Transport Costs**', '**Treatment Scenario Costs**' and **HCRW Treatment Cost Model**, and there are further minor modules, viz. '**Disinfection of Wheelie Bins**' and **Load and Unload Times**. These modules determine the **costs** associated with the various activities, and then allow for the addition of a user-determined **profit mark-up**, to arrive at a **price** for each activity; this allows for the possibility of 'outsourcing' some or all the activities to the private sector. Each of the modules is discussed in more detail below.

Two '**Scenario Costs**' sheets have been included in the model; one for **all** HCRW generated in Gauteng, and one for HCRW generated by provincial health-care facilities **only**.

The results from the two Scenario Costs sheets, together with the comparative costs of the 'Status-Quo' situation regarding collection, transportation and treatment of HCRW in Gauteng, are summarised in the '**Cost Summary**' sheet.

A description of the various sheets/modules of the model follows.

HCRW GENERATION DATA

As referred to in the note in row 5 of this sheet, monthly HCRW generation masses have been taken from Table 3.8 of the "Feasibility Study Into The Possible Regionalisation Of HCRW Treatment/Disposal Facilities In Gauteng": DACEL, 2000. Although this Study did not seek to differentiate between "dry", "wet" and "sharps" waste, a reasonable estimate of this breakdown could be established from the actual data collected at hospitals and clinics during this study. This data suggested that the following 'split' of HCRW (in percentage by mass) between the various categories would be appropriate:

Type of waste	Hospitals	Clinics
Dry	88.5%	89.5%
Wet	7.5%	0.5%
Sharps	4.0%	10.0%

It was assumed that ‘small’ sources of HCRW (GP’s, dentists, vets, pharmacies, etc.) would show a similar percentage to clinics.

From this sheet, it may be seen that the total monthly HCRW mass for the province is estimated to be 1,175 tons (row 19). The total monthly HCRW mass generated by provincial facilities (not shown as a separate total in the sheet) amounts to 574 tons. The HCRW quantities used in the sheets ‘Scenario Costs All Facilities’ and ‘Scenario Costs Provincial’ are based on these totals.

TRANSPORT COSTS MODULE

This sheet/module determines the **per-container price** of transporting the various types of HCRW container from the central storage area of hospitals/clinics to the treatment facility/facilities. In the case of wheelie bins, the per-container cost **includes** the cost of transporting an empty bin back to the hospitals/clinics from the treatment facility/facilities.

In rows 5-14 of the **Transport Costs** sheet, vehicle parameters are entered. (A total of 5 vehicles was considered in the model, but this could be increased/decreased as required.) Messrs. McCarthy Toyota Trucks, Johannesburg, provided truck prices.

In rows 15, 18, 21 and 25, the maximum capacity of each vehicle is inserted in terms of the various HCRW containers under consideration. (Note that vehicles A and B were not considered viable for the transport of wheelie bins, due to their small size.) Note also that in the case of wheelie bins, the maximum capacity is ***per floor/level***, allowing for calculations based on either one or two floors/levels in the truck (see below).

In rows 31-33, the capital costs associated with the vehicles are entered. The depreciation period (in years) is set using the ‘spinner’ button in row 36.

The model calculates (in row 42) **the total annual fixed cost** based on the above and on the annual license cost (entered in row 41) and on the annual ‘cost of finance’ rate (i.e. interest rate) set in the ‘**Scenario Costs All Facilities**’ sheet. In row 43, an additional annual cost is determined, viz. an estimate of the ***additional*** annual cost associated with the provision of a second floor/level in the truck. (The estimated capital cost of this has been taken as 10% of the basic truck plus body cost.)

In row 45, estimated per-kilometre maintenance costs are entered, and in cell D46, the life-expectancy of a set of tyres (in kilometres).

The model calculates **total per-kilometre costs** in row 48.

In rows 51-70, the total annual crew-cost (per shift) is determined. A driver plus two helpers constitutes a ‘crew’.

In row 73, a ‘spinner’ button sets the number of floors/levels in the wheelie-bin trucks (one or two); the average load capacities (number of containers) are calculated in rows 75-78. These are based on an average load equal to 80% of maximum capacity. (Although it is obviously desirable that the maximum capacity of the vehicle is always utilised, this is impossible to achieve in practice: it has been assumed here that loads will generally vary between 60% and 100% of maximum capacity, with the average being 80% of maximum capacity.)

In rows 80-83, loading plus unloading times are determined for each vehicle and HCRW container type (as applicable). These times are based on the 'fixed' and 'variable' (i.e. per-container) load-plus-unload times reflected in cells K80-L83. These latter times are carried from the sheet **'Load and Unload Times'** (see below).

The 'spinner' button in cell L85 allows for a 'time-penalty' to be applied when multiple floors are used in trucks transporting wheelie bins. The rationale for this is that (i) the more bins that are carried by a truck, the more time that will be required to rearrange bins within the truck; (To be able to unload empty bins will inevitably require that full bins need to be moved within the truck, and/or unloaded from the truck and re-loaded), and (ii) it will take longer to lift/lower the mechanical tailgate to the higher level.

In rows 85-209, the **per-container price** of transporting the various HCRW containers is determined. These prices are influenced by (i) the number of shifts that each truck works in a day (the 'spinner' button in cell E86 allows for one, two or three shifts per day), (ii) the average round-trip distance that the trucks travel (see below), (iii) the average road-speed assumed for the trucks and (iv) the profit mark-up on the transport operation (the 'spinner' button in cell C 116 allows for this to be set, as a percentage mark-up on cost).

Average round-trip distance: this is a function of the number and location of treatment facilities considered under the **Treatment Scenarios** (see below). In the case of Gauteng, the X-Y co-ordinates of all hospitals (provincial and private) were determined during the 2000 DACEL Health Care Risk Waste Study. This allowed the straight-line distance between each hospital and any number of points representing treatment facilities to be determined. In the present model, it was assumed that HCRW would be transported from each hospital to the nearest treatment facility; the road distance to this facility was taken to be 1.3 times the straight-line distance. From the road distances between all hospitals and the nearest treatment facility, an average road distance, and hence an average round-trip distance, could be determined.

Average road-speed was assumed to be 40 km/hr for the smaller trucks and 35km/hr for the heavier trucks on the 80km round-trip, reducing progressively to 30km/hr and 25km/hr respectively on the 15km round-trip.

