ENVIRONMENTAL AND FINANCIAL FEASIBILITY OF SELECTED HEALTH CARE WASTE MANAGEMENT SCENARIOS FOR GAUTENG PROVINCE

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ABOUT THE SPEAKER

Mr Kristiansen has vast experience in waste management - including hazardous/infectious waste, sanitary engineering, water supply and environmental. He has, among others, been posted in Egypt for more than 1½ year and in South Africa for 3 years managing comprehensive large-budget health care waste management projects including capacity building, development of policies, strategies and guidelines as well as practical implementation of technical and training solutions with procurement, supervision and commissioning of treatment plants and waste handling equipment. Furthermore, he has been on several missions to South East Asia and to Southern Africa on assignments and project preparation missions and he has substantial experience in Eastern and Central Europe from several assignments in the region, including Russia, Ukraine, Belarus, Moldova, Latvia, Lithuania, Poland and Hungary.

ABSTRACT

As part of the comprehensive project “Sustainable Health Care Waste Management in Gauteng” an elaborate environmental and financial feasibility study has been made for selected provincial health care waste management scenarios. Furthermore, the study assessed the health, safety and socio-economic impacts of the scenarios qualitatively and comparison was made with the prevailing containerisation and treatment used today in Gauteng province.

The findings of the Feasibility Study show that compared to today’s system of predominantly using disposable cardboard boxes that are incinerated in incinerators with no flue gas cleaning systems and limited control of the combustion process significant reductions of the emissions to the atmosphere can be achieved by improving the emission standards for incinerators and/or introducing non-burn treatment technologies. Also, it is clearly demonstrated that introduction of safer and reusable containerisation has a significant environmental benefit while providing a better and more occupationally safe service at a similar or slightly reduced cost.

Finally the Feasibility Study demonstrates that whilst the type and amounts of emissions from incinerators with flue gas cleaning devises and alternative non-burn treatment technologies are materially different in nature and type it is difficult to clearly determine which if the two types of treatment technologies is globally and overall the least damaging in environmental terms.

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INTRODUCTION

The Feasibility Study was initially conducted for the purpose for informing the contents of a pilot test of the such possible technical specifications at a full-scale test at one provincial hospital and one provincial clinic, after which it was to inform the decision on the future specifications in the next province-wide health care waste collection and treatment tenders for Gauteng's provincial hospitals and clinics.. The Feasibility Study was prepared as a collaborate effort by all the co-authors with significant inputs from Gauteng Department of Agriculture, Conservation, Environmental and Land Affairs as well as valuable input from the Gauteng HCW management service industry and manufactures who reviewed and commented on the document.

Based on the outcome of the Feasibility Study approximately R 710,000 was committed for testing equipment, capacity building systems, training programmes and assisting service providers in adapting their infrastructure for the purpose of the test.

The main criteria for any options to be tested in the HCW Pilot Projects were:

1. Minimisation of occupational health and safety risks throughout the entire process and in particular: i) needle stick injuries, ii) exposure to pathogens in general and iii) heavy and awkward lifts;
2. Environmentally sustainable or as a minimum based on best available environmental practice;
3. Affordable and cost effective integrated solutions, in particular: i) allow for more cost effective containerisation, ii) allow for cost effective internal and external collection and transportation, iii) allow for cost effective management and treatment of HCRW at the treatment plant;

