GAUTENG DEPARTMENT OF AGRICULTURE, CONSERVATION, ENVIRONMENT AND LAND AFFAIRS

SUSTAINABLE HEALTH CARE WASTE MANAGEMENT IN GAUTENG

Emission Monitoring Requirements for HCRW Incinerators and Assessment of the Cost of Compliance

D A Baldwin, Environmental and Chemical Consultants cc

FEBRUARY 2004

CONTENTS

1. Introduction: 1

2. Assessment of Incineration Emission Monitoring Requirements 1

3. International Approaches and Standards 3

3.1 US Environmental Protection Agency 3

3.2 European Union 4

4. Analytical Procedures for Emission Measurements and Approximate Cost of Tests: 5

5. Assessment of Original Monitoring Programme 8

5.1 General Assessment 8

5.2 Original Monitoring Programme: Costs 8

6. Final Monitoring Programme 10

6.1 General Assessment 10

6.2 Final Monitoring Programme: Estimated Costs 12

7. Comparative Costs of the Monitoring Programmes 12

8. Reporting Requirements 14

9. Conclusions 14

10. References 15

1. Introduction:

At workshops and other discussion sessions held during the development of the Gauteng Sustainable Health Care Waste Management programme, two of the important issues discussed were the emission standards and monitoring requirements for health care risk waste incinerators. Many participants expressed their concern that the proposed frequency of monitoring would prove expensive and, therefore, unaffordable. The project, therefore, undertook a study of the monitoring requirements internationally and discussed the proposals with a number of South African experts. The costs of analysis were then taken into account in drawing up the minimum required monitoring frequencies although the prime objective was to ensure that they were adequate to allow the authorities to determine compliance with the required standards. The studies were undertaken during 2002 and 2003 and, after much discussion they finally resulted in the publication of the DEAT Minimum Environmental Performance Requirements for Controlled Combustion Treatment Facilities in terms of Regulation 9(2) (Gauteng HCWM Regulations, Draft 7, 12 August 2003). This objective of the current document is to present a review of the studies that led to the proposed regulations to give interested parties some indication of the approach that resulted in the requirements. Clearly, the document contains some degree of hindsight particularly as a study was run parallel with this one on the compliance and monitoring requirements for non-burn technologies [1] and the policy should be similar for both technologies. This report is, we believe, an accurate representation of the studies undertaken.

2. Assessment of Incineration Emission Monitoring Requirements

The health care risk waste policy document produced in November 2001 [2], proposed the analytical requirements and frequency of analysis given in Box 1, and as indicated in section 1 concern was expressed about the high frequency of monitoring required. Hence, it was decided to undertake an investigation to determine the minimum number of parameters to be monitored plus a frequency of analysis that would allow the authorities to ensure that a permitted incineration/combustion facility was conforming to an acceptable level of environmental performance and yet would prove to be reasonably affordable. The need for continuous monitoring of certain key parameters, such as carbon monoxide was also evaluated.

The method used was to determine (a) how the parameters listed in Box 1 were measured (b) the frequency of analysis that is required internationally, i.e. the USA and Europe, and (c) to obtain an estimate of the costs of the various tests in South Africa. Once these issues had been evaluated, an approach was developed that is considered to be appropriate for the country in discussion with South African experts in the field, the Department and other experts. The results of these studies are presented in this document.

The approach to emission monitoring selected by the Department includes the following phases, i.e. it is similar to the approach accepted for non-burn technologies [1]:

- The performance testing phase, where the facility must demonstrate that it can meet the design specifications and the emission standards that were presented to the Department as part of the EIA,
- A standard monitoring phase, which is in place for the first and possibly subsequent years and
- A conditional phase, where a decreased frequency of monitoring for selected species may be approved, provided the facility has demonstrated to the satisfaction of the Department that it can regularly meet the required standards.

BOX 1: Minimum Requirements for Thermal Treatment Facilities

The absence of suitable South African flue gas emission standards Gauteng will enforce the current Emission Guidelines published by DEAT.

It is expected that national government will revise the current lenient requirements of the "1965 Atmospheric Pollution Prevention Act" (Act 45 1965) as it currently does not set any specific limits in the form of maximum allowable concentrations of selected pollutants be standard volume of flue gas.