For the purposes of this model, the number of treatment facilities considered was one, three, ten and twenty. In the case of just one facility, this was positioned at the 'centre of gravity' of all the hospitals in the province. In the case of three, ten and twenty facilities, these were positioned at the largest (as measured in terms of HCRW generation) three, ten and twenty hospitals, respectively.

Note: The treatment facility locations assumed here serve to illustrate the effect of centralising vs. decentralising the treatment of HCRW in the province, and do not necessarily represent practical locations for such facilities.

Based on all the above, **average round-trip distances** were determined as follows:

- One facility: 80 kilometres
- Three facilities: 57 kilometres
- Ten facilities: 28 kilometres
- Twenty facilities: 15 kilometres

The minimum per-container cost for each round-trip distance and each type of container shows up in serise-coloured text (see for example rows 113-116). 'Array' formulas are used to isolate the annual cost associated with operation of the truck offering the best per-unit price (see for example cells K101-104); these formulas consider columns E-I as an 'array', and search for the value in each of rows 101-104 that corresponds with the minimum value in rows 113-116. Should it be necessary to change these array formulas, for example to allow for more/fewer columns, care should be taken to use the 'Ctrl-Enter' keys after editing the formulas, as opposed to just the 'Enter' key.

LOAD AND UNLOAD TIMES

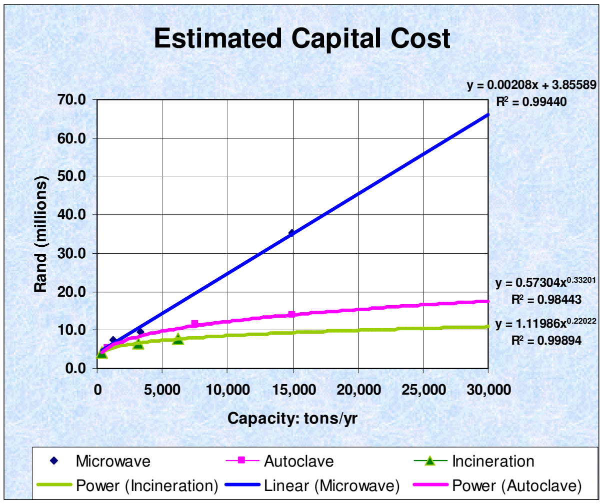
As mentioned above, the number of trips that a truck can make in a shift depends *inter-alia* on the time it takes to load and unload the vehicle. As the mode of loading the containers differs considerably (manual lifting in the case of cardboard boxes, and mechanical tailgate in the case of wheelie-bins), and as the number of containers carried by the trucks varies considerably (e.g. average loads of 144 boxes for truck "B" vs. 64 x 240 L wheelie-bins or 20 x 770 L wheelie-bins for truck "D" (assuming two floors/'layers'), it was deemed prudent to estimate the loading and unloading times as accurately as possible. This was done by breaking up the loading (i.e. at the hospital/clinic) and unloading (i.e. at the treatment facility) operations into discrete activities, and applying estimated times to these activities.

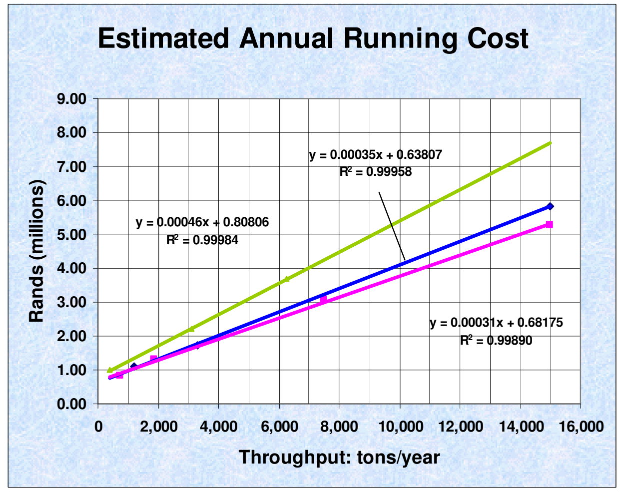
In the '**Load and Unload Times**' sheet, time taken for each activity has been classified as 'fixed' where the time is independent of the number of HCRW containers to be loaded/unloaded, and 'variable' if it depends on the number of containers. The fixed and variable activity times are totalled, and an overall fixed time for loading and unloading, and an overall per-unit time for loading and unloading, determined. These overall times are 'relaxed' by 25% (i.e. increased, to allow for rest periods, delays, etc.) before being carried to the '**Transport Costs**' sheet.

TREATMENT SCENARIO COSTS MODULE

As indicated above, three types of treatment are considered here, viz. incineration, autoclaving and microwave treatment. Also as mentioned above, treatment is considered to take place at either one central facility or at three, ten or twenty decentralised facilities.

In addition to the three types of treatment, the **Treatment Scenario Costs** module has to cater for two different scenarios, depending on whether **all** or only **provincial** HCRW is to be treated at the facilities.
The **capital cost** and **annual running cost** associated with each type of treatment, and covering a range of capacities and throughputs, is determined in the '**HCRW Treatment Cost Models**' sheet (see below). From this sheet, graphs relating estimated Capital Cost to capacity (in tons of HCRW per year) and estimated Running Cost to throughput (tons of HCRW treated per year) were derived. For ease of reference, these graphs are reproduced below. 'Best-fit' lines were fitted to the data points, and the equations of these lines are shown on the graphs.





In the '**Treatment Scenario Costs'** module, the scenario catering for the treatment of **all** HCRW generated in Gauteng appears in rows 5-55, and that catering for the treatment of HCRW produced by **provincial** health-care facilities **only** appears in rows 58-109.

<u>All HCRW generated in Gauteng:</u> In row 9, the **annual HCRW capacities** required **per plant** are shown; these have been determined from the monthly HCRW quantity in cell G10 of the **Scenario Costs All Facilities** sheet, allowing for a percentage of installed overcapacity (to cater for mechanical breakdown, provincial or national emergency, etc.) as follows:

in the case of only **one** plant, **100%** overcapacity at the plant
in the case of **three** plants, **33%** overcapacity at each plant
in the case of **five or more** plants, **25%** overcapacity at each plant

In row 10, the **annual HCRW throughputs** are shown, viz. the actual expected tonnage of HCRW that the plant(s) will handle, per plant.

