6. FEASIBILITY STUDY INTO THE REGIONALISATION OF HEALTH CARE RISK WASTE FACILITIES IN GAUTENG

6.1 Introduction

As indicated in Chapter 4 titled “Status Quo on the Medical Waste Treatment Facilities” of this report, the majority of HCRW incinerators in Gauteng are owned and operated by Provincial Hospitals. Other priorities have delayed the upgrading/replacement of these units, as required to meet the emission standards laid down by DEAT in 1994 for various scheduled processes, including HCRW incineration. Full compliance with the emission standards is required by the year 2002.

During the 1998-1999 budget cycle, the first two incineration facilities were upgraded, viz. those at Tambo Memorial and Tembisa Hospitals. The Gauteng Department of Transport and Public Works has now presented a programme that envisages the replacement/installation of incinerators at all Provincial Hospitals by 2009, requiring an extension of DEAT’s original deadline by 7 years.

GDACEL in turn has embarked on a process to develop a HCW strategy for Gauteng. This process includes a feasibility study into the possibility of the regionalisation of HCRW treatment/disposal facilities in the province. This approach is in line with the National Waste Management Strategy (NWMS) as sound HCRW management has been identified by the NWMS as being a priority concern.

The feasibility study described in this chapter focussed on determining the financial feasibility or otherwise of regionalisation of HCRW incineration in the province, with specific regard to HCRW generated by Provincial Hospitals.

6.2 Problem Definition

The estimated current rate of HCRW generation by provincial hospitals has been discussed in Chapter 3 : Status Quo Report on the Sources of HCRW in Gauteng, which forms part of the present study. Currently, this HCRW is either (a) incinerated on-site at the hospital concerned, (b) removed by a waste management contractor and incinerated at a third-party incineration facility, or (c) regrettably, dumped illegally. In certain cases, a combination of (a) and (b) occurs. An estimate of current overall monthly cost associated with the destruction of HCRW generated in Gauteng provincial health care facilities, is presented in Section 6.3 below.

The current study sought to establish whether the overall cost referred to above could be reduced by “regionalizing” incineration of HCRW, i.e. by utilising a number of new (or upgraded/expanded existing) incineration facilities, as a departure from the current practice of undertaking on-site incineration at the majority of provincial hospitals.

In order to establish whether overall costs incurred by HCRW treatment/disposal of provincial health care facilities could be reduced, it was necessary to “model” various scenarios and compare the results. For this purpose, a numerical model was developed which is described in Section 6.4 of this Chapter.

6.3 Current Incineration Costs for Provincial Hospitals

As referred to elsewhere in this report, information on costs associated with the operation of incinerators at provincial hospitals were generally not available, or not known to the persons interviewed. In addition, there is a very real risk that costs obtained through canvassing incinerator users produces results which are not comparable, i.e. not all costs are included in all cases, and costs ("overhead" costs in particular) are treated in different ways. For this reason, it was decided that it would be prudent to develop an independent cost-model for incinerators, which would ensure that all installations were treated in a consistent manner. The same cost model could then also be used for "new" installations, as discussed below during the investigation into possible regionalisation of HCRW treatment/disposal operations.

6.3.1 Incineration Cost Model

Costs associated with incineration can be divided into two main classes**: Fixed** (Monthly) **Overhead Costs** and **Variable Costs**.

Fixed (Monthly) **Overhead Costs** are costs that are/would be incurred, irrespective of the extent of usage of the incinerator(s). Components of this cost include the depreciation of the capital cost of the installation, a portion of the maintenance cost of the incinerator itself, the annual electricity connection fee, a portion of the electricity consumption costs, and the salaries/wages of the staff associated with the incinerator (whether directly, as in the case of operators, labourers, etc., or indirectly, i.e. supervisors, administrative and financial personnel, etc.).

Variable costs are costs associated with actual operation of the incinerator. Chief among these is the fuel (usually diesel oil) cost, the electricity consumption cost, the costs associated with the removal and disposal of ash, as well as a portion of the maintenance cost of the installation, and in particular the incinerator(s). (The more the incinerator is used, the more maintenance is required, in the form of burner nozzles, thermocouples, refractory linings, etc.).

A typical model is presented below as Table 6.1, which is for the Tembisa Hospital incinerator. It should be noted that all costs are current (Year 2000) costs. A brief explanation of the model is set out below, in which the rationale and assumptions made are explained/noted. (For ease of reference, paragraph numbers below match the section numbers in the table.)

1. **Property (land) costs**: In all cases dealing with **existing installations**, the acquisition cost has been taken as **nil**.

2. **Development costs:** Reasonable assumptions have been made regarding the building size (which has been related to incineration capacity in all cases) and infrastructure development costs. The same per m^2 costs have been applied in all cases. Note that no cost has been associated with diesel storage tanks, as these are typically installed by the fuel supplier, who levies a surcharge on each litre of diesel sold in order to recoup the equipment/installation costs.

3. **Incinerator:** Make and model are given, together with the number of units installed. Operating hours per day is a variable in the model, i.e. can be increased or decreased as

required (see below). Installed cost of the incinerator(s) has been determined using current *Macroburn* and *Toxic* pricing. For other makes of incinerators, comparable *Macroburn* pricing has been used. (This pricing has been determined according to relative HCRW kg/hr treatment capacity.) Rated power (in kW) has been set as a function of HCRW treatment capacity (2.0 + 0.016 x capacity) kW, as has diesel usage (7.0 + 0.14 x capacity) lit/hr. (This applies to all incinerators except the Toxic; fuel usage on the Toxic 350 is approximately 19 lit/hr.) Diesel usage figures have been established by taking manufacturer's claimed figures, corroborated with actual usage figures as recorded and kindly made available by Sanumed. No separate allowance has been made for fuel usage during warming-up of the incinerator. Where incinerators are coal-fired, equivalent diesel-firing costs were used; where gas-firing is used, 90% of the equivalent diesel-firing costs were applied. Annual maintenance costs associated with the incinerator have been taken as 12% of the installed capital cost: this percentage was derived using actual maintenance costs as kindly made available by Sanumed. This percentage is high in comparison with conventional plant and equipment, and reflects the harsh conditions under which the equipment operates.

a. **Scrubbers:** This section has been included to cater for new installations (see below). No costs have been reflected in the case of existing installations, as none of the incinerators installed at provincial hospitals currently have scrubbers installed.

4. **Sundry Equipment:** Self-explanatory.

5. **Power & Consumables Cost:** In this section, total electricity usage (kWh) and fuel usage (lit) are extended at representative rates (R0.1838/kWh – Eskom Small Business rate; and R 2.95/lit – "bulk" diesel user rate, incl. 5c/lit surcharge for storage facilities). The apportionment of these and other costs into "Fixed Overheads" and "Variable Costs" is also reflected in the two columns, which commence to the right of Section 6. The assumption has been made that 5% of the electricity cost, and 50% of the maintenance and "miscellaneous services" costs (e.g. ash-removal, etc.) are "fixed", with the remaining percentage "variable".

6. **Depreciation and Cost of Capital:** The "original capital cost (excluding land) at time of installation" is estimated by deflating the 2000 cost by 8% p.a. over the installed life of the facility. Annual depreciation is then determined using the "original capital cost" and an "economic life" of 20 years. Interest Cost has been taken as nil for all existing facilities.

7. **Personnel Costs:** Reasonable assumptions have been made regarding the personnel required to operate, load and clean the facility; an allowance has also been made, where justified by the size of the facility, for supervision and administration personnel costs. Personnel costs have been treated as "fixed".

The model output consists of a "Fixed Overhead/month" figure, (rounded to the nearest R'000) and a variable cost, expressed in R/kg of HCRW incinerated. The figures for Tembisa are R 12 000 and R 0.87/kg, respectively. The total "**cost per kilogram**" figure for Tembisa is R 1.32.