Schedule 2, Process 39 Atmospheric Pollution Prevention Act 1965 *Guidelines(DEAT)*		Proposed Monitoring Frequency (Permit conditions can vary)	EU	US
		Standard (minimum) per year	Dec. 2000	Sept. 1997
Type				S/M/L*
Units	mg/Nm^3		mg/Nm^3	mg/Nm^3
PM/dust	180	12 (4)	10	53/26/26
CO	-	Continuous	50	36
TOC	-	-	10	-
Dioxin/furan (nanogram) TEQ	0.2	4(1)	0.1	1.76/0.46/0.46
HCl	30	12 (4)	10	17
HF	-	-	1	-
SO_2	25	12 (4)	50	112
NO_x	-	-	200	366
NH_3	-	-	10	-
Pb, (same for Cr, Be, Ar, As, Sb, Ba, Ag, Co, Cu, Mn, Sn, V, Ni)	0.5	4 (1)	0.05	0.92/0.05/0.05
Cd (same for Tl)	0.05	4 (1)	0.05	0.12/0.03/0.03
Hg	0.05	4 (1)	0.05	0.42
Ref. Cond.	11% O_2, 273 Kelvin, 101.3 kPa			

Notes:

* S/M/L: Small (<200lb/h)/Medium/Large facilities (>500lb/h). Limits recalculated to same standard conditions

The current national emission standards for a Schedule 2, Process 39 in terms of the Air Pollution Prevention Act (Act 45 of 1965) are listed in Box 1 and, for comparison, those required in the European Union and the USA. It is expected that the standards in SA will be made more stringent in the future, particularly that for particulates, which is considered by many to be too high. However, in the current study, only the frequency and cost of analysis are important and not the actual standards, unless of course they have an impact on the analytical procedure, which is apparently not the case.

In this document, the costs of compliance with the Gauteng proposed requirements given in Box 1 and the actual minimum requirement, which are presented later, have been estimated using data obtained from local suppliers of monitoring equipment and services. The approaches used by the US Environmental Protection Agency and the European Union to monitoring of health care risk waste incinerators were considered, when making a decision on the Gauteng minimum requirements and these are presented briefly below.

3. International Approaches and Standards

3.1 US Environmental Protection Agency

The EPA recognises three sizes of incinerator, small <200lbs/hr (<91kg/hr), medium, and large >500lbs/hr (>227kg/hr) and the emission standards are set according to size (see Box 1). The small incinerators are defined as being “rural” that is they are located 50 miles from the nearest metropolitan area and burn less than 2000 lbs or ~1 ton of waste *per week*. The emission standards for the small incinerators are based on “good” combustion and no emission control devices are installed. For the medium and large incinerators, the standards are set with the premise that emission control, e.g. wet scrubber, dry injection/fabric filter or a spray dryer/fabric filter devices are installed, i.e. the standards cannot be met without gas cleaning.

The US EPA Compliance Testing and Monitoring requirements for health care risk waste incinerators are listed in table 1 [3]. Note that a full test, i.e. analysis of all regulatory parameters, is only required during the initial stack testing phase. For medium and large incinerators annual testing is required only for PM, CO and HCl, although even this requirement is relaxed to each third year, once a facility has demonstrated that it has complied with the requirements for three consecutive years: for small or “rural” facilities no further analysis is required just an annual inspection. Note that the requirements listed in table 1 are significantly lower, except for particulates and HCl, than those proposed in the strategy document (Box 1) for Gauteng Province.

Table 1: US EPA Emission Monitoring Requirements for Health Care Risk Waste Incinerators

Frequency/Test	**EPA Method**
Initial Stack Test	
Particulate Matter (PM)	Method 5
Carbon Monoxide (CO)	Method 10 or 10B
Dioxin/Furans	Method 23
Hydrochloric Acid (HCl)	Method 26
Lead, Cadmium, Mercury	Method 26
Opacity	Method 9
Annual (or Third Year Stack Test) for Medium and Large Incinerators	
Particulate Matter	Method 5
Carbon Monoxide (CO)	Method 10 or 10B
Hydrochloric Acid (HCl)	Method 26
Annual for Medium and Large Incinerators	
Opacity	Method 9

The US EPA guidelines require, however, that a facility monitor certain operating parameters on the incinerator and emissions cleaning equipment, see table 2: the parameters being set during the initial performance tests.

Table 2: Operating Parameters that must be monitored

Unit	Operating Parameter
Incinerator	Waste Charge Rate
	Secondary Chamber Temperature
	By-pass Stack Temperature*
Wet Scrubber	Pressure Drop (or horsepower or amperage)
	Liquor Flow or Dosing Rate
	pH
	Flue Gas Temperature
Dry Scrubber	Absorbent Flow Rate (e.g. Carbon for dioxins/furans/Hg)
	HCl Absorbent Flow Rate (e.g. Lime)
	Fabric/Ceramic Filter Inlet Temperature

* *This measurement ensures that emissions that by-pass the scrubbers, e.g. when shut down for maintenance, etc. are at an adequate temperature. In South Africa, it is recommended that the incinerator be shut down at all times during scrubber maintenance and, therefore, measurement of this parameter is not considered necessary under these circumstances.*

Thus, in the US, provided a facility maintains its performance within the parameters set during the initial phase, the emissions are considered to conform to the requirements and they are, therefore, only required to analyse infrequently. This approach requires the authorities to closely monitor and control the treatment facilities, which implies that sufficient resources, both financial and human, are available and that a strong legal framework is in place.