In row 12, the **Capital Cost** of each plant is determined from the equation for the best-fit line applicable to the capital cost vs. capacity graph for the respective treatment type (see above), and in row 17, the annual running cost for each plant is similarly determined from the equation for the best-fit line applicable to the annual running cost vs. throughput graph for the respective treatment type.

The monthly finance cost (row 15) is determined by applying the annual cost of finance (set in the **Scenario Costs All Facilities** sheet) to the capital cost.

In row 16, monthly depreciation is calculated, based on the depreciation period selected by the user using the 'spinner' button in cell B16 (a range from 5 to 15 years has been allowed).

In row 19, total monthly cost is determined and, based on the profit mark-up selected by the user ('spinner' button in cell B20), the total monthly amount (cost plus profit) is determined in row 21. From this, a **treatment price per kilogram of HCRW** can be deduced, for use in the **Scenario Costs All Facilities** sheet.

(Note that the treatment price per kilogram ***drops*** between one and three facilities, and then increases as the number of facilities increases; this is due to the disproportionately high capital cost associated with the single facility, where 100% overcapacity has been assumed, as mentioned above.)

HCRW produced by provincial health-care facilities only: In row 63, the **annual HCRW capacities** required **per plant** are shown; these have been determined from the monthly HCRW quantity in cell G10 of the **Scenario Costs Provincial** sheet, allowing for the same percentage of installed overcapacity as mentioned above.

In the subsequent rows of the sheet, the same logic as that described above for all HCRW generated in Gauteng is followed. The **treatment price per kilogram of HCRW** is deduced in row 76, for use in the **Scenario Costs Provincial** sheet.

HCRW TREATMENT COST MODELS

For each treatment technology considered, and for a range of plant capacities, Capital and Running Costs were determined using the models on this sheet.

Capital Costs include land purchase and development costs, building costs, equipment costs, consulting and EIA (environmental impact assessment) costs. (The cost of equipment was based on International/South African price levels and was obtained from suppliers, plant operators and publications.)

Running Costs include fuel (gas), power and water costs, maintenance costs, the cost of process chemicals, and residue disposal costs (treatment and/or transport and safe disposal), monitoring costs, auditing fees and salaries and wages.

It was assumed that plants would operate 26 days per month (i.e. six days/week); incineration plants would run 20 hours/day (except the lowest plant size, which would only operate 12 hours/day) and other plants 24 hours/day.

Total Capital Cost and Total Annual Running Cost for each technology were plotted on graphs, and ‘best-fit’ lines were fitted to the data-points. In the case of Annual Running Costs, straight lines were fitted. In the case of Capital Costs, ‘power’ curves were fitted in the case of incineration and autoclave treatment, reflecting the ‘economies of scale’ that apply to plants using these technologies. In the case of microwave treatment, the maximum available plant-size treats 3,295 tons/year. To achieve larger capacities, additional units have to be used, effectively causing total Capital Cost to increase in direct proportion to capacity, i.e. no ‘economy of scale’ comes into effect.

DISINFECTION OF WHEELIE BINS

This sheet determines the total monthly cost associated with the disinfection of wheelie bins or re-usable plastic boxes. Based on the number of units to be treated per day (row 7: plastic boxes, row 8: 240 L bins ***or*** row 9: 770 L bins), a capital cost for the required plant is assumed. (At capacities of up to 600 240 L bins/day or 200 770 L bins/day, manual cleaning of the bins is assumed, using high-pressure water guns; above this capacity, mechanisation/automation is assumed, with bins passing through a ‘spray tunnel’ on a conveyor. Although automation would save on the labour required for the actual cleaning process, labour would still be required to move the bins into and out of the plant.)

Monthly costs are made up of a finance cost (calculated at the interest rate set in the **Scenario Costs All Facilities** sheet), a depreciation charge (a nominal 10-year depreciation period is used), a repair and maintenance cost (set at 10% of the capital cost of the plant) and consumable costs (disinfectant, electricity and water). These latter have been based on reasonable per-unit rates.

Finally, a per-bin disinfection cost is determined; as there is little variation in the per-bin cost over the range of plant size considered, the average per-bin disinfection cost has been applied in the **Scenario Costs All Facilities** and **Scenario Costs Provincial** sheets.

STATUS QUO COSTS: ALL FACILITIES

Monthly HCRW quantities in rows 9-12 are drawn from the sheet '**Scenario Costs All Facilities**'.

It is assumed that HCRW (dry, wet and sharps) is containerised in 142 L cardboard boxes, 50 L cardboard boxes and 10 L plastic containers, respectively. The mass of HCRW per container (cells E19-E21) is as assumed elsewhere in the model. The estimated current 'cost per container' has been inserted in cells F19-F21. This cost (i) includes for the supply, collection and destruction of the container (as per provincial Department of Health requirements) and (ii) includes VAT.

In rows 33-35, the number of HCRW containers generated per month is determined; from this, the monthly cost (cells G44-G46) can be determined.

In order to render the 'status-quo' costs comparable with the scenarios presented in the sheet '**Scenario Costs All Facilities**', an equivalent labour-cost (at the HCRW generators) has to be included in the monthly costs (row 42).

The total estimated monthly HCRW containerisation and destruction cost is determined in row 47. This total is carried to the 'Cost Summary' sheet, for comparison with the 'new' scenarios.

The user's attention is drawn to the notes appearing in rows 51 and 53. In particular, it should be noted that the calculation of 'status-quo' costs here assumes that all Gauteng HCRW is containerised and destroyed in the same manner. This is clearly not the case in practice, but is an acceptable assumption here, where the objective is to determine comparative rather than actual costs.

STATUS QUO COSTS: PROVINCIAL

Monthly HCRW quantities in rows 9-12 are drawn from the sheet '**Scenario Costs Provincial**'.

The logic followed in this sheet is identical to that followed in the '**Status Quo Costs: All Facilities'** sheet, as described above.

The total estimated monthly HCRW containerisation and destruction cost (provincial health-care facilities only) is determined in row 47. This total is carried to the 'Cost Summary' sheet, for comparison with the 'new' scenarios.