Table 6.1: Incinerator Cost Model

	Incinerator Designation:		**46**	Place:	**Tembisa**				
	Existing / New / Upgraded		**Existing**	Name:	**Tembisa Hosp.**				
1	**Property Parameters: (all costs exclude VAT)**								
	Site Area		0	square metres					
	Estimated Land Cost		R 200	/m2	**R 0**				
2	**Development Costs:**		**m2**	**Cost/m2**	**Amount**				
	Earthworks, roads & drainage		500	R 100	50,000				
	Building		75	R 2,500	187,500				
	Electrical: Switchgear & Reticulation								
	KVA required:		25		50,000				
	Diesel storage tanks & equipment		40,000	litres	0				
	Fire-fighting & emergency equipment				15,000				
	Environmental Impact Assessment				0				
	Total development costs				**R 302,500**				
3	**Incinerator:**								
	Make & Model: ***M Monk LA350***			No. of units:	2				
	Operating hours per day:				8				
				Per Unit	**Total**				
	Capacity:		kgs/hour	64	128				
			kgs/day	512	1,024				
	Rated Power		kw	3	6				
	Daily Power consumption:		kwh	27	53				
	Diesel consumption		lit/hr	16	32				
	Diesel consumption		lit/day	128	256				
	Installed cost:			R 250,000	**R 500,000**				
	Estimated annual maintenance cost:			12.00%	R 60,000				
4	**Gas Scrubbers:**								
	Make & Model: ***n/a***			No. of units:	0				
5	**Sundry Equipment:**								
	Office & Washroom furniture				2,000				
	Computer				5,000				
	Store				3,000				
	Coldroom				0				
	Ash skips				0				
	Total Sundry Equipment cost:				**R 10,000**				
	Estimated annual maintenance cost:			10.00%	R 1,000				
	Total Capital Cost:				**R 812,500**				
	Estimated total annual maintenance cost:				R 61,000				
							Est. Fixed Overheads	**Est. Variable costs**	
6	**Power & Consumables**								
	Working days per annum:	300							
	Annual usage & cost:	**Quantity**	**Unit**	**Unit Cost**	**Total Cost**				
	Incinerators:								
	Electricity	16,000	kwh	R 0.18	2,900		**R 580**	**R 2,320**	
	Diesel	76,800	lit	R 2.95	226,560			**R 226,560**	
	Other				0				
	Scrubbers:								
	Electricity	0	kwh	R 0.18	0			**0**	
	Water	0	lit	R 0.00	0			**0**	
	Lime	0	kg		0			**0**	
	Sundry consumables:								
	Clothing				2,500		**R 2,500**		
	Other				2,500		**R 2,500**		
	Water				4,000		**R 4,000**		
	Misc. services: ash removal, etc.				10,000		**R 5,000**	**R 5,000**	
	Annual Eskom connection cost:				1,800		**R 1,800**		
	Total Annual Power & Consumables Cost				**R 250,260**				
	Total annual maintenance cost				**R 61,000**		**R 30,500**	**R 30,500**	
7	**Depreciation & Interest on Capital**								
	Est. original Capital cost (excl. land) at time of installation:		1	R 752,000					
	Depreciation on orig. capital cost (excl. land) over		20	years	**R 37,600**	per year	**R 37,600**		
	Interest on capital cost @		0%		**R 0**		**R 0**		
					R 348,860				
		Number	Annual Cost	Amount					
8	**Personnel costs**	0	R 150,000	R 0					
		0	R 80,000	R 0					
		0.2	R 50,000	R 10,000					
		2	24000	48000					
					R 58,000		**R 58,000**		
	Total annual cost				**R 406,860**				
	Capacity:								
	hours/day **days/week**	**weeks/yr**							
	8 6	50	307,200	kgs/yr	**1.3244**	**Rand/kg**			
			25,600	kgs/mon					
							R 142,480	**R 264,380**	**R 406,860**
						Per month	**R 12,000**		
							Annual capacity (kgs):	**307,200**	
							Variable cost/kg:	**R 0.87**	

Models were produced for each provincial hospital / community health centre installation. In each case, the operating hours/day for the incinerator was set at a figure that would allow all, or as much as possible, of the HCRW generated at the hospital to be incinerated on site. (The maximum working hours/day was limited to 16, i.e. two 8-hour shifts.) The number of personnel required to operate/load the incinerator was gauged from the number of shifts and the mass of HCRW to be handled. These models are attached as Annexure 6.1.

The estimated Fixed Monthly Overhead and Variable costs for each of the provincial hospital incinerators, as obtained directly from the models described above, are presented in ***Table 6.2*** below. This table also reflects the estimated total HCRW generation figure for the hospital as determined in accordance with Paragraph 3.8 in Chapter 3.

From this table, it can be seen that the estimated total HCRW produced by the provincial hospitals (including the 5 Community Health Centres also having incinerators) is 432 000 kg/month. Of this, a total of 272 700 kg/month could be incinerated on-site, and the remaining 159 300 kg/month would have to be removed and incinerated elsewhere. The estimated total cost of the on-site incineration is R519 000 per month, and for the removal/incineration by contractors, R291 000 per month. (In both cases, these amounts **exclude** the cost of the HCRW containers. In the case of removal/incineration by contractors, where the cost of supplying the container is typically included in the overall price charged, this has necessitated the deduction of the cost of the container: the calculation to effect this is shown in the note at the bottom of ***Table 6.2***.)

Table 6.2

The total monthly HCRW removal/destruction cost is therefore approximately **R810 000**.

This figure may be considered as the "**base-line cost**", with which alternative scenarios, as described below, can be compared.

As can also be seen from ***Table 6.2***, the incineration **capacity** of the provincial hospitals plus CHC's (based on 16 hours/day x 6 days/week x 50 weeks/year – equivalent to 400 hours/month) is 592 000 kgs/month, i.e. approximately 137% of the estimated 432 000 kg/month generated.

From the above it is evident that although the Gauteng Provincial Hospitals **collectively** have sufficient capacity to cater for treatment/disposal of the HCRW being generated, the cost of onsite incineration is high, due to the low volumes being treated at numerous facilities, each of which has comparatively high fixed costs.

6.4 Development of Numerical Model for comparison of HCRW incineration scenarios

The possible regionalized treatment of HCRW falls into a broad category of so-called "allocation" problems, wherein it is sought to "allocate" a resource, commodity, product, etc. (in this case HCRW) such that a number of criteria are satisfied, and subject to certain "constraints". In the case at hand:

(a) All the HCRW needs to be allocated to and treated at an incineration facility;
(b) The maximum capacity of the incineration facility/facilities cannot be exceeded; and
(c) The overall cost (i.e. transport plus incineration) must be minimised.

While the problem as stated above lends itself to solution using the techniques of linear programming ("LP"), it was felt that this method was less than ideal in relation to the HCRW problem for two reasons, viz.

(a) it is cumbersome to manage when both the number of incineration facilities in operation, and their location, would require many changes during investigation of various scenarios; and

(b) it is abstract, i.e. does not offer a visual context within which scenarios can be developed, tested and changed.

For this reason, it was decided to expand on a computer program developed originally in Denmark, which facilitated on-screen representation of all HCRW sources (hospitals) and incineration facilities, and also allowed the latter to be easily moved from place to place on-screen. From the screen positions, the program automatically calculates all point-to-point distances, as required for cost computations. The visual context has been further enhanced by the addition of a longitude/latitude grid, and by incorporation of the Gauteng provincial boundary.

6.4.1 Model Logic

The logic used to establish the overall cost associated with a given scenario is as follows:

(i) The program computes the distance from each hospital to each incineration facility (only facilities with capacities > 0 are included in the computation; by setting a capacity = 0, the facility can in effect be "switched off")

(ii) The program computes the transportation cost (per kg HCRW) from each hospital to each incineration facility. (The derivation of the per-kilometre transportation cost is described in Paragraph 6.4.3 below.)

(iii) The program computes the incineration cost (per kg of HCRW) at each incineration facility. This per kg cost is calculated as the sum of the **Variable** cost per kg* and the **Fixed Monthly Overhead Cost*** divided by the monthly incinerator capacity. (In cases where the total mass of waste allocated to a facility is less than the capacity, this results in an understatement of the cost per kg, and therefore of the overall cost. For this reason, successive iterations of the model are run, reducing the capacity at the incineration facility/facilities until the actual mass allocated closely matches the capacity in each case. It was decided not to automate this process, as it could potentially lead to instability of the model. In practice, a small number of iterations is sufficient to achieve a solution, particularly when the number of incineration facilities is small.

