Response to the Consultation on a National Policy Development Process For High Temperature Thermal Waste Treatment

By

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For

GroundWork South Africa

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"*High costs, limited infrastructure, and the composition of the waste stream suggest that incineration is an inappropriate technology for most African cities*." UNEP 2005 (United Nations Environment Programme and Calrecovery Inc 2005)

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Summary

There can be little doubt that the development of a comprehensive policy on hazardous waste production and management is an urgent and essential requirement for South Africa.

It is disturbing, however, to see that the current consultation and most of the associated reports appear to have been developed in a policy vacuum and have tenuous, if any, links with the emerging waste policy framework in South Africa. No explanation is offered for the failure to do this and it is assumed that the reason is largely related to the appointment of external consultants with little knowledge of the previous developments.

An alternative, possibly less charitable explanation, would be that such linkages would highlight the failure of DEAT to deliver on previous promises and deadlines.

It is important to recognise these failures, however, as they are indicative of some of the problems of developing an appropriate policy, legislative, regulatory and operational framework for wastes where little or none currently exists. The over-optimistic projections made at the end of the last century risk being repeated - but with possibly greater environmental damage and with greater risks to the credibility of the administration, if the current rush to sanction thermal treatments is not appropriately tempered with the reality of the current capacity for effective regulation and control.

The evidence indicates that the environmental costs of landfill and incineration are broadly similar but the social costs of incineration are much higher because of the higher capital costs. Therefore, rather than place such strong emphasis on incineration and thermal treatment at this stage, it is strongly recommended that DEAT should focus on longer term and more sustainable solutions. Priority should be given to waste minimisation and implementation of the Zero Waste declaration made at Polokwane in 2001.

This submission is divided into a several Annexes dealing with different aspects of the consultation documents. At attempt has been made to make each of these relevant to the formulation of appropriate policy and the emphasis has been on the policy development issues rather than the technical assessment of the consultation documents and literature reviews. Inevitably, however, elements of the submission have been drawn into more technical discussions.

The Existing Policy Framework and Context:

The recent historical legacy of the incineration in the US, Japan and Europe – where serious contamination has been caused through high emissions to atmosphere and careless handling of ash residues could all too easily be repeated in South Africa. The cost to the waste management industry of overcoming those problems in the developed world has been enormous – both financially and in loss of credibility and public goodwill. According to

Lukey et al., (Lukey, Brijlall et al. 2004) and Seeliger et al. (Seeliger, van der Westhuizen et al. 2003) the South African government has been perceived to be unwilling and/or unable to enforce pollution and waste-related legislation (Godfrey and Nahman 2007). It is vital that South Africa in this late rush to make apparent progress should learn from these mistakes.

In 1999 the National Waste Management Strategies and Action Plan (South African Department of Environmental Affairs and Tourism (DEAT) 1999) laid out the "immediate objectives" which were to be achieved by implementation of this Action Plan over the period July 1999 to December 2004. These objectives included the development of first generation integrated hazardous waste management plans which were to be developed by the provincial environmental departments and reviewed by national government within the period 2002 to 2004. The plan required that municipalities to finalise their IWMPs by 2003 and that they "will be ready for implementation in January 2005".

Yet Godfrey (Godfrey and Nahman 2007) reports that as at mid-2005, only 58.3% of municipalities who responded to their questionnaire had completed, or were in the process of completing, an IWMP. Of those municipalities that have completed IWMPs, many of these documents are in fact only Status Quo Analyses, a first step towards IWMPs.

A review of capacity assessments of local municipalities in South Africa (Municipal Demarcation Board 2005) indicated that 59.7% of municipalities could not fully perform their waste management functions as assigned to them under legislation, due principally to insufficient budgets, insufficient staff and insufficient equipment.

The development of waste policy in South Africa has been closely followed and recently reviewed by Godfrey (Godfrey and Nahman 2007)
The findings of on-going research conducted within South Africa on waste policy instruments shows that while typical command-and-control instruments lack effective monitoring and enforcement, alternative policy instruments such as economic or information based strategies, are either slow to find favour or fail soon after implementation.

Developing countries, such as South Africa, face a number of challenges to the successful implementation of alternative, first world, waste policy instruments including institutional challenges (financial and human resources); insufficient political support; an unsupportive legal environment; lack of clarity regarding the role of government and the intention of policy, leading to a lack of ownership and to ineffective policy; and a lack of supporting data.

These challenges do not, however, imply that there is no place for such instruments in developing countries. Instead, what is needed in the implementation of waste policy instruments in developing countries is a stage- based, tailored approach, which takes cognisance of identified challenges in their design and implementation, thereby recognising the realities of developing country circumstances. There is no evidence that this approach has been adopted in the current consultation documents nor is there any obvious recognition of the fundamental importance of the range of policy instruments that are required if an holistic waste strategy, with emphasis on reduction and elimination is to be implemented. The likely outcome of the current approach would be piecemeal approval and authorisation of incinerators and cement kilns without any coherent strategy for optimising regulatory control or minimising environmental impacts. A more sensible strategy would be to develop the country specific framework for the implementation of the full range of necessary policy instruments focussing on collecting useful and reliable waste data and minimising any residual wastes for treatment.

An ideal policy foundation for the development of these tools arose in 2001. The South African, Polokwane Declaration on Waste Management of September 2001 set a goal, to ''Reduce waste generation and disposal by 50 and 25%, respectively by 2012 and develop a plan for ZERO WASTE by 2022''. (Department of Environmental Affairs and Tourism (DEAT) 2001) This provides a great opportunity to divert the Policy thrust away from this history of failure of 'command and control' regulatory and legislative developments.