SCENARIO COSTS: ALL FACILITIES

In this sheet, all the 'cost-components' are brought together to derive total monthly costs for the various scenarios.

In cells G7-G9, the monthly total HCRW quantities, as split into dry, wet and sharps, are reflected. These are the quantities in the '**HCRW Generation Data**' sheet, ***as adjusted up or down by the user*** through the use of the 'spinner' button in cells E9-E10. (This adjustment has been provided so that the effect on the scenarios of increases in HCRW quantities {due to population growth, higher levels of servicing, etc.} as well as decreases {due to better segregation of waste, etc.} can be readily evaluated.) (It should be noted that the adjusting the HCRW quantity in this sheet has a corresponding effect on the HCRW quantity from the provincial health-care facilities only sheet, viz. '**Scenario Costs: Provincial**'.)

Major quantitative assumptions made, including procurement prices for the various HCRW containers, etc., as well as the 'annual finance cost' (i.e. the interest rate charged on borrowed capital) used throughout the model, are reflected in **cells K4-Q33**.

The four containerisation scenarios are presented in columns E-G, I-L,N-P and R-T respectively, starting in row 37. (The scenarios are reflected diagrammatically in Figure 7.1)

In rows 42-46, the number of 'primary' HCRW containers is determined, based on the monthly HCRW quantities in cells G7-G9 (see above) and the HCRW-mass-per-container assumptions reflected in cells N7-N17. In row 48, the number of wheelie-bins required per month and per day is determined (scenarios 2 and 3 only), based on the HCRW-mass-per-container assumptions reflected in cells N13-N14.

In rows 51-84, the total (monthly) cost of containerisation of the waste is determined, for each scenario. Capital costs are reflected in rows 53-67: in the case of scenario 1, there is only a small element of capital cost, relating to bag-holders on nursing trolleys, 'cage trolleys', which are introduced to facilitate movement of the HCRW containers within the health-care facilities, and pallets and (hand-operated) pallet-trucks for moving the boxes from the 'central waste store' to the trucks, and thence to the treatment plant; in the case of scenarios 2 and 3, in addition to the capital cost of cage trolleys, bag-holders and bag-holding brackets on nursing trolleys, there is the substantial cost associated with the procurement of the wheelie-bins.

Careful consideration was given to the likely total number of wheelie-bins and re-usable plastic containers required. Considering the daily wheelie-bin/plastic container usage total as a 'set', it could be argued that a full additional set would be in transit to/from the treatment facilities on any day, and a further set would be at the treatment facilities. This means that a **minimum of three sets** would be required, before allowing for any spare bins at the health-care facilities to cater for (i) days on which no collections take place, either by design or accident, (ii) the time-delay in deployment of empty bins/collection of full bins within the health-care facilities, and (iii) bins undergoing repair.

The model allows the user to select values between 2 and 7 for the number of wheelie-bin 'sets' provided, and between 2 and 10 for the number of plastic container 'sets' provided ('spinner' buttons in cells D62 to D64). It is believed that for the 770 L wheelie bins, which are used **only** for internal transport of the HCRW, movement to the central store and thence to the treatment facility, three sets of bins may be sufficient. In the case of the 240 L wheelie-bins, which are also used as storage containers in the sluice-rooms, in addition to internal movement and transport off-site, between four and five sets of bins will probably be required. For the plastic containers, which serve as 'primary' HCRW receptacles, as well as being used for transport and storage, it is believed that at least six sets will be required.

Because of the high capital cost of the wheelie-bins and plastic containers (scenarios 2, 3 and 4), the period over which they are depreciated has a significant impact on the total scenario costs. However, it would be reasonable to assume that this period would bear a strong relationship to the usage of the wheelie-bins/plastic containers (as measured by the number of 'cycles' to which the wheelie-bins/containers are subjected). The model allows the user to select a value between 50 and 500 for the number of 'cycles' representing the expected useful life of the wheelie-bins/containers. A value of 150 is believed to be reasonable, and is used in the 'base-line' scenarios.

Labour costs (at the HCRW source) are reflected in row 73. As indicated under **Assumptions** (see cells K32-Q32), one HCRW worker has been provided for each 200kg per day of HCRW generated at hospitals. A theoretical analysis indicated that the mode of containerisation had little effect on the mass of HCRW that a worker could handle in a day, provided that, in the case of Scenario 1, wheeled 'cage-trolleys' were provided, able to accommodate at least six full 142 L boxes plus two sharps containers and one 20 L bucket.

In view of this, the same number of HCRW workers has been provided under each scenario.

By means of the 'spinner' button in cell D83, the monthly maintenance charge can be adjusted. This maintenance charge is provided chiefly to allow for maintenance of the equipment/hardware required, other than the wheelie bins and re-usable containers. A rate of at least 5% per annum of the capital cost is suggested.

The total monthly containerisation costs are reflected in row 84.

In the Transportation and Treatment sections of the sheet, it becomes necessary to take account of a further variable, viz. the number of treatment facilities under consideration.

In the Transportation section (rows 87-92), the unit costs are brought in from the applicable cells of the '**Transport Costs'** sheet/module (see above). These unit costs are the **minimum values** for each container-type and average round-trip distance (as determined by the number of facilities involved), as derived in the '**Transport Costs'** sheet/module. For each scenario and each of the four round-trip distances, a total monthly transportation cost is determined in this section. The number of trucks required is also reflected.

The monthly cost associated with cleaning and disinfection of the wheelie bins (scenarios 2, 3 and 4 only) is introduced in row 97.

In rows 103-106, the unit treatment-costs (as deduced in the '**Treatment Costs**' sheet/module) are introduced.

Total monthly treatment costs are calculated in rows 108-111, using the monthly total HCRW quantity and the unit rates referred to above. (In the case of disposable containers {scenario 1}, the mass of the cardboard boxes is added to the HCRW mass, to arrive at the total mass {HCRW plus boxes} requiring destruction.)

In rows 116-119, the total monthly costs are determined for each scenario, each treatment type, and each of the four degrees of centralisation/decentralisation of treatment facilities (viz. 1, 3, 10 and 20 facilities). The results are graphed in rows 122-145, and also carried to the '**Cost Summary**' sheet (see below).