The computation of these costs is described in Section 6.4.2 below.

(iv) From (ii) and (iii) the program computes the total cost (per kg of HCRW) to transport the waste from each hospital to each incineration facility and incinerate it.

(v) The program then allocates waste, utilising the familiar "container-packing" algorithm, viz. the hospitals are dealt with in order of volume of HCRW generated, with the largest "blocks" of HCRW being allocated to the least-cost facility; smaller "blocks" are allocated later, and the smallest "blocks" last. (This algorithm, although efficient in terms of the computational effort required, will generally not produce the absolute least-cost solution; for example, it can lead to anomalies in the model results, with small "blocks" being routed to relatively remote facilities. These anomalies do not, however, compromise the principles of the model but rather provide opportunities for greater refinement of the actual waste allocation in practice, through the use of, say, the LP techniques referred to above. (Comparative tests, which we performed to confirm the accuracy of the model, indicated that results were always within 5% of the least-cost solution, as determined through LP, and were often within 2%. Absolute least-cost solutions are, however, seldom totally applicable/practical in real-life.)

Application of, and output from, the Model is presented in Paragraph 6.5 below.

6.4.2 Incineration Cost Model

The development and application of this model has been dealt with in Section 6.3.1 above. However, as there are certain additional /different considerations in the case of "new" incinerators, certain relevant aspects of the model are described below.

An important additional component of the **Fixed Overhead Cost**, when evaluating potential new facilities, is the "cost of capital", usually determined as the interest that would have to be paid on the capital necessary to purchase the land and develop the facility. In the particular case of a new incineration facility, an Environmental Impact Assessment ("EIA") is required and the cost of this is treated as a capital cost (as with other investigative/consulting costs). These costs are amortised over the economic life of the facility (assumed in this case to be 20 years.)

If new facilities are required to have gas-scrubbers installed, both the capital cost and the **Variable Costs** need to reflect this.

A typical model is presented below as ***Table 6.3***, which is for a potential new incinerator (with gas-scrubbers) located in Roodepoort. A brief explanation of the model is set out below, in which the (additional) assumptions made are explained/noted. (As before, paragraph numbers below match the section numbers in the table.)

1. **Property (land) size and cost:** A site size of 4,000 m^2 has been chosen. This is probably larger than actually required, notwithstanding the relatively large capacity envisaged (900 kg/hr HCRW). The land acquisition cost has been based on a price of R 200/m^2 , which is conservative for industrial land in this area.

2. **Development costs:** The cost of the EIA has been estimated at R200 000 in all cases. This figure has also been used in the case of the Tambo Memorial and Tembisa Hospitals, where new incinerators have been installed but have not yet officially been put into operation.

3. **Incinerators:** As before.

4. **Scrubbers:** A "wet scrubber" option has been chosen, as opposed to a considerably more expensive ceramic ("dry") filter. The estimated capital cost (for a 900 kg/hour HCRW installation) is R 2,8 million. Installed power required is approximately 55kW (the majority of which is required by the powerful fan).

5. **Sundry Equipment:** Self-explanatory.

6. **Power & Consumables Cost:** Incinerators: as before;
   Scrubbers: approximately 30 kg of "sorbent" is consumed per hour, at a cost of R 2.00 per kg, and the residual wet waste (approx 60 kg/hour) requires removal and safe disposal. Electricity consumption figures for the scrubbers are more than double those for the incinerators, due to the fan.
   (For smaller and larger scrubber installations, the above (capital and running-cost) estimates have been used as a reference, appropriately adjusted to account for size differences.)

7. **Depreciation and Cost of Capital**: Annual depreciation (on buildings, infrastructure and equipment) is determined on a straight-line basis, using an economic life of 20 years.

The Interest Cost has been based on an interest rate of 12% for all new facilities; the total capital cost (i.e. including the purchase price of the land) has been used in the calculation.

8. **Personnel Costs:** Reasonable assumptions have been made regarding the personnel required to operate, load and clean the facility; additional personnel (one per shift) have been allowed for operation of the gas-scrubbers (where installed) in larger installations.

As before, the Incinerator Model output consists of a "Fixed Overhead/month" figure, (rounded to the nearest R'000) and a variable cost, expressed in R/kg of HCRW incinerated. The figures for the example shown in ***Table 6.3*** are R185 000 and R0.52/kg, respectively.

Models were produced for each proposed new facility. In most cases, new facilities were operated on at least a two-shift basis, which is considered reasonable in view of the high capital cost of the installations. The number of personnel required to operate/load the incinerator was gauged from the number of shifts and the mass of HCRW to be handled. These models are attached as ***Annexure 6.2***.

6.4.3 Transportation cost model

In order to establish representative costs for road transportation of HCRW, a Transportation Cost Model was developed.

The first step was to identify suitable vehicles for this purpose. *Messrs McCarthy Toyota Trucks, Midrand* were approached, who kindly provided recommendations and costs based on the requirements indicated, viz:

(a) Vehicles were to have bodies designed to accommodate the maximum number of 142 L HCRW containers (plastic-lined cardboard boxes with overall dimensions approx. 45 cm x 45 cm x 70 cm high.);

(b) It would be necessary for the vehicles to transport containers safely, whether the vehicle was full or partially full. For this reason, and to obviate the need to stack boxes on top of one another, a shelf having a retaining lip would be provided at a suitable height;

(c) A central or offset passage would be provided to allow access for loading/unloading and securing of the boxes. Access would be via a single rear door. The coachwork should allow for easy internal cleaning/disinfecting, and be of corrosion-resistant material;

(d) The chassis was to be fixed, i.e. non-articulated, to provide for maximum manoeuvrability in confined spaces;

(e) Also for reasons of manoeuvrability, overall size and road speed, only vehicles having a payload up to 5-tons would be considered.

Table 6.3 : New Incinerator Cost Model

Table 6.3 p2

Messrs *McCarthy Toyota Trucks* recommended consideration of two "Dyna" chassis-cab models, viz. the 4-093, having a payload of approx 1.5 tons, and the 7-094 (with a chassis-extension to 6m) having a payload of approx. 4 tons. Details of each of these vehicles, together with capital and operational costs, etc., are presented in ***Table 6.4*** below, being the Transportation Cost Model. A brief explanation of the model is set out below, in which the rationale and assumptions made are explained/noted. (For ease of reference, paragraph numbers below match the section numbers in the table.)

1. **Vehicle parameters:** Self-explanatory. Note that the maximum number of 142L HCRW containers that can be transported by the two vehicle sizes is 42 and 108, respectively.

2. **Costs:** These are divided into annual fixed costs and per kilometre costs. Vehicles are depreciated over 5 years, at which time a "salvage value" is recovered. Reasonable assumptions are made regarding tyre replacement and diesel; consumption consistent with "urban cycle" type operation.

3. **Crew costs:** A driver and one helper is assumed.

4. **Costs applicable to model:** In order to translate the fixed and variable costs as referred to above into "per kg (of HCRW) per km" transportation costs, as required for use in the regionalisation model, assumptions have to be made in respect of the amount of HCRW that each vehicle could transport in a given period. This in turn depends on (i) the number of loads that the vehicle can transport in one day, (ii) the average "round-trip" distance, and (iii) the mass that the vehicle transports per load. The assumptions that have been made in this regard are reflected in the table.

Importantly, it should be noted that the numerical model assigns transportation costs in accordance with the one-way, straight-line distance between hospital and incinerator. This means that two further steps are required, viz.:

(a) Transportation costs must be expressed in this "one-way" format. To achieve this, the formula used is: one-way transportation cost (Rand per kg-km) = total annual cost of ownership and operation ÷ (average load mass x kms travelled per year ÷ 2). These costs are R0.0287 per kg-km for the Dyna 4-093 and R0.0142 per kg-km for the Dyna 7-094 respectively, based on the assumptions set out above.