The Polokwane Declaration also reaffirmed a commitment to the Integrated Pollution and Waste Management Policy, the National Waste Management Strategy and the principles of waste minimization, reuse and recycling for sustainable development.

The essential difference in this approach to that promulgated previously is that it is intrinsically sustainable, safe and precautionary. Instead of promoting an ultimately futile programme of risk management with inadequate resources the vision encapsulated in the Polokwane Declaration is to eliminate 'hazard' and thus reduce residual risks to near zero. This is an ambitious goal but, given the failures to implement an effective regulatory policy to date, it is probably the only option which can be truly protective and consistent with the requirements of the Constitution. Furthermore it promises to allow South Africa to avoid the expensive and damaging mistakes of Europe and the USA.

The development of any strategy for Hazardous Wastes treatment and disposal should, in any case, be in accordance with the provisions of the National Implementation Plan ('NIP') for the Stockholm Convention[1]. Unfortunately South Africa has not yet submitted such a plan even though the deadline was 17th May 2006[2]. This is another powerful reason to delay the development of this incineration-oriented strategy.

The 2000 White Paper on Integrated Pollution and Waste Management for South Africa (Republic of South Africa Department of Environmental Affairs and Tourism (DEAT) 2000) recognised:

"the fragmented and uncoordinated way pollution and waste is currently being dealt with, as well as the insufficient resources to implement and monitor existing legislation, contributes largely to the unacceptably high levels of pollution and waste in South Africa".

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[1] In spite of receipt of a GEF grant of $499,000 for this work http://www.gefonline.org/projectDetails.cfm?projID=1785

[2] http://www.pops.int/documents/implementation/nips/submissions/default.htm

It went on to promise:

"This White Paper will implement co-operative governance as envisaged by the Constitution. The current fragmentation, duplication and lack of co-ordination will be eliminated."

The current consultation, which is set largely in a data and policy vacuum, can only hinder the implementation of that promise

Current Policy Towards Open Burning of Waste:

Open burning of wastes remains a problem in South Africa and whilst the Department technically prohibits the burning of waste at landfill sites they still permit it in certain circumstances and, indeed, give guidance about how it should be done (Republic of South Africa Department of Water Affairs and Forestry (DWAF) 1998).

There is no doubt that open burning of this type is the cause of serious environmental pollution (Lemieux 2002; Lemieux, Lutes et al. 2004; UNEP 2005) and should be prohibited without exceptions.

Annex 1 – Waste Arisings

Summary: The formulation of appropriate policy for the reduction, treatment or disposal of wastes absolutely requires that good information is collected on waste arisings, distribution and composition. The consultation documents and literature reviews fail to do this.

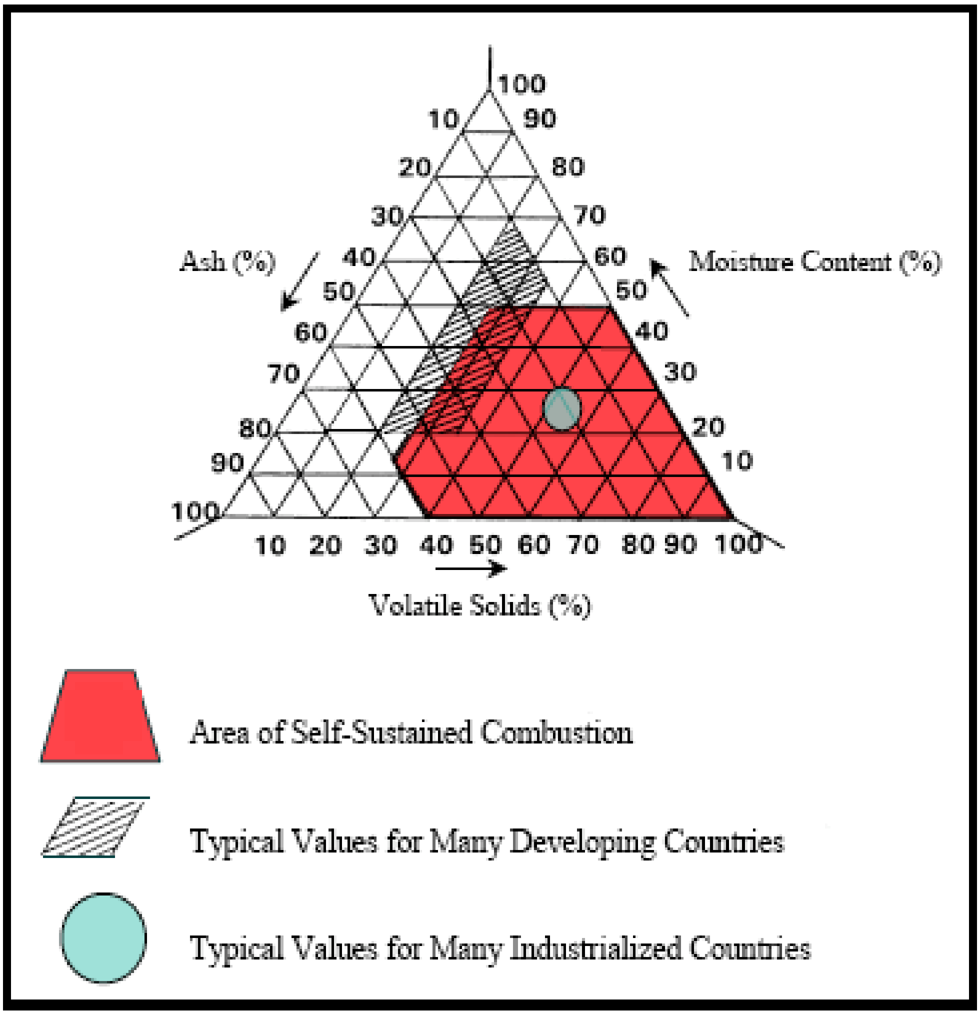
The dictum *"If you can't measure it then you can't manage it"* is particularly true in relation to waste management. This is true both for waste minimisation and for planning and regulating disposal capacity. The Holcim GTZ guidelines (Holcim and GTZ 2006), for example, say:

"Cement plant operators must know the quantity and characteristics of the available wastes before applying for a permit for co-processing."