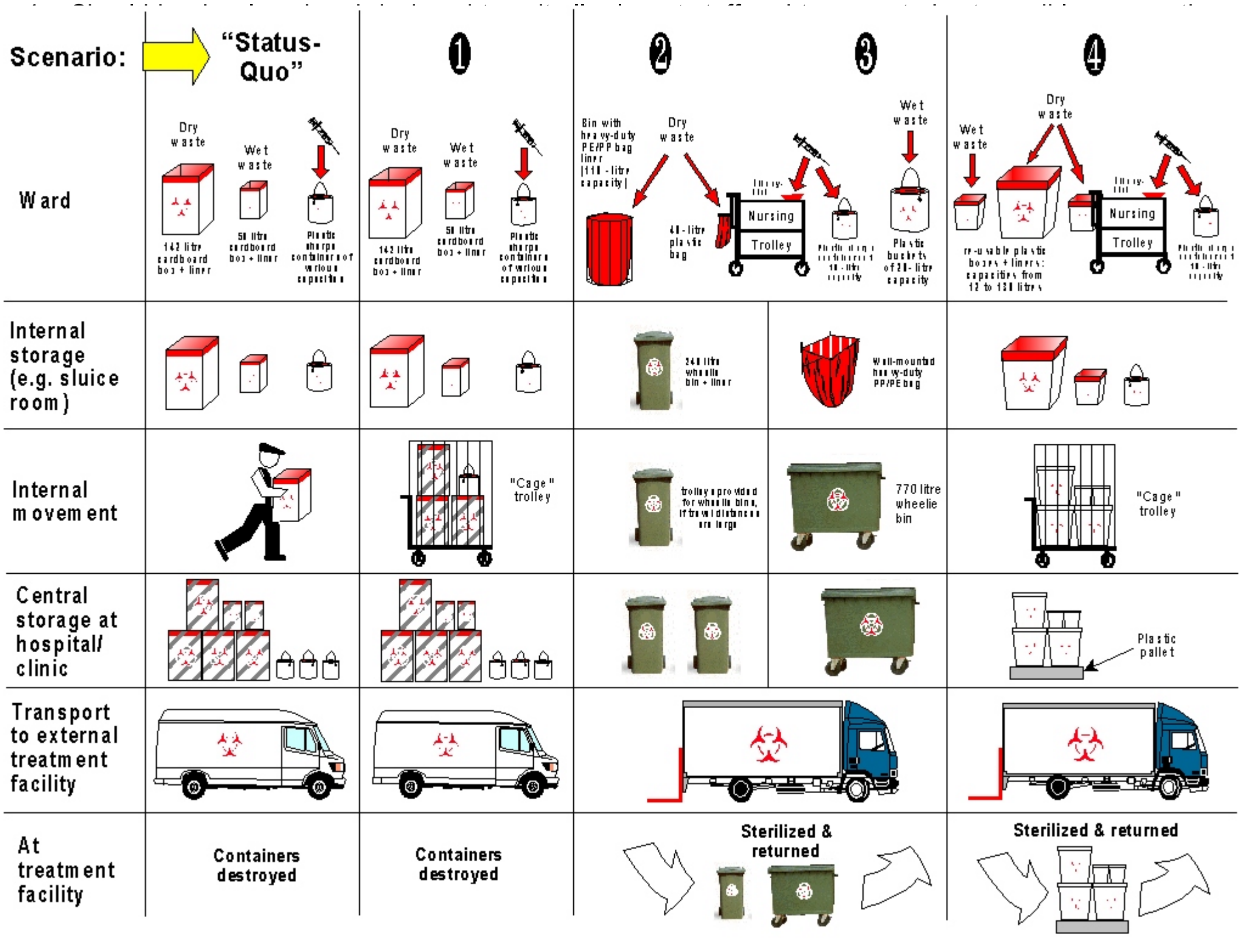

Figure 1: Selected Scenarios for Management of HCRW in Gauteng assessed in the Feasibility Study

Based on the aforesaid criteria three regional HCW Management Scenarios were selected for further assessment and comparison with the current Status Quo. The final selection of Scenarios was informed by consultations with the provincial health care facilities and the HCW Service industry, all of which was done against the background of the Gauteng HCW Management policy of November 2001.

SELECTION OF SCENARIOS, APPROACH AND KEY ASSUMPTIONS MADE

Selected Scenarios

Figure 1 above shows the status quo and the four scenarios investigated in the Feasibility Study. The scenarios were designed to evaluate and compare disposable and reusable containerisation options, incineration and non-burn treatment options as well as on-site versus regional treatment options.

The scenarios include the current situation (Status Quo), Scenario 1, which is similar to Status Quo but with improved treatment and reduced manual handling, whereas Scenarios 2, 3 and 4 include more elaborate changes to the containerisation and internal transport of HCRW by using different sizes of reusable wheelie bins or stackable plastic boxes instead of the disposable cardboard box system that is presently in use.