(b) A correction must be made to allow for the fact that straight-line distances between two points are **less than the road distances.** The correction applied here is 25%, i.e. the road distance between two points is taken to be 25% more than the straight-line distance. The one-way transportation costs, as referred to in (a) above, increase to R 0.0359 per kg-km and R 0.0178 per kg-km respectively, when based on one-way straight-line distances.

Further, it is necessary to make a decision on which of the two vehicles would be used. Although the larger Dyna (Model 7-094) is more cost-effective than the smaller Model, there may be other considerations (such as the need to also service clinics, which typically only generate small quantities of HCRW). This suggest the use of a "mixed" fleet, comprised of both vehicle models described above, and indeed other sizes of vehicle.

For purposes of this study, and to allow simulation wherein the HCRW generated by both hospitals and clinics is treated on a regionalized basis (see Sections 6.5.2 and 6.5.3 below) without necessitating a change to the transportation cost, we have assumed that HCRW will be transported by the two sizes of vehicles considered above in the ratio 2:1, i.e. twice as much waste (by mass) will be transported in the larger vehicles as in the smaller vehicles, over any given period. The one-way transportation cost associated with this "mixed" fleet is therefore (⅔ x R0.0178 + ⅓ x R0.0359) = R0.0238 per kg-km, say R0.024 per kg-km.

6.5 Application of the Model

The first model that runs (Section 6.5.1 below) are solely to provide a **comparison with the current practice of incinerating waste on-site** at many of the provincial hospitals. These scenarios **would not be applied in practice**, as (i) any new strategy for HCRW treatment and disposal **must include waste generated at provincial clinics as well**, and (ii) it will almost certainly be necessary to provide gas-scrubbers when new incineration facilities are commissioned.

More "practical" scenarios, involving the incineration of both hospital and clinic waste, appear in Sections 6.5.2 and 6.5.3 below.

During **all** the model runs described below, it was only attempted to determine whether one, two or many new facilities, with or without the simultaneous use of existing facilities, would offer the most economical solution. Incinerators have therefore been "sized" (i) according to the estimated current rate of HCRW generation, and (ii) without allowing for "spare" capacity. Although allowances would have to be made for both of these factors in any practical design, its omission here has little or no effect on the **principles** established. If necessary however, the alternative scenarios could be re-evaluated at design stage, having made the appropriate (quantitative) adjustments.

Where new facilities are proposed, it was generally decided to locate these at or near existing landfill sites. The rationale for this is explained in Section 6.7 at the end of this chapter.

6.5.1 Investigation of various scenarios without gas scrubbers

(Total mass of HCRW to be incinerated per month: 432 000 kg.)

Scenario 1, One (new) incineration facility, sited such that overall HCRW transportation and incineration costs are minimised

Features of this scenario are:

- All existing incinerators at provincial hospitals are "switched off";
- All HCRW is transported to a single facility, comprising of 3 x 300 kg/hr incinerators, operational for 24 hrs/day, 6 days/week.

Results may be summarised as follows:

- Estimated overall monthly cost is **R580 000**;
- Optimum siting (i.e. resulting in lowest overall cost) is in vicinity of the Johannesburg Hospital.

- ***Table 6.4*** : Cost Model : Transportation

Scenario 2, One (new) incineration facility, sited in vicinity of existing Marie-Louise landfill (Greater Johannesburg Metropolitan Council) in Roodepoort

Features of this scenario are identical to the previous scenario, with the facility moved to a more suitable location. The resulting estimated overall monthly cost is **R630 000**, i.e. 9% higher than the previous scenario.

Scenario 3, Two new incineration facilities: one sited in vicinity of existing Marie-Louise landfill (Roodepoort), and one in the vicinity of the GJMC's "Northern Works" site (at Diepsloot, north of Dainfern)

Features of this scenario are:

- As for previous scenarios, all existing incinerators at provincial hospitals are "switched off";
- HCRW transported to two new facilities: At Roodepoort (2 x 300 kg/hr incinerators, operational for 24 hrs/day, 6 days/week) and at Northern Works (one 300 kg/hr incinerator, operational for 24 hrs/day, 6 days/week.

Results may be summarised as follows:

- Estimated overall monthly cost is **R570 000**;
- Overall cost is therefore marginally lower than for a single facility at Roodepoort.

Scenario 4, One new incineration facility, sited in vicinity of existing Marie-Louise landfill; full utilisation of existing incinerators at Tambo Memorial and Tembisa Hospitals

Features of this scenario are:

- HCRW is transported to a new facility at Roodepoort (2 x 300 kg/hr incinerators, operational for 24 hrs/day, 6 days/week) as well as to the existing incinerators at Tambo Memorial (16* hrs/day, 6 days/week) and Tembisa Hospital(16* hrs/day, 6 days/week).
- It is understood that DACEL will require automatic feeders on these units, and allowance was therefore made for the additional capital cost (estimated at R60 000 per incinerator). DACEL would further prefer the incinerators to operate 24 hours per day, which would require mechanical de-ashing. Although it is possible to 'retro-fit' mechanical de-ashing equipment to the units, (a) the cost will be high (of the order of R120 000 per incinerator) and (b) the manufacturers may be unwilling to guarantee the modification. In view of this, the assumption was made that the units will operate for only 16 hours/day, to allow for manual de-ashing.

EIA costs for Tambo Memorial and Tembisa Hospitals (estimated at R200 000 each) have been included in the calculations.

Results may be summarised as follows:

- Estimated overall monthly cost is **R650 000**;

This is more expensive than all the other options.

For each of the above scenarios, a "sensitivity analysis" has been performed: Each scenario has been re-evaluated, having **doubled** the transportation costs (R per kg per km). This tests the sensitivity of the scenarios to the transportation costs used in the model and can be expected to have a higher influence on the more "centralized" scenarios, i.e. ones having fewer incineration facilities with longer transport distances.

Results for all the above scenarios are tabulated in ***Table 6.5*** below to facilitate comparison:

Table 6.5: Comparison of various scenarios without gas scrubbers

Facility/facilities	Scenario 1	Scenario 2	Scenario 3	Scenario 4
New 900 kg/hr facility at optimum location	▲			
New 900 kg/hr facility at/near Marie Louise (Roodepoort)		▲		
New 600 kg/hr facility at/near Marie Louise (Roodepoort)			▲	▲
New 300 kg/hr facility at Northern Works			▲	
Existing Tambo Memorial Hospital 64 kg/hr facility				▲
Existing Tembisa Hospital 64 kg/hr facility				▲
Estimated total monthly transportation + incineration cost	**R580 000**	**R630 000**	**R570 000**	**R650 000**
Sensitivity Comparison: Model Transportation costs increased by 100 %: **Total Monthly Cost**	**R890 000**	**R980 000**	**R820 000**	**R920 000**

Conclusions drawn from investigation of various scenarios *without gas-scrubbers* for provincial hospitals only

Some valuable conclusions can be drawn from the above, viz,:

- Each of the above scenarios (setting aside the results based on doubled transportation costs) is more economical than the existing arrangement of on-site incineration plus third-party contractor removal/disposal. This would still pertain even if a substantial "profit element" were added, i.e. if incineration facilities were owned/operated on a commercial basis by a private contractor;
- The most economical arrangement consists of two new facilities, viz. a 600 kg/hour facility at or near the Marie Louise landfill in Roodepoort and a 300 kg/hour facility at Northern Works;
- Under sensitivity analysis conditions, the above scenario (viz. two new facilities) remains the most economical.

While the above scenarios offer valuable comparisons with the current situation *vis á vis* HCRW derived from provincial hospitals, **they do not represent practical solutions** in that any evaluation of the potential economic advantage of provincial regionalisation **needs to cater for HCRW derived from all provincial health-care institutions**, viz. hospitals, community health centres and clinics. The scenarios investigated below therefore cater for HCRW derived from all provincial institutions.