SCENARIO COSTS: PROVINCIAL

This sheet/module follows the same logic as the '**Scenario Costs: All Facilities**' sheet (see above), except that the quantities of HCRW involved relate **only to provincial health-care facilities**. (As mentioned previously, it should be remembered that the HCRW quantities upon which this sheet are drawn from the '**HCRW Generation Data**' sheet, **as adjusted** up or down by the user through the use of the 'spinner' button in cells E9-E10 of the '**Scenario Costs: All Facilities**' sheet.)

The 'Assumptions' (cells K4-Q33 mirror those in the '**Scenario Costs: All Facilities**' sheet, and cannot be changed here. Similarly, the number of 'sets' of wheelie-bins provided, the annual wheelie-bin maintenance cost percentage and the period over which wheelie bins are depreciated cannot be set in this sheet, but mirror the values set in the '**Scenario Costs: All Facilities**' sheet.

In rows 116-119, the total monthly costs are determined for each scenario, each treatment type, and each of the four degrees of centralisation/decentralisation of treatment facilities (viz. 1, 3, 10 and 20 facilities). The results are graphed in rows 122-144, and also carried to the '**Cost Summary**' sheet (see below).

COST SUMMARY

This is a summary of the results determined in sheets '**Scenario Costs: All Facilities**', '**Scenario Costs: Provincial**', '**Status Quo Costs: All Facilities**' and '**Status Quo Costs: Provincial**'.

For ease of reference, major assumptions (viz. interest rate, depreciation periods for treatment plants, trucks and equipment, usable life of wheelie-bins/re-usable plastic containers (measured in 'cycles'), number of floors/levels in wheelie-bin trucks, number of 'sets' of wheelie-bins/re-usable containers provided, number of {transport} shifts worked per day, etc.) are also shown.

Results for **all Gauteng HCRW** are shown in rows 36-39, and for provincial HCRW in rows 45-48. Note that total monthly costs have been rounded to the nearest R 0.1 million, as further decimal places cannot be considered significant.

Results are graphed in 3-D 'bars' in rows 53-87.

16 Annex 4: Background Data for Calculation of Cost of Technologies

2. Microwave Treatment

			Capacity/yr =		**14,826**	**tons**		**Capacity/yr =**		**3,295**	**tons**		**Capacity/yr =**		**1,198**	**tons**	
			Capacity/hr =		**1,980**	**kg**		**Capacity/hr =**		**440**	**kg**		**Capacity/hr =**		**160**	**kg**	
			Days/month =		**26**			**Days/month =**		**26**			**Days/month =**		**26**		
			Op. hrs/day		**24**			**Op. hrs/day**		**24**			**Op. hrs/day**		**24**		
	Capital Costs				**Rand**					**Rand**					**Rand**		
1	Property	Area, m2	7,000	R200/m2	1,400,000			3,000	R200/m2	600,000			2,000	R200/m2	400,000		
2	Development Costs																
		Earthworks, Roads, etc, m2	3,000	R120/m2	360,000			1,500	R120/m2	180,000			1,000	R120/m2	120,000		
		Building, m2	350	2,800	980,000			250	2,800	700,000			250	2,800	700,000		
		Electrical, Switchgear etc.			440,000					220,000					220,000		
		Emergency Equipment			82,000					82,000					82,000		
3	Equipment				30,937,500					6,875,000					5,156,250		
4	Initial Monitoring				60,000					60,000					60,000		
4	Consultancy Fees				400,000					400,000					400,000		
5	Sundry Equipment				500,000					343,750					257,813		
	Total Capital costs				**R 35,159,500**					**R 9,460,750**					**R 7,396,063**		
	Running Costs				**Per Annum**					**Per Annum**					**Per Annum**		
					Rand	***Unit costs***				**Rand**	***Unit costs***				**Rand**	***Unit costs***	
6	Microwave	Electricity, kw		337.5	505,440	R 0.20	/kw-h		75	112,320	R 0.20	/kw-h		52.5	78,624	R 0.20	/kw-h
		Water, l/h		153	8,020	R 0.007	/litre		34	1,782	R 0.007	/litre		24	1,258	R 0.007	/litre
		Maintenance, % p.a		5%	1,546,875				5%	343,750				5%	257,813		
7	Sundry Equip	Maintenance		10%	50,000				10%	34,375				10%	25,781		
8	Disposal of residues			90%	1,142,214	R 85.60	/ton		90%	253,825	R 85.60	/ton		90%	92,300	R 85.60	/ton
		Lifts @ 6 tons ea.		2471.04	1,482,624	R 600.00	/lift		549.12	329,472	R 600.00	/lift		199.68	119,808	R 600.00	/lift
9	Disposal of Pathological & Chemical Waste																
		Waste%		2.50%	370,656	R 1,000.00	/ton		2.50%	82,368	R 1,000.00	/ton		2.50%	29,952	R 1,000.00	/ton
10	Monitoring			monthly	6,000	R500.00/mth			monthly	6,000	R500.00/mth			monthly	6,000	R500.00/mth	
11	Auditing			annual	10,000				annual	10,000				annual	10,000		
12	Salaries/wages				600,000					500,000					450,000		
13	Sundry Consumables				100,000					50,000					25,000		
	Total Running Costs				**R 5,821,828**				**Sub Total**	**R 1,723,892**				**Sub Total**	**R 1,096,536**		