3.2 European Union

The EU follows a similar approach to that in the US in that the permit conditions require the facility to maintain its operating parameters within certain permitted limits [4]. Operating requirements for health care risk waste incinerators include:

- For hazardous waste, which contains more than 1% of halogenated organic substances, the temperature has to be raised to more than 1100°C for more than 2 seconds. This requirement is set in order to destroy as many organic pollutants such as dioxins as possible. Note that health care risk waste will fall into this category as it normally contains more than 1% PVC. The temperature must be measured continuously near an inner wall or some other representative point in the combustion chamber – this would be achieved in the secondary chamber of an incinerator.
- An automatic system must prevent waste feeding:
    - At start up before the temperature reaches 1100°C
    - Whenever the temperature is not maintained at 1100°C and
    - When continuous measurements that are required (see below) show that the emission limit value has been exceeded due to disturbances or failures of the purification (scrubbing) devices.
- The plants must be operated to achieve a level of incineration such that the slag or bottom ash have a Total Organic Carbon of <3% or the loss on ignition is <5% of the dry weight of the material.

The EU emission standards, which are included in Box 1, are generally stricter than those required in the US and they clearly cannot be met without having emission cleaning equipment installed. It should be noted here that the US standards are from 1994, modified in 1997, while the EU standards apply to new plants from 28th Dec. 2002 and existing plants, i.e. those plants permitted before that date from 28th December 2005 Also, we should add that the US standards are particularly for HCRW incinerators whereas the EU standards are predominantly written for large scale incinerators burning more than 3,000 kg/hour of municipal waste or 10000 kg/hr of hazardous waste.

The emission monitoring requirements are listed in table 3.

Table 3: EU Exhaust Gas Monitoring Requirements for Health Care Risk Waste Incinerators

Parameter	**Standard**	**Conditional**
PM/Dust	Continuous	
CO	Continuous	
TOC	Continuous	
Dioxin/furans	- Every three months first year - Two measurements per year, thereafter	Can be reduced to once every year provided emissions are below 50% of the emission limit value.
HCl	Continuous	Periodic measurement can be approved provided the operator can prove emissions cannot exceed the prescribed emission limit.
HF	Continuous	May be omitted if treatment ensures that HCl meets the emission limit value. Periodic measurement can be approved provided the operator can prove emissions cannot exceed the prescribed emission limit.
SO_2	Continuous	Periodic measurement can be approved provided the operator can prove emissions cannot exceed the prescribed emission limit.
NO_x	Continuous	
Heavy Metals	- Every three months first year - Two measurements per year, thereafter	Can be reduced to once every two years provided emissions are below 50% of the emission limit value.
O_2	Continuous	
Pressure	Continuous	
Water Content	Continuous	Not required if exhaust gas sample is dried prior to analysis.
Other		Other emission limits, e.g. PAHs, as set in national legislation of member states

The initial or performance testing programme must also include verification of the residence time, as well as the minimum temperature and oxygen content of the exhaust gas, under the most *unfavourable* operating conditions. Waste water discharge limits and monitoring requirements are also set for the water used in wet scrubbers and this includes a dioxin measurement at the same frequency as that required for gas emissions, see table 3.

Note that the EU does not distinguish between different sizes of plants and, comparison of tables 1 and 3, shows that the monitoring requirements are much more comprehensive than in the US.

4. Analytical Procedures for Emission Measurements and Approximate Cost of Tests:

Each of the possible procedures and their costs, exclusive of VAT, are briefly discussed below.

1. Dust and Heavy Metals

   Dust and heavy metals are normally determined together since heavy metals are predominately associated with dust particles. Particulate matter is withdrawn isokinetically and collected on a glass fibre filter and after drying it is determined gravimetrically. The set up, analysis and interpretation costs for a single test in South Africa are of the order of R8000 to R10000.

2. Dust and Dioxins/Furans

   Dioxins and Furans are also largely associated with dust emissions and the samples are collected by isokinetic methods. The analysis of dioxins and furans is currently not available in South Africa and after collection and concentration of the samples, they are forwarded to laboratories in the USA or Europe for analysis. Because of the potential high toxicity of the samples, they must be packaged and transported according to international standards. The total cost for sample collection, packaging and postage is ~R20000.00. Normally two samples are taken, which together with the two blank samples that are required, results in an analytical cost of ~R60000.00, which must be paid in foreign currency; this gives an approximate total cost of R80000.00 for the measurement of dioxins/furans. The typical time required to obtain the results from date of sampling is two months. It is important to recognise that, for this high cost, the concentrations of dioxins and furans emitted from the incinerator stack at a particular instance in time is obtained and the result need not be that representative of the actual performance of the incinerator, because the amounts of these hazardous compounds generated and isomers formed are highly dependant on the waste being incinerated and any precursors that are present. The lack of facilities for dioxin analysis in South Africa is mainly due to lack of market demand, as the cost to set up a facility is extremely high and is estimated at R10 million with an operating cost of R2 million per annum. Clearly, a reasonable turn over of samples is required to make it cost effective. Making dioxin analysis a Gauteng minimum requirement will help to increase the market demand, but it should be noted that even if a facility is set up in South Africa, it does not mean that the cost of an analysis will necessarily be lower unless demand is high and/or it is subsidised, e.g. by the Government.