6.5.2 Investigation of various scenarios both with and without gas scrubbers, and including HCRW from BOTH provincial hospitals AND provincial clinics

(Total mass of HCRW to be incinerated per month: 573 000 kg)

Of the approximately 25 scenarios investigated, 15 are listed in ***Table 6.6*** below. These scenarios reflect the total monthly cost associated with the operation of up to four **new** incineration facilities, and up to three **existing** facilities (Tambo Memorial, Tembisa and Pretoria Academic). Scenarios were also investigated involving the replacement of existing incinerators at Tambo Memorial, Tembisa and Pretoria Academic with new 300 kg per hour facilities at these locations.

In all cases that involves **existing** incinerators, the cost were included of up-grading the units to allow for automatic feed. However, for the reasons mentioned in Paragraph 5.5.1 above, no allowance was made for mechanical de-ashing at these facilities; thus only allowing for these units to operate sixteen hours per day, six days per week.

In all cases involving **new** facilities, or **new incinerators** at existing facilities, allowance was made to operate the facilities for 24 hours per day, six days per week, as mechanical de-ashing will be required on all such facilities.

The cost of EIA's has been allowed for in all instances.

In addition to the locations considered in the scenarios described in Paragraph 6.5.1, the following were also considered: "**Alpha Quarries**", off the Old Pretoria Road, near the Jukskei River in Midrand (as a possible alternative to the Northern Works); **Hatherley**, the existing landfill site of the Greater Pretoria Metro Council, to the east of Mamelodi; and **Platkop**, the existing landfill site of the Eastern Gauteng Services Council, off the N3 highway on the R550 to Kliprivier.

As before, the sensitivity of each of the scenarios were tested by doubling transportation costs (R per kg per km). This tested the sensitivity of the scenarios to the transportation costs used in the model, and can be expected to have a higher influence on the more "centralized" scenarios, i.e. ones having fewer incineration facilities with longer transport distances.

Finally, the scenarios have been "ranked" from the one with the lowest to the one with the highest monthly cost.

Table 6.6

Conclusions drawn from investigations of various scenario's *with and without gas scrubbers* for ALL provincial health institutions

As new facilities that are to be developed will almost certainly have to have gas scrubbers incorporated, the focus was in particular on the results/costs making provision for scrubbers (printed in red in ***Table 6.6***).

Conclusions that can be drawn from the results are:

- Scenarios A, B, C and D are the lowest, second lowest, etc. in terms of the total monthly cost, and **remain** the lowest under the sensitivity-analysis conditions;
- Each of the above scenarios embodies a 600 kg per hour facility at/near the Marie Louise landfill;
- Each of the above scenarios involves a total of three facilities: In scenarios A and B all the facilities are new, and in scenarios C and D two out of the three facilities are new;
- Monthly costs are much higher if only one (new) facility is involved (scenario L), or if four or more (new) facilities are involved (scenario O);
- With two new facilities only (scenario E), costs are only marginally higher than for scenario D. However, under the sensitivity analysis, the increase is more marked;
- There is little difference in cost between the use of the Northern Works and Alpha Quarries (scenario E, cf. scenario F).

6.5.3 Investigation of various scenarios both with and without gas scrubbers, and including HCRW from BOTH provincial hospitals AND provincial clinics with provision made for additional waste generated by proposed extension of 800 new beds at Pretoria Academic Hospital.

(Total mass of HCRW to be incinerated per month: 613 000 kg)

(Note: The DoH requested that the implications associated with the possible addition of 600-800 beds at Pretoria Academic Hospital should be considered, in order to ascertain whether this altered the choice of a least-cost HCRW incineration solution for Gauteng.)

As in Paragraph 6.5.2 above, a number of scenarios were investigated, of which 13 are listed in ***Table 6.7*** below. Note that the same nomenclature as before has been used for the various scenarios (viz. "A", "B", etc.). However, two scenarios, C* and D*, although similar to the previous C and D scenarios, require increased capacity at Marie Louise landfill.

The scenarios have once again been "ranked" from lowest to highest total monthly cost.

Table 6.7

Conclusions drawn from investigation of various scenarios both *with and without gas scrubbers* for ALL provincial health institutions including extension of Pretoria Academic Hospital.

As stated before, new facilities developed will almost certainly have to have gas scrubbers incorporated and the focus is therefore on the results/costs making provision for this (printed in red in ***Table 6.7***)

Conclusions that can be drawn from the results are:

- Scenarios A and B remain the lowest and second lowest in terms of total monthly cost, and **remain** the lowest under the sensitivity-analysis conditions; scenarios C* and D* have dropped down considerably in the rankings;
- Each of the above scenarios embodies a 600 kg per hour facility at/near the Marie Louise landfill;
- Each of the above scenarios involves a total of **three new facilities. I**n scenario A these are located at Marie Louise, Tambo Memorial and Pretoria Academic, and in scenario B these are located at Marie Louise, Tembisa and Pretoria Academic respectively.

6.6 Conclusions

The following conclusions may be drawn from the above:

a) The current practice of incinerating HCRW "on site" at provincial hospitals is comparatively uneconomic. The estimated cost of "on-site" incineration, plus the costs associated with the use of third-party removal/incineration by waste management contractors, is R810 000 per month. Application of the numerical model developed as part of this study suggests that the total monthly cost could be reduced to approximately R630 000 if one new 900 kg/hour facility was brought into operation at or near the Marie-Louise landfill site in Roodepoort, and a fleet of purpose-built vehicles was used to transport the HCRW from hospitals to this facility. The most economical arrangement (total monthly cost approximately R570 000) consists of two new facilities, viz. a 600 kg/hour facility at or near the Marie Louise landfill in Roodepoort and a 300 kg/hour facility at Northern Works landfill.

b) When applied to the total estimated HCRW emanating from both provincial hospitals and clinics, the model indicates that the optimal (i.e. minimum cost) configuration of incineration facilities (with or without gas-scrubbers) comprises three new facilities, or two new facilities together with retention of existing (but upgraded) facilities at Tambo Memorial and Pretoria Academic Hospitals. Monthly costs increase if only one new facility is introduced, or if more than three new facilities are introduced.

c) When applied to the total estimated HCRW emanating from both provincial hospitals and clinics, and taking into account the proposed addition of 800 new beds at Pretoria Academic Hospital, the model indicates that the optimal configuration (with or without gas-scrubbers) comprises three new facilities, i.e. at Marie-Louise, Tambo Memorial and Pretoria Academic, or at Marie-Louise, Tembisa and Pretoria Academic, respectively.

d) Sensitivity analyses, performed to test the "stability" of the optimal scenarios, as described in (b) and (c) above, through doubled transportation costs, confirm the triple new-facility scenario to be the most economical choice.

6.7 Investigation into alternative sites for locating the medical waste treatment/disposal facilities, considering both the environmental and the economic viability.

The siting of an incinerator or incineration facility is without doubt the most important aspect of the planning for health care waste management. In terms of the EIA regulations, the developer is required to submit a pre-scoping document and to identify a number of sites (preferably three or more) that could be appropriate for locating an incinerator. A matrix comparing the relative merits of the selected sites should be drawn up and the preferred site motivated in terms of the selection criteria. The issues that must be considered are in many ways similar to those used for siting a landfill, and embrace:

Economic Criteria:

a) Distance of site from waste sources;
b) Site access – roads may have to be constructed;
c) Visibility of site – there may be a screening cost;
d) Land availability – competitive uses may increase costs of acquisition;
e) Availability of services – electricity, water, sewage etc.

Environmental and Health and Safety Criteria:

a) Presence of sensitive ground or surface water resources;
b) Topography of the site and surroundings, e.g. valleys where temperature inversion could occur should be avoided;
c) Land zoning – land zoned industrial is preferred;
d) Sensitivity of receiving environment – an existing landfill or derelict mining land would be preferable;
e) Quality of soil – low permeability soils would reduce pollution potential from spills, ash, etc.;
f) Impact on public healthy and safety.

Public Acceptance Criteria:

a) Distance to residents or other incompatible land use – a distance of 1km is preferred, although such distance should finally be determined by means of air dispersion models;
b) Prevailing wind direction – the treatment facility should be located downwind of any residential areas;
c) Visibility;
d) Access – roads that pass through residential or other sensitive areas should be avoided;
e) Displacement of inhabitants.