For Scenarios 1, 2, 3 and 4 calculations were made for various treatment options including incineration, microwave and autoclave technologies assumed to comply with the Gauteng Minimum Requirements in terms of emission to air and the level of microbial inactivation achieved. Calculations were further made for the options of having 1, 3, 10 or 20 treatment facilities, where 1-3 treatment facilities represent a regionalised approach to the treatment infrastructure and 10-20 treatment facilities represent an on-site treatment approach.

Methodology and Approach

The Feasibility Study was conducted as a desktop study based on actual and confirmed costs and was later verified through observations from the pilot projects at Leratong Hospital and Itireleng Clinic. However, a number of assumptions were made for both the environmental emission rates as well as the financial unit costs, capital costs etc. The main assumptions made are presented in the tables 2, 3 & 4 below.

<u>Environmental Calculations</u>

The environmental calculations are based on a number of assumptions, as listed in the tables 2, 3 and 4 below.

Table 2: *Key Assumptions made for the assessment of the environmental impact of the Scenarios*

- *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 were 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. However, at this scale it is not assumed financially viable to recover energy based on today's energy prices in SA, etc.;
- 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 3: *Principal Environmental Impact caused by Principal Treatment/Containerisation Scenarios*

Impacts	Status Quo	On-site Incineration	On-site Sterilisation	Off-site Incineration	Off-site Non-burn treatm	Assumptions/Differences
	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

Compared to international standards the emission requirements for incinerators in South Africa are currently not very strict. There are several cases of open burning of waste and practically all old incinerators are operated without any flue gas cleaning system capable of removing acid gases, dust, metals or dioxin/furans.

For the purpose of the environmental calculations assumptions were made for the emission rates of incinerators without flue gas cleaning as well as incinerators complying with the proposed Gauteng Incinerator Emission Standards. From table 4 it is clear that there is a significant difference in the emissions caused by complying and non-complying incinerators.

Table 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				

Financial Calculations

An elaborate financial model using Excel Spreadsheets was developed for the financial calculations. The model allowed for adaptation and variation analyses. The Financial Model is made available on the Project web-pages (www.csir.co.za/ciwm/hcrw) for further development and adaptation by others wishing to do so.

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 create the possibility of 'outsourcing' some or all the activities to the private sector. The modules are not further discussed in this paper but are described in detail on the Project Web-page.

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.

Table 6: *Principal Assumptions made in the Cost Model*

Assumption	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: 87.5% Wet: 4.5% Sharps: 8.0%	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: ranges from one worker per 75 kg HCRW/day to one worker per 165 kg HCRW/day, depending on mode on containerisation * 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 : 80 kg; 100 L plastic container: 6.8 kg; 50 L plastic container: 5.0 kg. Number of ‘sets’ of containers provided in system (a ‘set’ is defined as the number of containers that are filled in one day): 660 & 770 L wheelie-bins : 8 sets; 240 L wheelie-bins : 10 sets; re-usable boxes : 8 sets; cage-trolleys for re-usable boxes: 5 sets.	
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-bins = 25 mins + 1.5 min/bin 770 L bins = 27 mins + 3.6 min/bin 100 L plastic containers: 21 min + 1.3 min/container ; cage-trolleys for plastic containers: 27 min + 3.6 min/trolley	
Interest & Depreciation	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 mark-up	Present Study	User-defined in model.	

GENERAL FINDINGS OF THE FEASIBILITY STUDY

Findings of the Environmental Calculations

Based on a literature search and particularly the Dutch LCA Tool SimaPro5 (www.pre.nl) emission rates for the manufacturing of receptacles was determined. Furthermore the use of water and detergents was estimated for assessing the environmental impacts caused by the various containerisation options. It became clear that there is a significant difference in the environmental impact caused by disposable cardboard boxes compared to any of the options based on reusable polypropylene containers, even when allowing for additional transportation and washing of the containers (table 7).