Furthermore UNEP (United Nations Environment Programme and Calrecovery Inc 2005) emphasises that "*Waste characterisation surveys … should be carried out to collect information on generation rates, physical composition, bulk density, and storage indicators. Physical and chemical characteristics of the wastes, such as calorific value and chemical composition, are determined through laboratory analyses. If these types of data are required, it is important to determine the capabilities and experience of the laboratories such that reliable data are obtained.*" Clearly this cannot be done in detail for the whole of South Africa but it is disappointing to see that the consultation documentation includes none of this information.

Without such data it is not possible to have any confidence whatsoever about the proportion of the waste stream which may be suitable for incineration. The World Bank (Rand, Haukohl et al. 1999) says, for example, that "*the average lower calorific value of the waste must be at least 6 MJ/kg throughout all seasons. The annual average lower calorific value must not be less than 7 MJ/kg.*"

UNEP confirms (United Nations Environment Programme and Calrecovery Inc 2005) that even <u>urban</u> wastes generated in developing nations can be approximately 50% to 70% putrescible on a wet weight basis and that the quantities of discarded paper and plastics are relatively small. Therefore, the overall percentage of dry, combustible (volatile) matter is small. Additionally, the ash content of urban wastes in some locations in developing countries can be substantial (e.g., up to 60% where wood ash, coal ash, or both are major waste by-products of domestic activities). The combination of these attributes of the wastes, UNEP says, "*can render the waste conversion system as a net user of energy, as opposed to a net supplier…The upshot of this situation is that incineration and thermal processing in general for energy production may not be applicable to a developing nation, or may be feasible only in certain locations or under special conditions*". This is demonstrated graphically on the Tanner diagram below. Much of the current waste stream in South Africa is likely to be found in the shaded area and thus outside the parameters of self-sustaining combustion – or at best where self-sustaining combustion is only marginal (and possibly seasonal):



Comparison of the thermal characteristics of MSW and those required for self-sustained combustion
(United Nations Environment Programme and Calrecovery Inc 2005)

We have therefore reviewed the available literature on waste arisings and composition in an effort to establish if there is sufficient information available upon which to base the proposed policy developments.

The 1999 Action plan for Integrated Waste Management Planning says that annual reporting of waste generation in South Africa is a legal requirement – but that it was not then undertaken. There is little evidence that this has changed though several isolated attempts to quantify waste generation in South Africa have been carried out by DEAT and DWAF.

Karani (Karani and Jewasikiewitz 2007) recently published total South African waste arisings for 1992 and 1997:

TABLE I. Waste generation rates in South Africa in 1992 and 1997.[a]

Waste stream	1992 (CSIR study)	1997
Mining	378.0	468.2
Industrial	23.0	16.3
Power generation	20.0	20.6
Agriculture and forestry	20.0	20.0[b]
Domestic and trade	15.0	8.2
Sewage sludge	12.0	0.3
Total	468.0	533.6

[a]This table provides information extracted from a study on waste generation rates in million tons per year in South Africa in 1992 and 1997. The study was conducted by Center for Scientific International Research (CSIR).

Theron (Theron 2005) appears to have used the 1992 breakdown of waste arisings to allocate the hazardous proportions:

Source	Qty	% of Total	Hazardous Portion (tons)
Mining	377	80.3	1,05
Industrial	22	4.7	0,81
Power generation	20	4.3	0,01
Agriculture	20	4.3	0,13
Domestic and trade refuse	18	3.8	0,13
Sewage sludge	12	2.6	0,13
Total	**469**	**100**	**2.26 = +/- 0.5 %**

There may be some difficulty in assessing hazardous waste arisings because of historic difficulties in defining hazardous waste. This is a common problem in countries with relatively recent legislative programmes and makes inter-country comparison of arisings particularly difficult. In the current Waste Management Bill (Republic of South Africa Minister of Environmental Affairs and Tourism 2007) the definition is still rather loose:

"Hazardous waste" *means any waste that contains organic or inorganic elements of compounds that may, owing to the inherent physical, chemical or toxicological characteristics of that waste, have a detrimental impact on health and the environment;*

There is, however, a useful set of guidance (Republic of South Africa Department of Water Affairs and Forestry 1998) – although this was apparently to be updated by 2006 and yet no revision seems to have been published yet. The Water Research Council publication (Brice, Sevitz et al. 2006) on hazardous waste categories is helpful and should assist with improved hazardous waste assessment in future.

A follow up study commissioned by DWAF as part of the baseline study for the National Waste Management Strategy estimated the total production of waste in 1996 to be 566 million tonnes per year, with the majority of waste, 464 million tons (82%), being generated by the mining sector. It is notable that industrial, domestic and sewage sludge wastes are very much lower in this later survey. It is suspected that this is due to the errors and uncertainties associated with the surveys rather than being due to the success of waste minimisation initiatives.

The total waste generation in South Africa appears to be approximately 14.5 tonnes per capita per year. However the 1999 Action plan for Integrated Waste Management Planning warned that estimates of per capita generation rates vary considerably between the local authorities, depending on the composition of the waste and the socio-economic status of the community.