3. Acid and Other gases

   Gases such as HCl, SO_2, NO_x, CO, NH_3, etc can be analysed separately or by continuous monitoring (see section 5). Separate monitoring requires a sampling train for each species and, thus, double sampling: it is estimated that the analysis of each gas would cost of the order of R5000.00.

4. Continuous Measurements

   Continuous monitoring systems available include for:

   - Gaseous compounds: there are basically three types:
     - *Extractive Systems*: the gas sample is extracted from the exhaust and transported to a conditioning system, where the gas is cleaned and any potential interfering species are removed. It is then passed through separate analysers, which each measure its designated pollutant concentration. Parameters that can be monitored in this manner include SO_2, NO_x, CO, THC, HCl, CO_2 and O_2.
     - *In-Situ Systems*: the gas enters a measurement cell that has been inserted into the stack and the concentration of pollutant can be measured by a variety of techniques. Individual monitors are available for SO_2, CO and O_2, but multi-component monitors for CO/CO_2; SO_2/NO_x and $SO_2/NO_x/O_2$ are also available.
     - *Fourier Transform Infra Red (FTIR) Systems*: these are essentially similar to extractive systems except that one instrument is used to monitor a variety of components, i.e. SO_2, NO_x, CO, HCl, CO_2 and O_2.

- Opacity monitoring is based on the transmissivity of projected light through the gaseous effluent; the light is attenuated by absorption and scatter and is then measured by a sensor.
- PM can be measured by a variety of techniques one of the most common being light scattering as in opacity monitoring, although acoustic and other devices are being used.

All continuous monitoring requires a data acquisition system that will include both hardware, such as a computer, monitor and printer, and software to store and manipulate the data and to provide reports.

In a study undertaken by the US EPA, the equipment costs for continuous monitoring listed in table 4 were used as default equipment costs for various techniques [5].

Table 4: Instrument and Other Capital Costs for Continuous Monitoring [5]

Equipment	**Cost, US $**		
	Extractive	In-situ	FTIR
Sampling System	45,000	1,500	42,800
Data Acquisition	20,000	20,000	16,000
FTIR Analyser	NA	NA	100,000
Sub-total:	65,000	21,500	158,800
Gaseous Compound Analysers			
- NO_x	10,440	NA	NA
- SO_2	12,500	35,000	NA
- CO	8,490	28,000	NA
- CO_2	7,890	NA	NA
- O_2	5,860	6,600	NA
- THC	10,200	NA	NA
- HCl	12,390	NA	NA
- SO_2/ NO_x	NA	37,000	NA
- SO_2/ NO_x/O_2	NA	45,000	NA
- CO/CO_2	NA	34,000	NA
Monitors			
- Opacity	25,000	25,000	25,000
- PM	37,700	37,700	37,700
- Flow	18,000	18,000	18,000
Civil works	20,000	NA	20,000
GRAND TOTAL*	**213,470**	**142,100**	**221,800**

* *Lowest cost for achieving analysis of all components in the list: note that some analytes are listed more than once in the left hand column and that, according to the 1998 table, THC and HCl are not available by in-situ techniques.*

Note also that the Extractive and FTIR systems will also need a shelter and other facilities for the unit near the stack. Additional operating costs, which are not included in the above list, would include those for maintenance of the equipment, operating personnel and, possibly, consultant and/or vendor service costs for specialist advice after the vendor contract period expires, which is normally at the end of the first year after installation.

The instrument costs given in table 5 were checked with various suppliers in South Africa.

Table 5: South African Equipment Costs for Continuous Analysis (includes costs of Sampling System and Data Acquisition)

Equipment	Average Cost, Rand	
	In-situ	FTIR
FTIR Analyser	NA	R1.1 to R1.25 million
Gaseous Compound Analysers		
- NO_x	45,000	NA
- SO_2	45,000	NA
- CO	268,000	NA
- CO_2	45,000	NA
- O_2	35,000	NA
- TOC	80,000	NA
- HCl	400,000	NA
- SO_2/ NO_x	NA	NA
- SO_2/ NO_x/O_2	NA	NA
- CO/CO_2	280,000	NA
Monitors		
- Opacity/PM	120,000	120,000
- Flow	11,000	11,000
GRAND TOTAL*	**1.02 million**	**1.23 to 1.38 million**

* *Lowest cost for achieving analysis of all components in the list: note that some analytes are listed more than once in the left hand column.*

All suppliers indicated that in-situ monitoring is more cost effective and reliable and, therefore, table 5 only gives the values for on-line monitors, where available. The data in table 5 give the average values obtained from suppliers, although the various companies sometimes gave considerably different costs for various items. For example, the cost for on-line continuous CO measurement was quoted between R 185,000 and R 350,000: the cost difference was at least partially related to the sophistication and computational power of the data acquisition, although the higher cost supplier also claimed increased reliability. While fitting of equipment during construction of an incineration plant is preferred, the actual cost of retrofitting equipment were considered by most suppliers, as being only slightly more expensive. The maintenance and operating costs for in-situ analysis is estimated at up to 15% of the equipment cost.