Table 7: *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

Based on the above assumptions and i) the standard emission rates of table 4 and 7, ii) the inclusion of usual emission rates caused by transportation using diesel powered trucks and average transport distances based on the size of Gauteng and the location of the health care facilities in relation to the treatment plants, iii) the significant emissions caused at landfills receiving the treated residues from either incinerators (ashes and flue gas cleaning residues) or the non-burn treatment plants (dried and size-reduced sterilised health care risk waste) and iv) the emission caused by the production of electricity consumed for the process, the total monthly emission caused by the various health care waste management scenarios was determined. The total estimated emissions are shown in table 8 below.

When the calculations were made it became apparent that it was primarily the type of treatment plant and the transportation distances (i.e. on-site or regionalised treatment) that made a difference, whereas the use of 240-litre, 770-litre or reusable stackable boxes did not result in major differences in the overall results. Whereas the 'Status Quo' scenario is based on the current poor environmental performance of incineration plants, it is assumed that 'Scenario 1' is based on compliant incinerators with advanced flue gas cleaning systems.

Table 9 and 10 below show the final overall total emission and impacts caused by the scenarios to the different media, especially air and water as well as the impact on resource depletion (fossil fuels, water, land use, etc.). The tables also show that there is a significant difference in the *types* of impacts i.e. the media being affected and the type of pollutants that are released for the different scenarios. Especially when comparing incineration versus the non-burn treatment technologies this is very clear, whereas the on-site versus regionalised treatment primarily has an environmental impact on the emissions caused by transportation, but a considerable financial impact.

The Feasibility Study has not developed a model for weighing these different types of emission against each other. Hence, it is assumed that only an assessment including actual sites and communities would allow for, for example, an evaluation of whether emission to the air as a point source (incineration) is more or less desirable than a marginal increase in emission from a power plant supplying energy to a non-burn treatment plant added to the subsequent emissions caused at the landfill receiving the treated residues?

This study assumes that provided incinerators are equipped with advanced flue gas cleaning systems it is not possible at this stage to determine if non-burn treatment or incineration is the environmentally most preferred option. However, the financial assessment below shows that for smaller plant capacities non-burn treatment appears most cost-effective whereas for larger plant capacities incinerators are most cost-effective. It is further to be recognised that all of this is affected by the exchange rate used, as certain treatment technologies are to be imported, whereas others are locally manufactured. This was in particular the case for the non-burn treatment technologies whereas the incinerators are manufactured locally.

Table 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

For the environmental assessments only a few selected key pollution parameters have been selected as an indication of the impacts caused by the scenarios. Hence, the fact that a particular pollutant is not indicated does not mean that that pollutant is not occurring.

Table 9: *Total Monthly Emissions and other impacts caused by the HCW Management Scenarios if applied throughout all health facilities in Gauteng*

TOTAL Incl. Manufacturing of containers				**Status Quc**	**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

Table 10: *Total Monthly Emissions and other impacts caused by the HCW Management Scenarios if applied throughout all health facilities in Gauteng (cont'd)*

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

Findings of the Financial Calculations

A summary of the outcome of the Financial Assessment of the Scenarios is presented in Table 9 below.

Table *9: Summary of Findings of the Financial Assessment of Total Costs of the Selected HCW Management Scenarios for Gauteng*

TOTAL MONTHLY SCENARIO COSTS (INCLUDING TREATMENT) (Million Rand)	Scenario 1 "Disposable Containers + cage-trolleys"			Scenario 2 "Re-usable Containers (240 L w/bins)"			Scenario 3 "Re-usable Containers (770 L w/bins)"			Scenario 4 "Re-usable Containers (plastic boxes) + cage-trolleys"			Status Quo "Cardboard boxes & poor incinerators"
Number of treatment facilities	Autoclave	Incinerator	Microwave	Autoclave	Incinerator	Microwave	Autoclave	Incinerator	Microwave	Autoclave	Incinerator	Microwave	Estimated total monthly notional cost (million)
1	R 3.26	R 3.32	R 3.96	R 3.44	R 3.50	R 4.10	R 2.85	R 2.91	R 3.51	R 3.50	R 3.55	R 4.15	R 3.70
3	R 3.56	R 3.62	R 3.84	R 3.66	R 3.72	R 3.93	R 3.14	R 3.19	R 3.40	R 3.68	R 3.73	R 3.94	
10	R 4.65	R 4.79	R 4.72	R 4.61	R 4.74	R 4.67	R 4.16	R 4.29	R 4.22	R 4.57	R 4.70	R 4.63	
20	R 6.19	R 6.56	R 6.25	R 6.01	R 6.36	R 6.07	R 5.60	R 5.94	R 5.65	R 5.95	R 6.29	R 6.00	