Karani et al (Karani and Jewasikiewitz 2007) estimated that the national average waste generation rate at 0.8 kg/capita/day for more developed areas and 0.3 kg/capita/day for less developed areas of South Africa. Service coverage estimates are around 80% for urban kerbside coverage (100% in more formally developed areas and 65% in less formally developed areas). Coverage in rural areas is sometimes very low and Karani quoted one estimate putting it at just 35%.

Collection and transfer efficiency is also low compared to developed countries' standards. Waste disposal in South Africa is mostly in landfills, but it is estimated that only 10% of landfills are managed in accordance with the Minimum Requirements (Department of Water Affairs, 1998).

The above studies show that industrial waste may amount to between 16 and 23 million tonnes per year. General waste arising from domestic activities, commerce and trade, secondary industrial operations and littering amounts to 12 million tonnes per year.

Waste generated by domestic households and trade is estimated to be between 8 and 15 million tonnes per year, with hazardous waste generation being very uncertain but possibly of the order of up to 2 million tonnes per year of which more than half arises from mining. The great majority of this hazardous waste is therefore unlikely to be suitable for thermal treatment.

A potentially useful breakdown of hazardous waste by general class and region of production was provided by Gibb in work for DEAT (Arcus Gibb for Department of Environmental Affairs & Tourism (DEAT) 2003). The results are presented at the end of this section though should be noted that they are reported in volumetric form. It appears from this data that about half the hazardous waste in South Africa arises in Guateng and that about 150,000 to 200,000 tonnes may currently be disposed of to landfill. COWI (Lauridsen 2007) say "*it is estimated that Republic of South Africa has at least 80,000 tonnes of organic hazardous waste*" and go on to suggest that this would justify the construction of an hazardous waste incineration plant "*should technology be found to be acceptable in the country*". Yet this claim is not referenced and no indication of the distribution of the wastes, the type of waste or possible alternative treatments is given.

Karani et al (Karani and Jewasikiewitz 2007) estimated arisings for 2010 as:

TABLE II. Summary of provincial general waste generation predicted for the year 2010.

Province	Predicted total waste	
	m^3/year	t/year
Eastern Cape	3 105 989	802 090
Free State	3 877 380	745 535
Gauteng	26 085 304	4 207 608
Kwa-Zulu-Natal	5 749 959	1 437 762
Mpumalanga	11 200 387	1 783 766
Northern Cape	956 369	191 669
Northern Province	2 374 864	623 678
North West	2 296 489	542 135
Western Cape	12 979 785	2 129 647
Totals	68 626 526	12 463 890

It is notable that this waste, assumed to be domestic and trade waste is still significantly lower than predicted by CSIR for 1992. The data does not appear to take into account the targets set following the Polokwane declaration (Mvuma 2005), as described in the summary and below. COWI (Lauridsen 2007), however, estimate that current municipal waste arisings are "*about 15 to 18 million tons*". The reference for this seems to be the Gauteng State of the Environment Report 2004 (Gauteng Department of Agriculture Conservation Environment and Land Affairs 2004) which says:

"*The Gauteng preliminary SoER indicates waste generated from households and requiring collection and disposal in Gauteng as roughly 146 kg/capita/annum (ranging from half that for the poorest and twice that for the most affluent). Extrapolating to a projected population for Gauteng for 2003 of 9 013 900, (population growth of 2 % since 2001 census and a 10 % increase in waste generation per capita, as identified by the Johannesburg Status Quo Report in 2003), waste generation of approximately 480 kg/capita/annum is estimated*".

It appears that there has been either a typo or a mistake in these calculations, as even with such high growth rates 146 kg/capita/annum does not result in annual arisings of 480 kg/capita/annum. It seems more likely that the result should have been 180 kg/capita/annum. 480 kg/capita/annum would put the waste arisings higher than New Zealand, Korea, Portugal etc as shown in a table from the report:

Table 9.1 Waste generation rates in selected countries (kg/capita/annum)

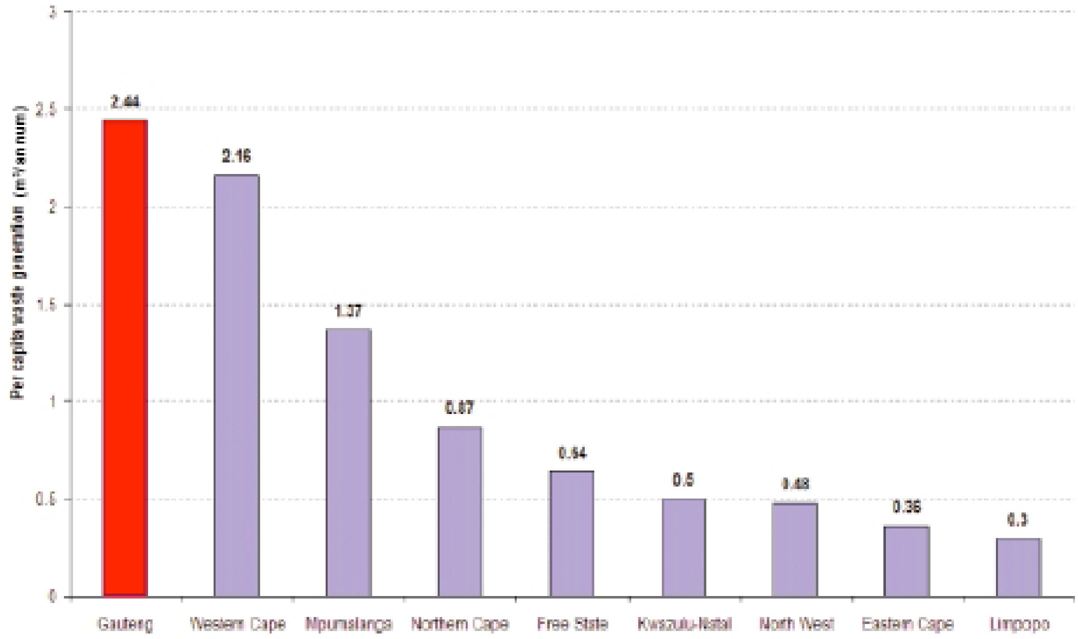
Country	Generation Rate (kg/capita/annum)	Country	Generation Rate (kg/capita/annum)
Australia	690	Japan	410
Austria	560	Korea	360
Belgium	550	Mexico	310
Canada	350	Netherlands	610
China	380	New Zealand	380
Denmark	660	Norway	620
Finland	560	OECD countries	540
France	510	Poland	260
Germany	540	Portugal	350
Hungary	450	Russia	340
Ireland	560	Sweden	450
Israel 700		United Kingdom	560