Treatment Cost Models for Various Technologies - Health Care Risk Waste

1. Incineration

			Capacity/yr =		**6,240**	**tons**		**Capacity/yr =**		**3,120**	**tons**		**Capacity/yr =**		**374**	**tons**	
			Capacity/hr =		**1,000**	**kg**		**Capacity/hr =**		**500**	**kg**		**Capacity/hr =**		**100**	**kg**	
			Days/month =		**26**			**Days/month =**		**26**			**Days/month =**		**26**		
			Op hrs/day		**20**			**Op hrs/day**		**20**			**Op hrs/day**		**12**		
	Capital Costs				**Rand**					**Rand**					**Rand**		
1	Property	Area, m2	4,500	R200/m2	900,000			3,500	R200/m2	700,000			2,000	R200/m2	400,000		
2	Development Costs																
		Earthworks, Roads, etc, m2	2,000	R120/m2	240,000			1,750	R120/m2	210,000			1,000	R120/m2	120,000		
		Building, m2	250	2,800	700,000			250	2,800	700,000			250	2,800	700,000		
		Electrical, Switchgear etc.			220,000					220,000					220,000		
		Emergency Equipment			82,000					82,000					82,000		
3	Equipment	Incinerator		4,800,000					3,850,000					1,960,000			
		Scrubber (dry)	(incl. In above)	0					0					0			
		Monitoring Equipment		150,000					150,000					150,000			
		Total			4,950,000					4,000,000					2,110,000		
4	Consultancy Fees (EIA, etc.)				400,000					400,000					400,000		
5	Sundry Equipment				247,500					200,000					105,500		
	Total Capital costs				**R 7,739,500**					**R 6,512,000**					**R 4,137,500**		
	Running Costs				**Per Annum**					**Per Annum**					**Per Annum**		
					Rand	***Unit costs***				**Rand**	***Unit costs***				**Rand**	***Unit costs***	
							1GJ=63m3					1GJ=63m3					1GJ=63m3
6	Incinerator/	Gas, m3/hr		410	1,258,895	R 31.00	/GJ		190	583,390	R 31.00	/GJ		95	175,017	R 31.00	/GJ
	Gas Cleaning	Electricity, kw	22.7	454	28,330	R 0.20	/kwh	11.75	235	14,664	R 0.20	/kwh	5	60	3,744	R 0.20	/kwh
		Water, kl/day		1	2,184	R 7.00	/kl		0.5	1,092	R 7.00	/kl		0.25	546	R 7.00	/kl
		Maintenance		10%	480,000				10%	385,000				10%	196,000		
		Process Chemicals, kg/kg waste		0.095	533,520	R 0.90	/kg lime		0.095	266,760	R 0.90	/kg lime		0.095	32,011	R 0.90	/kg lime
7	Gas Cleaning	Electricity, kw,kwhr/day	78.0	1560	97,344	R 0.20	/kwh	42	840	52,416	R 0.20	/kwh	15	180	11,232	R 0.20	/kwh
8	Sundry Equip	Maintenance		10%	39,750				10%	35,000				10%	25,550		
9	Disposal																
	Bottom Ash			15%	80,122	R 85.60	/ton		15%	40,061	R 85.60	/ton		15%	4,807	R 85.60	/ton
				Lifts @ 6 tons ea	93,600	R 600.00	/lift		Lifts @ 6 tons ea	46,800	R 600.00	/lift		Lifts @ 6 tons ea	5,616	R 600.00	/lift
		Ash Treat. 2.5% lime		2.50%	21,060	R 0.90	/kg		2.50%	10,530	R 0.90	/kg		2.50%	1,264	R 0.90	/kg
	Gas Cleaning	Residues: 0.1kg/kg waste		10%	218,400	R 350.00	/ton		10%	109,200	R 350.00	/ton		10%	13,104	R 350.00	/ton
				Lifts @ 6 tons ea	62,400	R 600.00	/lift		Lifts @ 6 tons ea	31,200	R 600.00	/lift		Lifts @ 6 tons ea	3,744	R 600.00	/lift
10	Monitoring			2/yr	80,000	Includes 1 x Dioxin Measurement/yr			2/yr	80,000	Includes 1 x Dioxin Measurement/yr			2/yr	80,000	Includes 1 x Dioxin Measurement/yr	
11	Auditing			annual	10,000				annual	10,000				annual	10,000		
12	Salaries/wages				600,000					500,000					400,000		
13	Sundry Consumables				75,000					50,000					25,000		
	Total Running Costs				**R 3,680,604**					**R 2,216,113**					**R 987,635**		

3. Autoclaving / Steam Sterilisation

No.	Item	Description			Rand	Unit costs	
			Mass/cycle		1,778	kg	
			Cycles/24hr		27		
			Op hrs/day		24		
			Days/month		26		
			Capacity/hr		2,000	kg	
			Capacity/yr		14,978	tons	
	Capital Costs				**Rand**		
1	Property	Area, m2	7,000	R200/m2	1,400,000		
2	Development Costs						
		Earthworks, Roads, etc, m2	3,000	R120/m2	360,000		
		Building, m2	350	2,800	980,000		
		Electrical, Switchgear etc.			440,000		
		Emergency Equipment			82,000		
3	Equipment				9,480,000		
4	Initial Monitoring				60,000		
5	Consultancy Fees				400,000		
6	Sundry Equipment				474,000		
7	Steam Gener	640x27/24=720 kg/hr (use 900 kg/hr unit)			250,000		
	Total Capital costs				**R 13,926,000**		
	Running Costs				**Per Annum**		
					Rand	***Unit costs***	
8	Autoclave	Electricity, kw,Rand		80	119,808	R 0.20	/kwh
		Water, l/cycle		470	27,715	R 0.007	/litre
		Steam, kg/cycle (see below for costs)		640	0	R 0	/ton
		Maintenance, % p.a.		5%	474,000		
9	Steam Gener	Percent of rated capacity		80%			
		Electricity kwh/hr at rated cap.		3	3,594	R 0.20	
		Gas m3/hr at rated cap.		160	471,625	R 31.00	/GJ
		Water lit/hr at rated cap.		990	41,513	R 0.01	1GJ=63m3
10	Sundry Equip	Maintenance, % p.a.		10%	47,400		
11	Steam Gener	Maintenance, % p.a.		10%	25,000		
12	Disposal of residues			100%	1,282,106	R 85.60	/ton
				Lifts @ 6ton ea	1,497,787	R 600.00	/lift
13	Disposal of Pathological & Chemical Waste						
		Waste%		2.50%	374,447	R 1,000.00	/ton
14	Monitoring			monthly	6,000	R500.00/mth	
15	Auditing			annual	10,000		
16	Salaries/wages				800,000		
17	Sundry Consumables				100,000		
	Total Running Costs				**R 5,280,996**		