Table 9 above shows the monthly costs for the entire province for the different scenarios under the given assumptions. Figure 10 below shows the relative costs for a regional treatment scenario for hospitals (29 sites) and clinics (approx 145 sites) managed by the provincial department of health in Gauteng only. Also the estimated current costs are indicated.

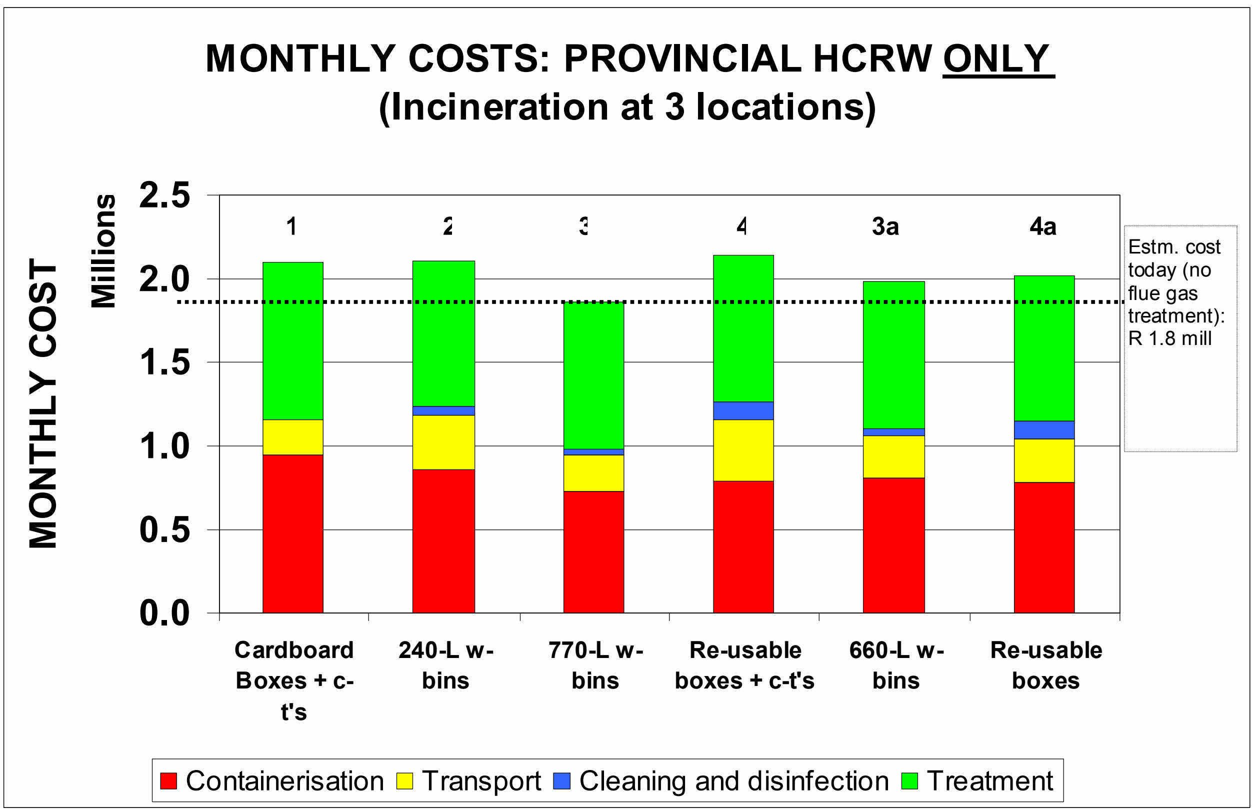

Figure 10: *Monthly Scenario Costs for Provincial Hospitals (29) and Clinics (approx 140) in Gauteng only*