Source: OECD Environmental Data Compendium Feb 2004

According to the mid-2007 estimates from Statistics South Africa[3], the country's population stands at some 47.9-million, up from the census 2001 count of 44.8-million. Therefore even assuming that the whole country generated waste at 180 kg/capita/annum this would result in a total arisings of 8.6 million tonnes which is very close to the 1998 estimates above.

The data urgently needs validation because the Guateng report shows the 1998 distribution of arisings and shows an implausible factor of eight variations across the country which indicates that the assessment has not been carried out consistently:

[3] http://www.southafrica.info/ess_info/sa_glance/demographics/population.htm



Source DWAF, 1998

Figure 9.1 Provincial per capita generation of general waste

It is very likely therefore that the COWI estimates of MSW arisings are not reliable.

It must be noted that estimates of waste arisings alone, even if accurate – and that seems unlikely in this context, not least for the reasons discussed above and because in spite of the large discrepancies between the 1992 and 1997 surveys they have not been updated with more recent results – are a poor indication of the wastes requiring treatment.

As an example an inventory assessments prepared to support the development of a Hazardous Waste Incinerator in Alberta, Canada, showed hazardous waste generation to range between 100,000 and 200,000 tonnes per annum (McQuaid-Cook and Simons 1989). Subsequent studies, however, revealed that up to 80% of this amount was recycled, treated on the site of generation, or sent out-of province for treatment and disposal. A more detailed analysis, such as in the Canadian case, can make a dramatic difference to the need for, and apparent economics of, a new incineration or treatment facility.

Only very crude data on levels of treatment seem to be available for South Africa (and none is provided in the consultation documents) but it is clear that much of the waste is recovered rather than disposed of. Theron (Theron 2005), for example, suggested that the levels of recovery were up to 38.7% for paper and board:

Type of Material	Total tonnage produced	Tonnage converted into packaging	Tonnage recovered	% of Total
Paper and board[2]	1 990 000	868 000	770 000	38.7
Plastics [3]	923 000	465 000	133 000	14.4
Tinplate	263 000	263 000	121 000	46.0
Glass[4]	521 000	509 000	102 500	19.7
Total	**3 697 000**	**2 105 000**	**1 126 500**	**30.5**

Temporal data for recycling are provided by Matete (Matete and Trois 2007) which appear to show that recovery rates rose to a very high 89% for paper and board by 2000:

Table 1
Statistics on recycling in South Africa

Product	Percentage recycled				
	1991	1992	1998	2000	Average
Paper and board	28.4	29	38	89	46
Plastics	14.8	11	12	29	17
Tinplate	26.3	21	67	46	39
Aluminium	29.6	36	45		
Glass	22.4	14	12.6	20	17
Average	24.3	22.2	34.9	46.0	30

Sources: Lombard (1997), Wiechers et al. (2002), Ridl (2003), Hugo (2004).

A possibly more realistic assessment of 40% by 2000 and 51.9% by 2002 is included in a recent paper by Karani et al (Karani and Jewasikiewitz 2007) :

TABLE IV. Percentage of recycled materials 1990–2002.

Category	% Recycled by year					
	1990	1992	1994	1996	2000	2002
Paper	29.0	28.4	38.0	38.0	40.0	51.9
Metals	21.0	26.3	29.9	51.0	40.8	63.5
Plastic	11.0	14.8	17.0	17.0	11.9	25.5
Glass	14.0	22.4	19.4	17.6	19.5	28.9

Source: Packaging Corporation of South Africa (PACSA) 2005.

Karani comments that the private sector is "*doing a lot more in the waste management sector especially in recycling. This is done because of the incentives and existing demand from the packaging industry that to some extent has to comply to international standards that require the industry to meet certain environmental criteria*".

Further "*At grassroots level there are ad hoc initiatives through NGOs and CBOs that encourage waste separation and recycling to generate income and employment for poor communities and contribute to cleaning up of the environment*".

Issues of concern and lessons that were identified and "*require significant attention in development of Integrated Waste Management Planning*" include:

- Recognition and support of community waste management and servicing
- The need to enhance private and public sector partnerships in waste management initiatives.
- Support to capacity building (which "*is critical to strengthening institutions and legislative framework that would encourage effective waste management systems*")

These issues should be considered as priorities for DEAT.

It is noted, by way of comparison, that in Europe hazardous waste generation increased by 13% between 1998 and 2002 to 58.4 million tonnes, i.e. 129 kg per capita, whilst gross value added grew by 10% (Commission of the European Communities 2005). This is particularly worrying because it demonstrates that the increase in hazardous waste is growing faster than the value added. It also shows that in most countries the link between economic activity and hazardous waste generation has not been broken – though there are exceptions.