Existing Landfill Sites

Many of the above criteria are satisfied by existing landfill sites, and certain landfills have therefore been considered "in principle" as potential incinerator sites. In particular:

Marie-Louise (Roodepoort): This facility is close to the "centre of gravity" of HCRW generation in the province, as discussed in Section 6.5.1above. It is also very accessible by road whilst being suitably far from residential areas.

Northern Works (Diepsloot): Not as desirable as Marie-Louise, but it is economically viable as an adjunct to Marie-Louise, catering for HCRW generated in the Greater Pretoria area, and northern Gauteng in general.

Platkop (Suikerbosrand): This facility is very accessible by road, and sufficiently far from residential areas (and built-up areas in general) to be of interest. From an economic point of view, it is too far south in the province;

Weltevreden (Brakpan): Similar to Platkop, in the sense that it is suitable in principle, but too far east to be economically suitable;

Simmer & Jack (Germiston): Suitable economically, but it may be too close to residential/built-up areas.

Hatherley (East of Pretoria): Environmentally suitable, but too far north-east to be economically suitable.

Existing Incinerator installations at Provincial Hospitals

For obvious reasons, hospitals are not environmentally sound locations for the siting of incinerators. However, we have considered the use of the existing incinerators at Pretoria Academic Hospital which is in good condition, and also the recently-replaced incinerators at Tambo Memorial and Tembisa hospitals in our economic feasibilities. These facilities could be usefully included in a regionalized HCRW incineration plan, burning both 'own' waste, and waste from other provincial institutions. It may, however, not be economically viable to retro-fit gas-scrubbers to these units, but this would have to be established after a technical investigation.

Although increasing the incineration capacity at Tambo Memorial and Pretoria Academic Hospitals (to say 300kg/hr) is very attractive economically (because of their spatial locations), this may not be desirable for environmental reasons. This being the case, alternative sites within reasonable proximity should be sought.

7. CONCLUSIONS

It is concluded that: -

- Medical waste, referred to by the United Nations and others as Health Care Risk Waste (HCRW), emanate from health care facilities and can be divided into infectious-, chemical-, radioactive- and general categories that identify the major hazards or risk it pose to human health and the environment. Infectious waste is further sub-divided into anatomical (pathological) waste and sharps. Chemical waste is determined by the extent of one or more of the following factors: corrosivity, reactivity, flammability and toxicity. Radioactive waste includes solid, liquid and gaseous waste contaminated with radioactive material. General waste finds itself in the HCRW stream as a result of poor segregation at source

- In South Africa the classification of waste generated from health care facilities has been linked to the legislation of hazardous waste in general. In terms of legislation, infectious, chemical and radioactive waste from health care facilities are all defined and listed under hazardous waste as Class 6 out of 9 classes. This approach is based on International Maritime Dangerous Goods (IMDG) (published as SABS Code 0228) which has been adopted as a code of practice in the country.

- While the categories of HCRW are known in South Africa, its composition is unknown. Experience from other countries (e.g. USA) indicates that although the infectious hospital waste is different from the general waste, there are considerable quantities of general waste that could be found in infectious wastes. This results in an artificial increase in tonnage of HRCW that costs more to dispose of per ton than the general waste.

- The presence of general waste in the infectious waste stream can be attributed to poor sorting of waste at source by health care workers.

- The composition of infectious (hospital) waste includes all components that could be found in the general waste stream with the exception of yard waste and building rubble. Such components are paper, rubber, textiles, food, glass, metals, plastics and fluids. Some of the components such as plastics, and in particular the Polyvinyl Chloride (PVC) type (which is estimated at 60g per bed), could be found in vinyl gloves, intravenous administration sets, syringes and needles. It contains chemical compounds that, when incinerated, will result in the emission of toxic gases which pose significant environmental pollution and health risks.

- The environmental burdens caused by incineration of PVC can be minimised by equipping incinerators with scrubbers, which is presently with the exception of one incinerator, not done in South Africa. The fitting of scrubbers is however likely to result in a significant increase in incineration costs. Another strategy would be to reduce the use of PVC in the medical industry. However, this would be a long term strategy and difficulties have been experienced introducing this in Europe.

- While incineration is currently the only method of HCRW treatment/disposal in South Africa, alternative technologies such as chemical disinfection, autoclaving and microwave technology could offer cost effective and environmentally sound solutions if fully developed.

- The major HCRW generators in Gauteng are community health centres, clinics and hospitals. The major HCRW generators contribute about 89% by mass of the total HCRW stream, with the remainder being generated by minor generators.

- Although the minor HRCW generators have a limited impact on the total HCRW stream, they are still important with regards to the risk that its HCRW creates for society.

- Currently there is "a total of approximately 600 "major" HCRW generators, and a total of approximately 9 700 "minor" HCRW generators located in Gauteng. (This excludes private residences.)

- The amount of HCRW generated per service area in kg/patient/day range between 0,06kg to 0,48kg for private clinics, 0,002kg to 0,5kg for public clinics, 0,5kg to 4,04kg for private hospitals and 0,23kg to 2,43kg for public hospitals. Based on the "Upper 90% confidence limit", a total of 1 175 tons of HRCW is generated in Gauteng per month.

- The current HCRW management stages that include segregation, containerisation, storage, collection, transportation and treatment/disposal are not standardised throughout all health care facilities and practices are in many instances far below the required norm.

- There are currently only limited awareness and education programmes on the risk associated with HRCW as well as correct management and handling procedures. Personnel responsible for education are in some instances not fully aware of their duties and responsibilities.

- Since payment for collection, treatment and disposal of HCRW is presently based on volume, financial losses are incurred by health care facilities not filling containers to full capacity.

- A total of 70 incinerators in Gauteng are located in 58 health care facilities consisting of private and public hospitals, laboratories, prisons and waste management companies.

- Of the 70 incinerators in Gauteng, 58 (83%) are operational and only 25 (37%) are registered, of which some are only temporary registrations.

- There are seven types of incinerators installed in Gauteng, with different makes and sizes of which some have been discontinued.

- Of the 70 incinerators in Gauteng, only one incinerator is equipped with a scrubber, which is currently not working.
- The capital and operational cost for an incinerator, as estimated by two commercial operators, is approximately R1,00 per kg.

- The IIMS has been developed according to the Terms of Reference as set out in this report. The IIMS is currently operational within DACEL offices.

- The current IIMS should be seen as the first step in developing an Incinerator Information System which encompasses more than just HCRW incinerators. Future developments of the IIMS are expected to add additional components, as the need for capturing additional information becomes necessary. The current system allows for easy upgrading and development as the requirements of DACEL develop.

- The current practice of incinerating HCRW "on site" at provincial hospitals is comparatively uneconomic. The estimated current cost of "on-site" incineration, plus the costs associated with the use of third-party removal/incineration by contractors, is R810,000 per month. Application of the numerical model developed as part of this study suggests that the monthly cost could be reduced to approximately R570,000 if two new facilities are brought into operation: one at or near the Greater Johannesburg Metropolitan Council's ("GJMC") Marie Louise landfill site in Roodepoort, and one at or near the GJMC's proposed Northern Works landfill site, north of Dainfern. A fleet of purpose-built vehicles would be used to transport the HCRW from hospitals to these facilities.

- When applied to the total estimated HCRW emanating from both provincial hospitals and clinics, the model indicates that the optimal (i.e. minimum cost) configuration of incineration facilities (with or without gas-scrubbers) comprises three new/upgraded facilities: one at or near the Marie Louise landfill site (600kg/hour), one at or near Tambo Memorial Hospital (new 300kg/hour unit replaces existing) and one at or near the Pretoria Academic Hospital (new 300kg/hour unit replaces existing). This scenario remains optimal when the possible addition of 800 new beds at Pretoria Academic Hospital is taken into account.

Sensitivity analyses, performed to test the "stability" of the optimal scenario, as described above, through doubled transportation costs, confirm the dual new-facility scenario to be the most economical choice.

A scenario substituting a new facility at or near the Pretoria Metro's Hatherley landfill site in place of the upgraded Pretoria Academic Hospital facility suggested above, indicates that there would be a cost-penalty of approximately 10% over the optimal scenario, this scenario is, however, relatively sensitive to increased transportation costs.