5. Assessment of Original Monitoring Programme

5.1 General Assessment

The proposed analyses and monitoring schedule for Gauteng given in Box 1 represent a compromise between the comprehensive requirements of the EU and the more limited requirements of the USA. Note that continuous monitoring is only required for CO and the analysis of NO_x and HF is not required: the standard programme for dioxins and heavy metals is the same frequency as in the EU regulations but both are decreased to 1 per year on the minimum monitoring requirements once a facility has demonstrated compliance for pre-determined period: this approach is used both in the US and EU. The relative costs of continuous and intermittent monitoring are discussed below.

5.2 Original Monitoring Programme: Costs

Using the data given in section 3, the costs for the proposed standard and minimum set of analyses (Box 1) are listed in table 6. To determine an annual cost for continuous monitoring of CO, an in-situ instrument is proposed, table 5, as this would be the cheapest option if one considers the much lower cost of the sampling system required and that little external facilities are required (see section 3). The capital cost has been amortised over 10 years with an interest rate of 12%: maintenance and support costs were estimated at an additional 15% per annum.

Using the figures derived in tables 4 and 5 for the total cost of monitoring and including them in assessment used in the feasibility study results in a substantial increase in cost for treatment of health care risk waste. For the standard monitoring programme, the cost increases for a 100kg/hr incineration facility from R5.98/kg to R7.64/kg, i.e. ~29%, whereas for the 500kg/hr facility, it increases from R1.30/kg to R1.50/kg, i.e. ~ 15%. The increase would be approximately half of this for the minimum monitoring programme.

Table 6: Approximate Costs for the Original Standard and Minimum Monitoring Programme

Schedule 2, Process 39 Atmospheric Pollution Prevention Act 1965 *Guidelines (DEAT)*		Proposed Monitoring Frequency (Permit conditions can vary)		
		Standard (minimum) per year	Approximate Costs Standard Analysis, R	Approximate Costs Minimum Analysis, R
Type				
Units	mg/Nm^3			
PM/dust	180	12 (4)	120 000	40 000
CO	-	Continuous	68 000	68 000
TOC	-	-	-	-
Dioxin/furan (nanogram) TEQ	0.2	4(1)	320 000	80 000
HCl	30	12 (4)	60 000	20 000
HF	-	-	-	-
SO_2	25	12 (4)	60 000	20 000
NO_x	-	-	-	-
NH_3	-	-	-	-
Pb, (same for Cr, Be, Ar, As, Sb, Ba, Ag, Co, Cu, Mn, Sn, V, Ni)	0.5	4 (1)	Included with PM	Included with PM
Cd (same for Tl)	0.05	4 (1)		
Hg	0.05	4 (1)		
Estimated Costs per annum			R628 000	R228 000

As might be expected the monitoring costs for a small incinerator are a very large proportion of the total cost of treatment of the waste: this supports the US approach, which requires an initial or compliance test for “rural” facilities and a lower annual analytical requirement than for large facilities. However, requiring no further emissions monitoring provided the facility is operated within the permit requirements may not allow sufficient control in the case of South Africa, where authorities have a much lower capacity to monitor adherence to the operating parameters.

It is useful to compare the cost of intermittent monitoring and continuous monitoring: note that the cost of undertaking 12 PM tests annually is as much as R120000. Since one is undertaking continuous measurement of CO in the proposed monitoring requirements, see Box 1, one has already installed a data acquisition system, which presumably could be used to collect data on more than one parameter. Using similar assumptions to those used for the CO monitor, the annual cost for continuous PM monitoring calculates out to only R34,500 which is significantly less than that required for 12 intermittent tests.

The other issue of concern illustrated in table 6 is the very high cost of dioxin analysis. An insistence on 4 dioxin analyses in the standard programme would cost a total of R320000.00 a year. It was considered by almost all parties that such a cost was not justified, as the actual value of the results is questionable; see section 6.

6. Final Monitoring Programme

6.1 General Assessment

Discussions with practitioners in the field have suggested that for South Africa, there should be a compromise between the very strict requirements of the EU and those of the US, because of cost implications and taking cognisance of the fact that there is limited capacity within the South African authorities to monitor the operations of the facilities.