The management of this waste costs €10 billion to €25 billion per year (CEC 2005 Op Cit) – at that price the cost of hazardous waste management in South Africa would be €342 to 856 clearly demonstrating the financial advantages of pursuing the waste minimization and elimination route described below.

Summary of Hazardous Waste by Region (m^3/annum) (Arcus Gibb for Department of Environmental Affairs & Tourism

	E Cape	Free State	Gauteng	KZN	Mpuma	N Cape	N Prov	N West	W Cape	TOTAL
Class 3: Flammable liquids	16 413	5 532	37 427	18 024	7 989	859	1 303	1 622	36 002	125 171
Onsite/other disposal	82	55	1 307	467	6 297	10	20	27	276	8 541
To Hazwaste site	16 331	5 477	36 120	17 557	1 692	849	1 283	1 595	35 726	116 630
Class 4: Flammable Solids	505	2 075	15 665	1 164						19 409
Onsite/other disposal		1 175								1 175
To Hazwaste site	505	900	15 665	1 164	0	0	0	0	0	18 234
Class 5: Oxidising Substances			3 632	186						3 818
Onsite/other disposal			40							40
To Hazwaste site	0	0	3 592	186	0	0	0	0	0	3 778
Class 6: Poisonous and infectious	16 395	2 913	28 216	159 751	1 203	217	4 326	1 485	24 754	239 260
Onsite/other disposal	15 672	1 210	14 926	140 240	1 159	202	4 303	1 468	7 435	186 615
To Hazwaste site	723	1 703	13 290	19 511	44	15	23	17	17 319	52 645
Class 8: Corrosives	2 676	3 582	29 576	6 254					4 020	46 108
Onsite/other disposal	1 338		11 391	3 190					2 007	17 926
To Hazwaste site	1 338	3 582	18 185	3 064	0	0	0	0	2 013	28 182
Class 9: Misc Dangerous	1 599	16 428	1 674 127	1 495 555	3 407 681	73	185	277	215 111	6 811 036
Onsite/other disposal	777	13 383	1 592 221	1 493 141	3 406 494				193 383	6 699 399
To Hazwaste site	822	3 045	81 906	2 414	1 187	73	185	277	21 728	111 637
ALL CLASSES	37 588	30 530	1 788 643	1 680 934	3 416 873	1 149	5 814	3 384	279 887	7 244 802
Onsite/other disposal	17 869	15 823	1 619 885	1 637 038	3 413 950	212	4 323	1 495	203 101	6 913 696
To Hazwaste site	19 719	14 707	168 758	43 896	2 923	937	1 491	1 889	76 786	331 106
Medical Waste (Part of Class 6)										
No of Hospital Beds	20 880	9 467	34 864	30 922	5 332	3 102	13 139	9 405	17 893	145 004
% Occupancy	80	70	80	80	80	70	80	70	80	
Waste Generated	11 853	4 702	19 790	17 553	3 026	1 547	7 458	4 671	10 167	80 767

(DEAT) 2003):

Note: Classification is in accordance with the *Minimum Requirements for the Handling, Classification and Disposal of Hazardous Waste,* Department of Water Affairs and Forestry, Second Edition 1998

Annex 2 - Waste Management Policies[4]

The main objective of the NWMS (Brice, Sevitz et al. 2006) is the reduced generation and environmental impact of all forms of waste, so that the socioeconomic development of South Africa, the health of its people, and the quality of its environmental resources are no longer adversely affected by uncontrolled and uncoordinated waste management. It is not clear quite how the current consultation links with that main objective or what is added to the existing waste Management Policy in South Africa which already incorporates many of the key tools which have provided the foundations for, for example, European Policy development in the EU "Waste Framework Directive". These include:

The Waste Hierarchy

It is only as recently as 1998, that the South African Department of Environmental Affairs and Tourism (DEAT) introduced the concept of waste hierarchy (Reduce – Reuse –Recover – Dispose) into the environmental legislation through the National Environmental Management Act (No. 107) (Matete and Trois 2007).

Emphasis should clearly be on waste reduction. FAO (Helps 2007) say "*Initiatives such as waste minimisation and cleaner production will allow these industries to avoid the repetition of mistakes made in Europe and the US in the past*."

For this consultation it is important to recognise that the waste hierarchy should be considered in the context of the Best Practicable Environmental Option (BPEO) as described below and it should not be assumed that incineration or energy recovery is necessarily environmentally preferable to disposal. It should be noted, in any case, that the European definition of disposal includes incineration (following the Waste Framework Directive and the decision of the European Court of Justice (European Court of Justice 2002)).

The European Commission's thematic strategy on waste prevention and recycling says that "*at low energy efficiencies incineration might not be more favourable than landfill*" (Commission of the European Communities 2005). Similar conclusions were reached by COWI themselves (COWI 2000) although not referenced here) they said:

*"The following conclusions seem to be relatively robust: There is **no easy and straightforward answer as to whether incineration or landfill disposal is preferable** from the point of view of external effects."*

Due to the importance of this question to the consultation it is examined in more detail below.

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[4] http://www.environment.gov.za/ProjProg/WasteMgmt/WasteMgmt_contents.htm

The Best Practicable Environmental Option (BPEO)

The National Waste Management Strategy and the "Minimum Requirements for the Classification, Handling and Disposal of Hazardous Waste, 2nd edition, published in October 1998[5]" adopt the concept of using the Best Practicable Environmental Option (BPEO) in order to provide affordable environmental protection in the light of the acceptance that "improved standards will inevitably result in increased costs". It is also is included in the current Waste Management Bill (Republic of South Africa Minister of Environmental Affairs and Tourism 2007).