		Rand	Unit costs	
Mass/cycle		1,334	kg	
Cycles/24hr		27		
Op hrs/day		24		
Days/month		26		
Capacity/hr		1,500	kg	
Capacity/yr		11,238	tons	
		Rand		
6,000	R200/m2	1,200,000		
3,000	R120/m2	360,000		
300	2,800	840,000		
		220,000		
		82,000		
		8,800,000		
		60,000		
		400,000		
		440,000		
		250,000		
		R 12,652,000		
		Per Annum		
		Rand	***Unit costs***	
	60	89,856	R 0.20	/kwh
	370	21,818	R 0.007	/litre
	480	0	R 0	/ton
	5%	440,000		
	60%			
	3	2,696	R 0.20	
	160	353,719	R 31.00	/GJ
	990	31,135	R 0.01	
	10%	44,000		
	10%	25,000		
	100%	961,940	R 85.60	/ton
	Lifts @ 6ton ea	1,123,762	R 600.00	/lift
	2.50%	280,940	R 1,000.00	/ton
	monthly	6,000	R500.00/mth	
	annual	10,000		
		700,000		
		87,000		
		R 4,177,866		

		Rand	Unit costs	
Mass/cycle		889	kg	
Cycles/24hr		27		
Op hrs/day		24		
Days/month		26		
Capacity/hr		1,000	kg	
Capacity/yr		7,489	tons	
		Rand		
4,500	R200/m2	900,000		
2,000	R120/m2	240,000		
250	2,800	700,000		
		220,000		
		82,000		
		8,210,000		
		60,000		
		400,000		
		410,500		
		225,000		
		R 11,447,500		
		Per Annum		
		Rand	***Unit costs***	
	40	59,904	R 0.20	/kwh
	300	17,690	R 0.007	/litre
	320	0	R 0	/ton
	5%	410,500		
	60%			
	2.4	2,157	R 0.20	
	105	232,128	R 31.00	/GJ
	660	20,757	R 0.01	
	10%	41,050		
	10%	22,500		
	100%	641,053	R 85.60	/ton
	Lifts @ 6ton ea	748,894	R 600.00	/lift
	2.50%	187,223	R 1,000.00	/ton
	monthly	6,000	R500.00/mth	
	annual	10,000		
		600,000		
		75,000		
		R 3,074,856		

3. Autoclaving / Steam Sterilisati

		Rand	Unit costs	
Mass/cycle		222	kg	
Cycles/24hr		27		
Op hrs/day		24		
Days/month		26		
Capacity/hr		250	kg	
Capacity/yr		1,870	tons	
		Rand		
2,500	R200/m2	500,000		
1,250	R120/m2	150,000		
250	2,800	700,000		
		220,000		
		82,000		
		4,000,000		
		60,000		
		400,000		
		200,000		
		150,000		
		R 6,462,000		
		Per Annum		
		Rand	***Unit costs***	
	20	29,952	R 0.20	/kwh
	180	10,614	R 0.007	/litre
	80	0	R 0	/ton
	5%	200,000		
	40%			
	1.8	1,078	R 0.20	
	45	66,322	R 31.00	/GJ
	275	5,766	R 0.01	
	10%	20,000		
	10%	15,000		
	100%	160,083	R 85.60	/ton
	Lifts @ 6ton ea	187,013	R 600.00	/lift
	2.50%	46,753	R 1,000.00	/ton
	monthly	6,000	R500.00/mth	
	annual	10,000		
		500,000		
		37,000		
		R 1,295,582		

		Rand	Unit costs	
Mass/cycle		89	kg	
Cycles/24hr		27		
Op hrs/day		24		
Days/month		26		
Capacity/hr		100	kg	
Capacity/yr		750	tons	
		Rand		
2,500	R200/m2	500,000		
1,250	R120/m2	150,000		
250	2,800	700,000		
		220,000		
		82,000		
		3,000,000		
		60,000		
		400,000		
		150,000		
		150,000		
		R 5,412,000		
		Per Annum		
		Rand	***Unit costs***	
	10	14,976	R 0.20	/kwh
	110	6,486	R 0.007	/litre
	32	0	R 0	/ton
	5%	150,000		
	20%			
	1.8	539	R 0.20	
	45	33,161	R 31.00	/GJ
	275	2,883	R 0.01	
	10%	15,000		
	10%	15,000		
	100%	64,177	R 85.60	/ton
	Lifts @ 6ton ea	74,974	R 600.00	/lift
	2.50%	18,743	R 1,000.00	/ton
	monthly	6,000	R500.00/mth	
	annual	10,000		
		400,000		
		25,000		
		R 836,940		

17 Annex 5: Background Data for Calculation of Environmental Impacts

Background calculations for emissions caused by manufacturing of receptacles.

Card board box w. liner

	Unit	
Cycles	times	1
Volume	Litre	140
Tara/unit	kg material	0.7
Contents/unit	kg HCRW	9
Weight of liner	kg	0.1
Tonees/month	tonnes	1172
Uses in Gauteng	Uses/year	130222

Packaging	8.16%	of total
Cardboard (tonne/year)		1094
Liner (tonne/year)		156

Wheelie bin 240 litre

	Unit	
Cycles	times	250
Volume	Litre	240
Tara/unit	kg material	15
Contents/unit	kg HCRW	18
Weight of liner	kg	0
Tonees/month	tonnes	1084
Uses in Gauteng	Uses/year	60197

Electricity per wash 0.4 kWh

		Cardboard box alone			Liner	Total			Wheelie bin			Washing	Total
	Unit	**/kg**	**/unit**	**/use**	**/use**	**/use**	**/kg HCRW**	**Total/months**	**/kg**	**/unit**	**/use**	**/use**	**/use**
Total fuel	MJ	25.70000	17.99000	17.99000	7.71601	25.70601	2.85622	3,347,493	77.16005	1,157.40079	4.62960	1.44000	6.06960
Water	kg	62.60000	43.82000	43.82000	6.09671	49.91671	5.54630	6,500,265	60.96712	914.50683	3.65803	7.00000	10.65803
Waste	kg	0.09090	0.06363	0.06363	0.00351	0.06714	0.00746	8,743	0.03510	0.52655	0.00211	0.10000	0.10211
CO	kg	0.00086	0.00060	0.00060	0.00007	0.00067	0.00007	88	0.00072	0.01082	0.00004	-	0.00004
CO2	kg	1.07000	0.74900	0.74900	0.18500	0.93400	0.10378	121,628	1.85000	27.75000	0.11100	0.16800	0.27900
Dust	kg	0.00151	0.00106	0.00106	0.00015	0.00121	0.00013	157	0.00149	0.02235	0.00009	0.00008	0.00017
HF	kg	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0	0.00000	0.00002	0.00000	-	0.00000
Hg	kg	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0	0.00000	0.00001	0.00000	-	0.00000
NOx	kg	0.00274	0.00192	0.00192	0.00096	0.00288	0.00032	375	0.00958	0.14370	0.00057	0.00028	0.00085
SO2	kg	0.00696	0.00487	0.00487	0.00129	0.00616	0.00068	802	0.01290	0.19350	0.00077	0.00040	0.00117
COD	kg	0.01500	0.01050	0.01050	0.00002	0.01052	0.00117	1,370	0.00018	0.00269	0.00001	0.00035	0.00036
HCl	kg	-	-	-	0.00000	0.00000	0.00000	0	0.00003	0.00050	0.00000	-	0.00000
CH4	kg	-	-	-	0.00061	0.00061	0.00007	79	0.00606	0.09090	0.00036	-	0.00036