Two of the main issues discussed were the benefits of continuous monitoring of not only CO but also acid gases such as HCl and SO_2 and particulates and the high costs of dioxin analysis.. Many South Africa practitioners were also of the opinion that the measurement of O_2 should be included in the monitoring programme, because an operator could dilute the CO by bleeding in large amounts of air, which will defeat the overall environmental objectives of the required standards. Thus, the proposed monitoring programme was revised and after many changes and permutations were considered, the final programme, which became the Gauteng Minimum Performance and Monitoring Requirements for Controlled Combustion Facilities, was devised and accepted. The programme is presented in Box 2 below: the following should be noted:

a) *Carbon Monoxide*: Continuous monitoring of CO is proposed as this species is a key dioxin precursor and therefore a continuous measure of the incinerator performance is obtained.

b) Acid Gases – Hydrogen chloride and Sulphur dioxide: The presence of significant amounts of organochlorine, such as PVC, in South African health care risk waste has been demonstrated both by evaluating the content of the waste stream and by emission measurements on existing incinerators, where values of 100 mg/Nm^3 to over 3000 mg/Nm^3 have been reported. Continuous measurement of HCl and SO_2 has therefore been included because these species are the ones that provide an indication of the efficacy of the gas cleaning equipment and have the most direct impact on the immediate surroundings.

c) *Dioxins*: Health care risk waste normally contains sufficient dioxin precursors, i.e. >1% organochlorine as PVC, and it is required internationally that a large facility measure for dioxins. However, provided continuous monitoring of the dioxin precursors, CO and HCl is required, the measurement of the dioxin/furan concentration becomes less important. Also, it must be recognised that a dioxin analysis just provides and indication of the performance of the incinerator at a single instant in time and, it highly likely that an operator will ensure his facility is performing at its best when such a measurement is made. Also, the cost of a dioxin analysis is extremely high, i.e. ~R80000.00 and it is recommended that a dioxin analysis be required during commissioning of the facility and then annually.

d) *Water*: Continuous measurement of water vapour is proposed: the data is used to present the CO and O_2 values on either a wet or dry basis. For most equipment, the CO monitor will measure this additional parameter.

e) *Heavy Metals*: Most heavy metals are associated with the particulates, but because of the importance of the amounts of heavy metals present the facility is expected to demonstrate compliance during commissioning of the facility and then a further four times in the first year. The facility operator may then apply for a reduction of the monitoring frequency provided compliance can be demonstrated but a minimum of one analysis for heavy metals is required per year.

BOX 2 Gauteng Emission Guideline Standards		
Type	Maximum allowable emission to air from controlled combustion treatment facilities (Daily average values)	Monitoring frequency samples per year: Standard (reduced after period of compliance)
Units	mg/Nm^3	
PM/dust	180	Continuous
CO	50	Continuous
Dioxin/Furan (nanogram) TEQ	0.2	1
HCl	30	Continuous
HF	-	-
SO_2	25	Continuous
NO_x	-	-
NH_3	-	-
Pb (same for Cr, Be, Ar, As, Sb, Ba, Ag, Co, Cu, Mn, Sn, V, Ni	0.5	4(1)
Cd (same for Tl)	0.05	4(1)
Hg	0.05	4(1)
Reference Conditions and Definitions	11% O_2, 273 Kelvin, 101.3 kPa. All parameters to be defined and measures as in Directive 2000/76/EC of the European Parliament and Council of 4 December 2000 on Incineration of Waste	

f) *Operating Parameters*: The actual operating parameters that must be monitored will vary depending on the type of incineration facility. The following parameters are typical but not necessarily exclusive of those that may be required by the Department:

- Incinerator
    - Waste Charge Rate, average mass of waste treated per hour of operation
    - Secondary Chamber Temperature (continuous)
    - Ash – loss on ignition (monthly)
- Wet Scrubber
    - pH of scrubber liquor (continuous)
    - Scrubber Liquor Dose or Flow Rate (continuous)
    - Flue Gas Temperature (continuous)
- Dry Scrubber
    - HCl Absorbent Flow Rate (continuous)
    - Fabric/Ceramic Filter Inlet Temperature (continuous)

6.2 Final Monitoring Programme: Estimated Costs

The costs based on the final programme given in BOX 2 are presented in table 8, below. The costs for continuous monitoring were calculated, as in section 4: the capital cost is amortised over 10 years with an interest rate of 12% with maintenance and support costs estimated at an additional 15% per annum. Note that the costs for monitoring the standard operating parameters, e.g. flue gas temperature; absorbent flow rate, etc. are not included in the cost estimates in table 8. The costs were determined at the end of 2002, so may have changed due to the variability in the Rand. However, they provide an indication of the amounts required and the relative costs between the various monitoring frequencies.