The best practicable environmental option means the most reasonable measure for providing the greatest positive impact and least negative impact on health and the environment;

BPEO is to be achieved by the promotion of a waste management process. The process comprises three basic steps: waste avoidance, correct classification and minimum requirements for the safe handling, treatment and disposal of waste. Again due to the importance of this issue for incineration it has been examined in more detail below in the context of life cycle assessment.

The European Parliament voted earlier this year on a formal waste hierarchy (European Parliament 2007) which lays down an order of preference for waste operations: re-use, recycling, other recovery operations and, as a last resort, safe and environmentally sound disposal. This is similar to that established in South Africa. Significantly, however, it was agreed by the Parliament (European Parliament 2007) that derogations from the order of priorities should only be allowed on the basis of established, publicly available scientific criteria. This would be good example for South Africa to adopt as it significantly reduces the uncertainty over BPEO assessments.

Waste Reduction and Zero Waste:

The Polokwane Declaration on Waste Management of September 2001 set a goal, to ''*Reduce waste generation and disposal by 50 and 25%, respectively by 2012 and develop a plan for ZERO WASTE by 2022*''. (Department of Environmental Affairs and Tourism (DEAT) 2001).

The Zero Waste approach concurs with the philosophy that ''*Nature does not produce waste. In nature, the waste of one organism or process becomes the food for another*''. i.e. Wastes should be regarded as a resource and sustainable development solutions should be sought in terms of their reuse and recycling. (Karani and Jewasikiewitz 2007). The principles are summarised by the Zero Waste International Alliance:

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[5] This, and the additional reports in the Waste Management Series, are described as "living documents" to be updated in the future, although this has not yet been done.

Zero Waste is a goal that is both pragmatic and visionary, to guide people to emulate sustainable natural cycles, where all discarded materials are resources for others to use.

Zero Waste means designing and managing products and processes to reduce the volume and toxicity of waste and materials, conserve and recover all resources, and not burn or bury them.

Implementing Zero Waste will eliminate all discharges to land, water or air that may be a threat to planetary, human, animal or plant health. (Zero Waste International Alliance, 2004)

A grand challenge facing government, industry and academia in South Africa is to redefine the relationship of technological society to the environment and to re-invent the use of materials. To address this challenge a more holistic approach will be required rather than piecemeal consideration of technological options.

This radically different approach to materials management needs to be linked to a significant reduction in primary resource use. As the pre-amble to the 2007 Waste Bill (Republic of South Africa Minister of Environmental Affairs and Tourism 2007) says, quite correctly:

"Whereas the minimisation of pollution and the use of natural resources through vigorous control, cleaner technologies, cleaner production and consumption practices and waste minimisation is the key to ensuring that the environment is protected from the impacts of waste;"

Targets have been set that are a useful start towards this but, oddly, the consultation again contains no reference to them:

	Municipal waste	Industrial waste
Waste generation	30% reduction	Keep the rate of increase below 10%
Waste recycling	10%→ 50%	10%→ 50%
Final disposal amount	60% reduction	30% reduction

(Mvuma 2005).

It is notable that in the consultation documents COWI claim, when commenting on the GroundWork objections to incineration (s 11.2 page 53), that the reduction of hazardous waste production and the "upper part" of the waste hierarchy promoted by GroundWork, is an element that *"all Government (sic) has adopted already"*. This is demonstrably incorrect for South Africa and DEAT has confirmed to GroundWork that *"work with respect to a waste minimisation policy … is ongoing"* (Fischer 2007).

It would be sensible to complete the work on the waste minimisation policy and develop an appropriate implementing framework before rushing to develop an incineration-based strategy which is likely to be in competition with the waste minimisation. The concept of Zero Waste includes much greater emphasis on the minimization of waste generation together with reuse and recycling of waste, and hence the diversion of waste away from landfill and particularly incineration. The additional emphasis on incineration arises because incinerators need waste a fuel whilst there is a much greater incentive to reduce wastes inputs to landfill sites to extend the landfill life and the need to find additional capacity.

Furthermore the main policy instruments for promoting the prevention of hazardous waste actually belong to the fields of chemical policy and resource management. Rather than attempting to stretch the waste legislation too much in the direction of waste prevention. Lilja et al. (Lilja and Liukkonen 2008) recommend the more sensible approach of including waste-related aspects in the chemical policy. The following topics, which should be read together the twelve guidelines to Green Chemistry in Annex 6, are suggestions for such an approach:

- Substitution or control of chemicals generating major volumes of hazardous wastes;
- Substitution or control of chemicals generating non-hazardous wastes that cause significant emission risks or occupational hazards in solid waste treatment;
- Substitution or control of hazardous chemicals causing major problems to solid waste recycling;
- Prevention and minimisation of waste arising from soil remediation by preventing chemical contamination of soil and buildings and by intelligent remediation strategies.

The only aspects of minimisation of existing hazardous waste that falls into the field of waste management and waste policy are recycling or chemical treatment for re-use together with improved source separation. In such issues, the inspection authorities can still have a key role in promoting hazardous waste minimisation.

These approaches are currently being developed in Finland and will be incorporated into the next National Waste Plan which is currently under preparation (Lilja and Liukkonen 2008).