Figure 10 includes some additional variants of the scenarios. Scenario 3a is based on a 660-litre wheeled wheelie bin instead of the 770-litre wheelie bin and Scenario 4a is the same as Scenario 4 but without the cage trolleys. Scenario 3a involves a slightly more expensive wheelie bin, hence, the higher costs, whereas

Scenario 4a involves more manual handling as the relatively expensive cage trolleys have been omitted and replaced with a simpler pallet system.

The financial analysis shows, quite remarkably, that it is possible to introduce a service that is better both in terms of environmental and occupational health performance at a cost that is similar to or even less than the current costs today. This is because of the scope for making the processes more effective and to capitalise on the savings from continued disposal of cardboard boxes. It is estimated that up to 10-15% of the mass being treated as health care risk waste today is, indeed, cardboard boxes that contributes not insignificantly to the total mass of waste requiring expensive treatment.

Another very likely and possible method of reducing the costs of health care risk waste management is to improve segregation. Studies on Gauteng have documented that between 22-30% of the waste currently undergoing expensive treatment is actually mis-segregated general waste such as fruit peels, paper, soft drink bottles etc. that could be disposed via the general waste stream at a significantly lower rate. Hence, there is a significant scope for reducing costs by improving segregation that would work across the board for all scenarios including the status quo.

FINAL CONCLUSIONS

The conclusions below are presented separate for the Environmental and the Financial Impacts followed by a final conclusion and recommendation.

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 bins, especially since the energy used for manufacturing cardboard boxes is 9 times more than what is required for reusable bins;
2. Use of disposable cardboard boxes results in the consumption of 1100 tonnes of cardboard and 160 tonnes of polypropylene per year. Even though water is required for washing of reusable wheelie bins, manufacturing of cardboard boxes leads to much higher use of water (ℜ10) and energy (ℜ10) 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 leads to less (half) 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 significant CO_2 emission compared to non-burn technologies;
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 viable or practical at this scale for SA;
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 technologies 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 (ℜ4);
11. Use of incineration causes more dioxin (ℜ7), dust, HCl, Hg, NO_x, than the use of non-burn technologies;
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 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 emission from transportation is 10% of the total dioxin emission for 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 that 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 nearby.

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 Gauteng HCW Management Policy are complied with. However, it appears that any of the proposed scenarios would be significantly better than the current situation (Status Quo).

Financial Conclusions

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.

<u>Treatment Technology</u>
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, as well as when considering **provincial** DoH HCRW only.

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 in 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 DoH 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.

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** DoH HCRW only, percentage increases are higher.)

Even if **transport costs 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 'economies-of-scale' effect.)

Mode of Containerisation

Under the 'base-line' assumptions, 770 L wheelie-bins offer the lowest-cost solution. This holds true in the case of **all** Gauteng HCRW, and in the case of **provincial** HCRW only.

Taking **provincial HCRW only**, and assuming three treatment facilities, the cost-advantage of the 770 L wheelie-bin scenario over the 660 L wheelie-bin scenario is approximately 5%; the cost advantage of the 770 L wheelie-bin scenario over the 240 L wheelie-bin scenario and the re-usable box scenario is approximately 11% in each case.

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'.

General Financial Conclusions

It is clear that the more treatment 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 only few large regionalised treatment plants are used.

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).

Final Conclusion and Recommendations

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

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 treatment;
3. 2-4 regionalised treatment plants appear to result in the lowest overall costs due to economies of scale;
4. Use of reusable wheelie bins is 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 increases 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 to be high when compared to the estimated cost of improved and efficient treatment systems;
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 emit very significant amounts of pollutants compared to internationally available state-of-the-art incinerators.
9. Compared to non-burn technologies, incineration has 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 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 to avoid damaging workers' health and creating more meaningful and dignified jobs and working conditions;
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.

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