Table 8: Final Monitoring Programme: Estimated Costs

	Costs, R		
Tests	Performance Testing	First Year of Operation	Second and Subsequent Years (conditional)
PM/dust	*	34,500	34,500
CO	*	68,000	68,000
Dioxin/furan (nanogram) TEQ	80,000	80,000	80,000
HCl	*	100,000	100,000
SO_2	*	11,500	11,500
Heavy metals	10,000	40,000	10,000
TOTAL	90,000	231,500	201,500
* Costs already included as continuous monitors fitted.			

The total monitoring costs in the first year of operation are estimated from table 8 at R291,500, including performance testing, and in subsequent years, provided the facility meets the requirements, at R201,500. These figures should be compared with those in table 6, for the original proposed monitoring programme of R628,000 and R228,000, respectively. The cost of the final programme during the second and subsequent years has not changed significantly, but the increase in continuous monitoring allows the authorities to assess the ability of the facility to continuously meet the required standards not just intermittently during the year.

7. Comparative Costs of the Monitoring Programmes

In the feasibility study certain fixed amounts were allowed for monitoring and testing on incinerators, i.e. an equipment cost of R150,000 and R80,000 for dioxin and other on-site costs. In order to get a better comparison of the impact of monitoring costs on the overall cost of treating health care risk waste, the values derived in tables 6 and 8, were used to calculate the treatment cost per kilogram for incinerators ranging from 100kg/hr to 1000kg/hr and the results are presented in table 9. Note that the scenario assumes that the incinerators are all working at full capacity for 20 hours per day and 26 days per month.

Table 9: Cost per kilogram of waste treated: Original and Final Monitoring Programmes

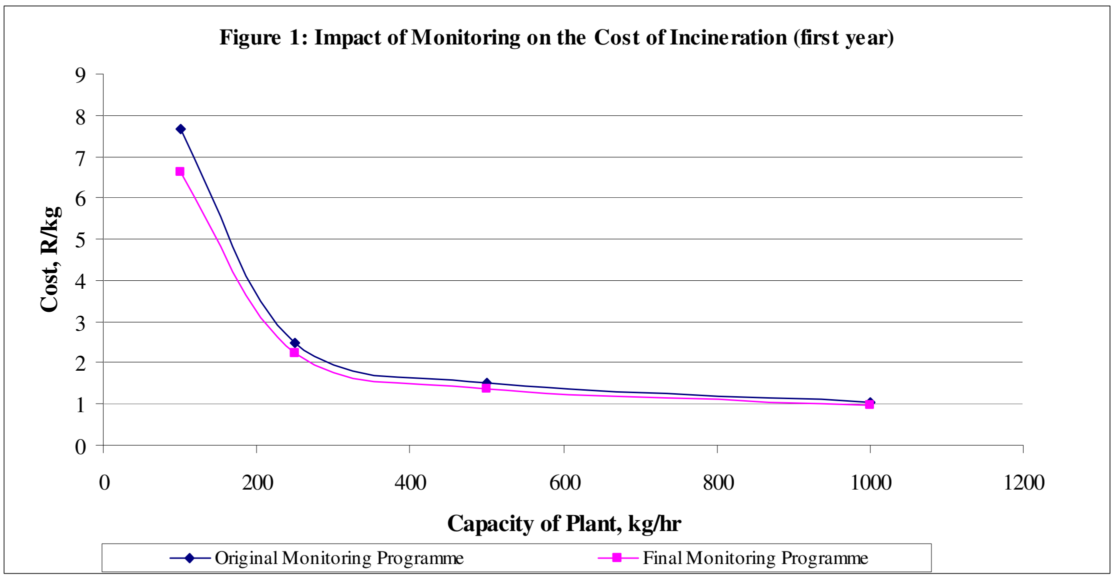
	Original Programme, R/kg	Final Programme, R/kg
First Year		
100 kg/hr	7.65	6.62
250kg/hr	2.50	2.25
500kg/hr	1.50	1.38
1000kg/hr	1.03	0.97
Second & Subsequent Years (conditional)		
100 kg/hr	6.31	6.22

250kg/hr	2.18	2.16
500kg/hr	1.34	1.33
1000kg/hr	0.95	0.95

The data in table 9 show that:

a) In the first year, which includes the performance testing phase, the costs are higher for the original programme than the final programme. However, as expected the impact of the monitoring requirements is significantly greater for the smaller incinerators with a capacity of less than 250kg/hr. The larger the capacity of the incinerator, the lower the impact of the monitoring costs, such that for an incinerator with a capacity of 1000kg/hr, the difference is only 6c per kg treated. The total costs for the first year are also illustrated graphically in figure 1.

b) For the second and subsequent years, the difference in the monitoring costs for the original and final programmes is very small and, therefore, the cost per kg of waste treated given in table 9 is essentially the same for both programmes.