Wheelie bin 770 litre

	Unit	
Cycles	times	250
Volume	Litre	770
Tara/unit	kg material	45
Contents/unit	kg HCRW	63
Weight of liner	kg	n.a.
Tonees/month	tonnes	1084
Uses in Gauteng	Uses/year	17199

Electricity per wash 0.9 kWh

Reusable box bin 120 litre

	Unit	
Cycles	times	90
Volume	Litre	120
Tara/unit	kg material	2
Contents/unit	kg HCRW	8.5
Weight of liner	kg	n.a.
Tonees/month	tonnes	1084
Uses in Gauteng	Uses/year	127476

Electricity per wash 0.2 kWh

Wheelie bin			Washing	Total			Reusable Box			Washing	Total
/kg	**/unit**	**/use**	**/use**	**/use**	**/kg HCRW**	**Total/months**	**/kg**	**/unit**	**/use**	**/use**	**/use**
77.16005	3,472.20238	13.88881	3.24000	17.12881	0.27189	294,601	77.16005	154.32011	1.71467	0.72000	2.43467
60.96712	2,743.52049	10.97408	10.00000	20.97408	0.33292	360,737	60.96712	121.93424	1.35482	2.00000	3.35482
0.03510	1.57966	0.00632	0.30000	0.30632	0.00486	5,268	0.03510	0.07021	0.00078	0.06000	0.06078
0.00072	0.03245	0.00013	-	0.00013	0.00000	2	0.00072	0.00144	0.00002	-	0.00002
1.85000	83.25000	0.33300	0.37800	0.71100	0.01129	12,229	1.85000	3.70000	0.04111	0.08400	0.12511
0.00149	0.06705	0.00027	0.00018	0.00045	0.00001	8	0.00149	0.00298	0.00003	0.00004	0.00007
0.00000	0.00007	0.00000	-	0.00000	0.00000	0	0.00000	0.00000	0.00000	-	0.00000
0.00000	0.00002	0.00000	-	0.00000	0.00000	0	0.00000	0.00000	0.00000	-	0.00000
0.00958	0.43110	0.00172	0.00063	0.00235	0.00004	40	0.00958	0.01916	0.00021	0.00014	0.00035
0.01290	0.58050	0.00232	0.00090	0.00322	0.00005	55	0.01290	0.02580	0.00029	0.00020	0.00049
0.00018	0.00806	0.00003	0.00080	0.00083	0.00001	14	0.00018	0.00036	0.00000	0.00016	0.00016
0.00003	0.00149	0.00001	-	0.00001	0.00000	0.10	0.00003	0.00007	0.00000	-	0.00000
0.00606	0.27270	0.00109	-	0.00109	0.00002	18.76	0.00606	0.01212	0.00013	-	0.00013

Emissions caused by treatment plants (including emissions caused by power production at a regional coal fired power plant):

Total Dioxin (Dioxin/Furan) emission from transport of waste from institutions, transport of residues and treatment:

Dioxin		Status Quo	Regional Incineration	Regional Non-burn	On-site Incineration	On-site Non-burn	Mix regional treatment	Mix all
Dioxin Transp 1	ngTEQ	0.0002	0.0003	0.0003			0.0003	0.0001
Dioxin Transp 2	ngTEQ	0.0000	0.0000	0.0001	0.0000	0.0001	0.0001	0.0001
Sub-total	ngTEQ	0.0002	0.0003	0.0004	0.0000	0.0001	0.0004	0.0002
Dioxin Treatment	ngTEQ	0.0139	0.0028		0.0028		0.0014	0.0014
Total	ngTEQ	0.0141	0.0031	0.0004	0.0028	0.0001	0.0018	0.0016
% of total from transport		1.3%	10.3%	100.0%	0.9%	100.0%	21.5%	14.4%

Power Plant (Treatm Plant consumption)				Status Quo	Regional Incineration	Regional Non-burn	On-site Incineration	On-site Non-burn	Mix regional treatment	Mix all
Power	-		MJ	126,576	126,576	632,880	126,576	632,880	379,728	379,728
Power			kWh/month	35,160	35,160	175,800	35,160	175,800	105,480	105,480
CO2	420.0	g/kWh	kgCO2	14,767	14,767	73,836	14,767	73,836	44,302	44,302
SO2	1.0	g/kWh	kgSO2	35	35	176	35	176	105	105
NOx	0.7	g/kWh	kgNOx	25	25	123	25	123	74	74
Dust	0.2	g/kWh	kgDust	7.0	7.0	35.2	7.0	35.2	21.1	21.1
Impact from Incineration										
CO2	2,234,998.5	mg/kg	kgCO2	2,619,418	2,619,418		2,619,418		1,309,709	1,309,709
Dust	416.5	mg/kg	kgDust	2,510	488		488		244	244
NOx	2,380.0	mg/kg	kgNOx	4,184	2,789		2,789		1,395	1,395
SO2	297.5	mg/kg	kgSO2	3,487	349		349		174	174
Total										
CO2			kgCO2	2,634,185	2,634,185	73,836	2,634,185	73,836	1,354,011	1,354,011
Dust			kgDust	2,517	495	35	495	35	265	265
NOx			kgNOx	4,209	2,814	123	2,814	123	1,469	1,469
SO2			kgSO2	3,522	384	176	384	176	280	280