If it is decided that increasing the size of incineration facilities at Provincial Hospitals is undesirable, and no suitable sites can be identified within reasonable proximity of Pretoria Academic and Tambo Memorial Hospitals, an alternative would be to establish two new facilities: one at or near the Marie Louis landfill site (600kg/hr) and one at or near the proposed Northern Works landfill (300kg/hr). This scenarios is, however, comparatively sensitive to increased transport costs.

- Having reference to a number of the best (i.e. 'least-cost') siting scenarios as determined in this study, a thorough investigation should be undertaken at and in the vicinity of the proposed locations to confirm the availability and suitability of sites for possible new facilities. Detailed feasibility studies should further be undertaken for the proposed new facilities, and for the HCRW transport systems to be used. Based on the outcome of such detailed studies, the financial model developed for this study should be used to confirm that the proposed regionalisation strategy remains the optimal solution.

In summary, the "economies of scale" that can be achieved through the regionalised incineration of HCRW emanating from provincial hospitals and clinics are substantial, and should be exploited.

8. RECOMMENDATIONS

It is recommended that:

- DACEL adopt the use of the international terminology of Health Care Waste (HCW), consisting of Health Care Risk Waste (HCRW) and Health Care General Waste (HCGW) in its policies, planning and operations when defining waste emanating from health care facilities.

- Detailed composition investigations on HCW emanating from hospitals and clinics be conducted to quantify the potential for savings that could be accrued through proper segregation as well as recycling.

- An awareness and education campaign be implemented to reduce the HCRW management costs by reducing the HCRW stream through effective segregation.

- Guidelines on responsible handling and management of HCRW during segregation, containerisation, storage, collection, transport treatment and disposal be established, standardised and enforced. This should include written procedures on responsible HCRW management as well as the way in which Occupational Health and Safety matters should be addressed by workers engaged in HCRW handling.

- During induction of newly appointed staff, the safe handling and segregation of HCRW be addressed in detail, with ongoing refresher courses being presented. This should include a training program for all personnel handling HCRW.

- Personal Protective Clothing with disinfection and disposal measures, where applicable, be provided to workers involved in HCRW handling and disposal and that the risks of transmitting diseases to the workers be emphasised.

- The principle of duty of care be promoted with generators of HCRW.

- A strategy on assessing ways of minimising the use of PVC be developed. Proponents should be encouraged to assess the appropriateness and cost effectiveness of chemical disinfection, autoclaving and microwave technology to the South African health care situation as alternatives to incineration.

- No new incinerators be permitted to operate without being equipped with scrubbers and complying with the 2009 DEAT emission requirements. The current incinerators not suitable for upgrading should be phased out by the year 2009.

- All institutions generating HCRW comply with the latest revisions of the SABS Code of Practice – Handling and Disposal of Waste Materials within Health Care Facilities. (SABS 0248)

- Compliance with guidelines and codes regarding the responsible handling and storage of HCRW be monitored by means of auditing programmes to be implemented at all parties involved in HCRW management.

- Containers used for HCRW be filled to capacity in all instances, without putting the safety and health of workers at risk, since payment for collection, treatment and disposal is based on volume.

- The accepted measurement system be changed from volume to mass measurement, thus resulting in more accurate data recording by all HCRW generators.

- Containers be marked in such a way that a HCRW tracking system be introduced that will ensure safe disposal of all HCRW generated.

- A regionalised approach be adopted for the treatment and disposal of HCRW emanating from provincial hospitals and clinics.

- The design-capacity of the regionalised facilities be carefully determined, taking into account:
  - The anticipated growth in the mass of HCRW generated over the design life of the facilities;
  - Whether the facilities should be sized to also cater for the HCRW generated by the private sector, particularly in view of the stricter regulatory environment envisaged for the future.

- By making use of the proposed optimal facility scenario as a basis, a thorough investigation should be undertaken at and in the vicinity of the proposed siting locations to confirm the availability and suitability of sites for possible new facilities.

- Firm costings be prepared for the proposed new facilities, as well as for the vehicles to be used for transporting the HCRW. Based on these costs, the model developed during this study should be used to confirm that the proposed solution remains optimal.

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ANNEXURE 3.3

Summary of Results

Each sample measure is either the average waste per person for all the measurements on a given hospital, or alternatively the average waste per person on a particular day. The results are presented first for the scenario where there is one measurement per institution and then for the situation where there is one measurement per day.

As we discussed telephonically all waste has been pooled (i.e. no distinction by container size) and the number of days is assumed to be the whole period from the first day through to the last day, even if no waste was collected on the days in between.

For each day there are two tables. The following information is provided.

Column	**Description**
Table 1	
Region	Region
Average Waste Per Patient (Kg)	This is the estimate of the mean waste per patient. It is the same for both approaches.
Estimated Variance	This is the estimate of the variance of the waste used by each patient based on the variance of the means. It is quite poorly estimated due to the few samples.
Total Patients	This is the total number of patient days over the period of investigation for the particular region.
Total Waste (Kg)	This is the total waste disposed by the given region over the period of investigation.
No of Samples	This reflects in the first instance the number of institutions in the region and in the second the total number of days in the survey, across the regions.
Table 2	
Region	As above
Average Waste Per Patient (Kg)	As above
Standard Error	This is the estimated variance of the estimate of the mean waste disposed by each individual.
No of Samples	As above
L90, U90	These are respectively the lower and upper bounds for a 90% confidence interval on the estimated mean waste per person. Thus given the above data we can be 90% sure that the real value of the "Average Waste Per Patient" lies between L90 and U90.
L95, U95	As above, but a 95% confidence interval.

For regions where there is only one institution no estimate of variance can be obtained when only one observation is calculated for each region. As such no results are presented for these regions in the section below.

One measurement per institution.

Table 1: Estimates of Parameters by District.

Region	Average Waste Per Patient (Kg)	Estimated Variance	Total Patients	Total Waste (Kg)	No of Samples
Central	1.23	2845.88	18211	22413.58	4
District	0.71	1.50	592	422.70	2
Private	1.57	1114.67	5842	9157.57	7
Regional	0.63	451.05	11021	6912.30	4

Table 2: Confidence Intervals for the Mean Parameter.

Region	Average Waste Per Patient (Kg)	Standard Error	No of Samples	L90	U90	L95	U95
Central	1.23	0.395	4	0.30	2.16	-0.03	2.49
District	0.71	0.050	2	0.40	1.03	0.07	1.35
Private	1.57	0.437	7	0.72	2.42	0.50	2.64
Regional	0.63	0.202	4	0.15	1.10	-0.02	1.27

One measurement per day.

Table 3: Estimates of Parameters by District.

Region	Average Waste Per Patient (Kg)	Estimated Variance	Total Patients	Total Waste (Kg)	No of Samples
Central	1.23	639.07	18211	22413.58	16
District	0.71	5.61	592	422.70	8
Military	0.90	50.42	975	880.25	5
Private	1.57	365.33	5842	9157.57	43
Regional	0.63	127.84	11021	6912.30	19
Soweto Clinics	0.05	2.24	14880	729.35	4

Table 4: Confidence Intervals for the Mean Parameter.

Region	Average Waste Per Patient (Kg)	Standard Error	No of Samples	L90	U90	L95	U95
Central	1.23	0.187	16	0.90	1.56	0.83	1.63
District	0.71	0.097	8	0.53	0.90	0.48	0.94
Military	0.90	0.227	5	0.42	1.39	0.27	1.53
Private	1.57	0.250	43	1.15	1.99	1.06	2.07
Regional	0.63	0.108	19	0.44	0.81	0.40	0.85
Soweto Clinics	0.05	0.012	4	0.02	0.08	0.01	0.09

The impact of variance estimation.

In the situations where there are only a few samples to estimate the variance, this estimate of the variance may be very poor. This is accounted for in the confidence intervals making then very wide, when there are few samples. To demonstrate the impact of this inaccuracy of estimates I have recalculated the confidence intervals assuming that the variances were known. The aim of this analysis is to indicate that dramatic improvements in these estimates could be obtained by adding more samples to the dataset. The means are probably much more accurate than is suggested by the confidence intervals above, but we don't have good estimates of the variances to determine these intervals.