The incinerators that are currently operating in Gauteng are listed in table 10: the approximate cost of monitoring in the second and subsequent years is presented and, since the cost of the two programmes are essentially identical only one set of illustrative costs covers both programmes.. Note that as expected, the lower the throughput on the incinerator, the higher the cost.

Table 10: Current Incinerators and the Estimated Annual Cost of Monitoring – Original and Final Programmes: *Second and Subsequent Years*.

Type of Incinerators	**Nominal Capacity**	**Actual Capacity**[1]	**Estimated annual cost of monitoring**	
	kg/h	Tons/month	R/year	R/kg/yr
Commercially Operated:				
SanuMed, Roodepoort, #1, #2, #3	1050	320	604,500	0.16

SanuMed, Rietfontein, #1, #2	400	140	403,000	0.24
Pikitup	350	80	201,500	0.21
Clin-X #1, #2 (not yet operational)	400	150	403,000	0.22
Clinical Waste Management (not yet operational)	140[2]	37	201,500	0.45
On-site facilities				
Approx. 58 plants operation	-	280	11,687,000	3.48
Totals		**1007**	**13,500,500**	

1. Actual capacity as reported in Gauteng HCRW Project Phase 1.
2. The capacity of the Clinical Waste Management facility was checked with company representative, i.e. 1.4 tons per 10hr cycle.

Clearly, the cost of monitoring has the greatest impact on the smaller incinerators particularly those with a capacity of 100kg/hr or less, which because of their lower capacity are the ones that provided they are operated efficiently would be expected to have a lower impact on the environment. Note that the US EPA does not require small incinerators, i.e. <91kg/hr, to operate a stack gas monitoring programme except during the initial or performance testing phase. This is at least partly due to the high costs of such a programme. Clearly, the correct siting of these small incinerators is essential to ensure that they have an acceptable impact on human health and the environment.

8. Reporting Requirements

The analytical data on the emissions and the required operating parameters must be supplied in regular reports to the DACEL: the actual requirements for a particular facility will be included in the Record of Decision. The report should be prepared or, at least, approved by a laboratory and/or an independent consultant and include copies of the original certificates of analysis from the laboratory plus examples of the print outs from continuous monitoring equipment. The report must list all instances of emissions that exceed the required standards and provide an explanation for these transgressions: a satisfactory programme for preventing further exceedences must be included. Note that the report, which must be submitted after the performance testing phase, is required before the Department can give final acceptance of the EIA and, hence, permission for operation of the facility.

9. Conclusions

The following conclusions can be drawn from this study:

a) The original monitoring programme proposed in the health care risk waste policy document has been evaluated and has been replaced by the final monitoring programme, which emphasises the continuous monitoring of particulates, CO, HCl and SO_2 in the stack emissions and periodic monitoring of heavy metals dioxin. The final programme has the significant advantage that it allows the authorities and the facility to more carefully monitor performance on a continuous basis, while it is in operation.

b) The cost of performance monitoring using the final monitoring programme is significantly reduced compared to the original monitoring programme.

c) The monitoring requirements can be reduced by the Department providing the facility has demonstrated that it can meet the required emission standards during the first year. The costs of monitoring in the second and subsequent years in both programmes, are virtually identical

d) The requirement for gas monitoring will clearly have the greatest impact on smaller incinerators: for example for the current small scale on-site incinerators operating at hospitals and other institutions in Gauteng, the cost per kilogram of waste treated could be as high as R3.48/kg. The impact on the larger commercial incinerators that are currently operational in Gauteng would only amount to between 16c and 48c per kilogram.

e) As can be seen from table 9 and figure 1, the overall cost of operating a small incinerator of ≤100kg/hr can be more than 7 times that of an incinerator with a capacity of ≥1000kg/hr, which makes it extremely expensive. Where possible large regional facilities with gas cleaning and the proper monitoring procedures should be used, as they are more cost effective and have a lower overall impact on the environment.

10. References

[1] Baldwin D A and Godfrey L, Evaluation of the Efficacy Monitoring Requirements for Non-Burn HCRW Treatment Facilities, April 2003

[2] Gauteng Health Care Waste Management Policy, November 2001

[3] US EPA: Technology Transfer Network – Air Toxics Website, Fact Sheet: Hospital/Medical/Infectious Waste Incinerators: Promulgated Subpart Ce Emission Guidelines – URL: http://www.epa.gov/ttn/atw/129/hmiwi/factseg.html

[4] European Union, Directive 2000/76/EC of the European Parliament and of the Council, 4 December 2000: Incineration of Waste

[5] US EPA: Continuous Emission Monitoring System, Cost Model, Version 3, 1998

Acknowledgments

The following were experts consulted during the development of this report:

- Mr Chris Albertyn, C & M Consulting Engineers
- Dr Brian Cowan, CSIR Bio/Chemtek
- Dr Christos Eleftheriades, Coal and Waste Utilisation Technologies
- Mr Mike Turnbull, S I Analytics