Variance				Estimated				Known			
Region	Average Waste Per Patient (Kg)	Standard Error	No of Samples	L90	U90	L95	U95	L90	U90	L95	U95
Central	1.23	0.40	4.00	0.30	2.16	-0.03	2.49	0.46	2.01	0.21	2.25
District	0.71	0.05	2.00	0.40	1.03	0.07	1.35	0.62	0.81	0.58	0.84
Private	1.57	0.44	7.00	0.72	2.42	0.50	2.64	0.71	2.42	0.44	2.69
Regional	0.63	0.20	4.00	0.15	1.10	-0.02	1.27	0.23	1.02	0.11	1.15

Variance				Estimated				Known			
Region	Average Waste Per Patient (Kg)	Standard Error	No of Samples	L90	U90	L95	U95	L90	U90	L95	U95
	1.23	0.19	16.00	0.90	1.56	0.83	1.63	0.86	1.60	0.75	1.71
District	0.71	0.10	8.00	0.53	0.90	0.48	0.94	0.52	0.90	0.46	0.97
Military	0.90	0.23	5.00	0.42	1.39	0.27	1.53	0.46	1.35	0.32	1.49
Private	1.57	0.25	43.00	1.15	1.99	1.06	2.07	1.08	2.06	0.92	2.21
Regional	0.63	0.11	19.00	0.44	0.81	0.40	0.85	0.42	0.84	0.35	0.91
Soweto Clinics	0.05	0.01	4.00	0.02	0.08	0.01	0.09	0.02	0.07	0.02	0.08

Approach to calculating the estimates of waste per person.

The data obtained gives the number of individuals at a hospital on a given day (or over a given period of time) and the amount of waste disposed for that period. From this information it is simple to derive an estimate for the average waste per person per day, by dividing the total waste by the total number of patient days (i.e. the sum of patients over each day in the period of interest.)

Now assume that the amount of waste consumed by each patient on a given day is a random variable denoted by X_i. Further assume that all the X_i are independently distributed with mean μ and variance σ^2. Then each estimated mean as described above is a random variable denoted $\overline{X}_{n_i}$, which is the sample mean of a random sample of n_i random variables X_i as described above. Since we do not have values for the variables X_i the mean values form the sample items.

As such we have a sample $\overline{X}_{n_1}, \overline{X}_{n_2}, \ldots, \overline{X}_{n_p}$. Assuming that the n_i are sufficiently large the central limit theorem ensures that each item follows a normal distribution with mean μ and variance σ^2 / n_i

Then it can be shown that the maximum likelihood estimates for the parameters μ and σ^2 are given by

$$\hat{\mu} = \frac{\sum_i n_i \overline{X}_{n_i}}{\sum_i n_i}$$ and

$$\hat{\sigma}^2 = \frac{1}{p}\sum_{i=1}^{p} n_i\left(\overline{X}_{n_i} - \hat{\mu}\right)^2 .$$

As usual the MLE is used in the unbiased form giving the unbiased estimate of σ^2 as

$$\hat{\sigma}^2 = \frac{1}{p-1}\sum_{i=1}^{p} n_i\left(\overline{X}_{n_i} - \hat{\mu}\right)^2 .$$

Now the variance of the estimate of μ is given by

$VAR[\hat{\mu}] = \frac{\sigma^2}{\sum_i n_i}$ and the estimate $\hat{\mu}$ is unbiased. As such the statistic $\frac{\hat{\mu} - \mu}{\hat{\sigma}}$ follows a *t* distribution with *p*-1 degrees of freedom. (1- α)% Confidence intervals for $\hat{\mu}$ can be obtained from the equation $\mu \in \hat{\mu} \pm \frac{\hat{\sigma}^2}{\sum_i n_i} t_{p-1,1-\alpha/2}$, where $t_{p-1,1-\alpha/2}$ is the $1-\frac{\alpha}{2}$ percentile of the t distribution with *p*-1 degrees of freedom.

ANNEXURE 4. 1: Sample Incinerator Survey Form:Health Care Risk Waste Incinerator Survey

Name Of Health Care Facility: ……………………………………………......
Physical Address: ...…………………………………………………………
Postal Address:………………………………………………………………
Tel No: (………) ………………… Fax No: (………) …...………......
Coordinates: X .... Y...
Date of Survey: ....
Interviewer: ....
Contact Person: ....
Ownership: Private / Government / NGO / Church/Mine/Other

A: Type of health care facility:

Hospital:	Clinic:	Laboratory:	Doctor: ......
Dentist:	Aids Care:	Hospice:	Mortuary: ......
Prison:	Vetinary Clinic:	Day Clinic:	

Other:......................... (please indicate type of facility).

B: Number of beds: .... Occupancy rate:....................%

C: Services generating health care risk waste:

Medical:	Maternity:	Surgical: ....
Casualty:	ICU:	Theatres: ....
Oncology Unit:	Outpatient Clinic:	Dialysis unit::........
Laboratories:	Pathology:	Blood Bank: ....
Pharmacy:	Other (please name) ....…….......	

D: Current health care risk waste treatment/disposal methods:

Own Incinerator: .... (Y/N)
External Incinerator: .... (Y/N)
If an external incinerator – who is the owner? ....…………......
Landfill: .... (Y/N)
Other: .... (Y/N)
If other method used please describe:...…………....

E: If own incinerator is used, please provide the following information (if you have more than one incinerator please provide details of the other unit(s) on a separate sheet):

Make: ....………………………...
Size: ....kg/h
Is it registered with the Department of Environmental Affairs and Tourism? .... (Y/N)
If so, please give the certificate number: ……...........
Type of incinerator:
Excess air (e.g. LA type retort): .... (Y/N).
Controlled air (e.g. Toxic): .... (Y/N)
Date installed: ………................

Condition of incinerator:

Good ....(Y/N)

Needs repair ....(Y/N)

Bad ....(Y/N)

Not Operational ....(Y/N)

Oil/fuel consumption .... litres/month

Operational Hours .... hours/month

Downtime .... hours/month

Equipped with scrubber? .... (Y/N)

Type of feeding?

Manual: .... (Y/N)

Mechanical: .... (Y/N)

Stack height: .... metres

Is it equipped with:

A primary burner? .... (Y/N)

A secondary burner? .... (Y/N)

Operating temperatures:

Primary .... *^{o}C*

Secondary .... *^{o}C*

Used for incinerating:

Health care risk waste only .... (Y/N)

General waste .... (Y/N)

Hazardous waste .... (Y/N)

(e.g. drugs, lab. waste)

Location of Incinerator:

Suitably located to minimise environmental pollution? .... (Y/N)

Suitably housed to prevent a local nuisance? .... (Y/N)

Operators:

How Many: ....

Educational Standard: ....

Number of Shifts ....

How is the Incinerator Ash Disposed?:

On-site: .... (Y/N)

With the General Waste: .... (Y/N)

Hazardous Waste Landfill: .... (Y/N)

F: Packaging and Handling of Health care risk waste:

Who handles your health care risk waste?

Internal Staff: .... (Y/N)

Waste Management Company: .... (Y/N)

Do you separate health care risk waste:

From general waste .... (Y/N)

From chemical hazardous waste: .... (Y/N)

Sharps from other infectious waste: .... (Y/N)

Have the waste handling staff experienced any needle stick injuries over the last five years? .... (Y/N)

Are sharps stored/collected in:

Old bottles or containers? .... (Y/N)
Special puncture proof containers? .... (Y/N)
Other? .... (Y/N)

Is the non-sharp health care risk waste stored/collected in:

Plastic Bags: .... (Y/N)
Cardboard Boxes (with liner): .... (Y/N)
Plastic bins: .... (Y/N)
Other: .... (Y/N)

G: What are your current treatment/disposal costs?

Sharps R............./kg
Other Infectious Waste R............./kg

H: The Province is considering the need for Regionalised Health care risk waste Treatment Facilities:

Does this have your support? .... (Y/N)
Would your Hospital/Clinic use such a facility? .... (Y/N)