There is no doubt that incineration undermines zero waste policies. Incinerators are capital-intensive projects which need to operate at high capacity and over long periods of time to recover that investment. This operational philosophy is inconsistent with waste elimination or even with high levels of recycling. Most incineration contracts require that waste is provided or high penalty payments are made and thus they are in competition with recycling and almost inevitably burn recyclable wastes. This is demonstrated in a recent waste analysis in Sweden (Petersen, Berg et al. 2005) where it was assessed that 40.3% of the wastes being incinerated by the Lidkoping incinerator were recyclables.

The only reference to 'Zero Waste' in the COWI literature review is a secondary quotation in an unreferenced[6] 'blog' in Annex 1 that comes from an

[6] Whilst a URL is given this link is broken. Although it seems to have come from a newspaper there is no indication of even which paper (or continent) this came from in the citation. This is hardly a professional approach to what should be a serious literature review.

unspecified country. It is assumed from the content that it may come from the Philippines but in that case the linkage to South Africa is unclear and at best tenuous.

The consultants not even refer to publications in the peer reviewed literature such as that by Matete (Matete and Trois 2007) which refers specifically to the experiences of 'Zero Waste' in South Africa.

Matete examines approaches to resolving the problems faced by South Africa, which is facing the challenge of meeting high standards in service delivery with limited resources. A particular challenge identified is the characteristic of current waste management practices in South Africa having a large disparity in service coverage between different communities in the same area. (citing (Government of South Africa 2003)).

It is not suggested that South Africa would be able to move to a 'Zero Waste" economy immediately but rather that the policy should firmly and consistently establish this as a goal. Most importantly those aspects of waste management which undermine the progress towards 'Zero Waste', including incineration, should be actively discouraged. This can be achieved in a manner consistent with the economic limitations discussed by Orloff (Orloff and Falk 2003). They argued that developing countries might have to take an incremental approach in managing hazardous wastes but that actions should not be delayed while awaiting expensive, state-of-the science technologies for treatment and disposal of hazardous wastes. Low-technology efforts to reduce the health and environmental impacts of hazardous wastes are better than none – and in the case of zero waste programmes are often more effective than the expensive technocratic solutions anyway.

A useful example as an interim stage would be to follow the approach adopted by Nova Scotia. In 1989 Canada established a national goal of diverting 50 percent of the nation's municipal solid waste from disposal by 2000. The province of Nova Scotia was the first and only province to achieve this goal.

In the early 1990s, Nova Scotia relied on substandard land-based disposal, incineration, and open burning and pollution prevention was minimal. In 1995, however, Nova Scotia adopted a comprehensive, province-wide strategy based on pollution prevention to fundamentally change its historical approach and to achieve the diversion goal. The strategy has been effective, has achieved substantial environmental benefits, and program costs are comparable to other North American systems (Wagner and Arnold 2008).

Luken et al. (Luken and Van Rompaey 2007) reported on some of the findings of a survey of 105 plants in nine developing countries and across four manufacturing sub-sectors on factors affecting environmentally sound technology adoption. Their survey identified drivers for and barriers to adopting environmentally sound technology as perceived by plant managers and key informants. Not surprisingly, environmental regulation and market pressure appear to exert more influence than community pressure on the adoption of environmentally sound technology. It is vital, however, that these signs are given clearly and consistently by DEAT. The current mixed message which arises from the current consultants ignoring the Polokwane Declaration on Waste Management is particularly damaging as it leads to uncertainty amongst stakeholders of the policy direction. Such uncertainty reduces the effectiveness of policy initiatives as stakeholders are not confident what measures they need to take to ensure compliance with future policies. DEAT should carefully consider the benefits of economic instruments, such as disposal taxes on landfill and incineration, as discussed briefly below, in order to provide the appropriate incentives to meet the waste minimisation targets.

The Right to Know and Access to Information

Foulon (Foulon, Lanoie et al. 2002) has outlined the evidence that the public disclosure of environmental performance does create additional and strong incentives for pollution control. One excellent example is the United States Toxic Release Inventory which has been reviewed by Jobe (Jobe 1999). Strong community and market response to the Toxics Release Inventory prompted the EPA to initiate its first voluntary pollution reduction program in 1991. The 33/50 Program had as its goal a 33 percent reduction in releases and transfers of 17 targeted chemicals by 1992 and a 50 percent reduction in release and transfers of the targeted chemicals by 1995 using 1988 as the baseline year. Data from the EPA indicates that these targets were exceeded with an overall reduction of 55.6 percent for the targeted chemicals by 1995. By EPA estimates, toxic releases of all listed chemicals have declined 46 percent between 1988 and 1995. This initiative was so successful that President Bill Clinton (Clinton 1995) proudly announced *" ...since the Community Right to Know Act has been on the books, reported reductions in toxic emissions are about 43 per cent for the whole country. Now that's a law worth passing. No new bureaucracy; just power to the people through basic knowledge."*

Public access to information is a constitutional right of all South Africans (Act 108 of 1996) (Republic of South Africa, 1996) enabled through the Promotion of Access to Information Act (Act 2 of 2000) (Republic of South Africa, 2000b). By increasing community awareness and understanding, it provides a mechanism for communities to participate in environmental planning, decision-making and policy development (Nauman, 2004; Kolominskas and Sullivan, 2004), in assessing the potential risks associated with local pollutant releases (Howes, 2001), and in placing pressure on industry and government to reduce emissions and discharges (Antweiler and Harrison, 2003; Kolominskas and Sullivan, 2004). The dissemination of information by government therefore provides a mechanism for supporting informed community participation in the management of waste.

Godfrey (Godfrey 2007) cites Kirby saying *''Freedom of information is important to justice . . . In a world of secrecy and opaque government, serious wrongs can occur which may never come to light. Freedom of information legislation is at once a means of casting the light of scrutiny into the dark corners of government and a contribution to a new culture of openness in public administration''*.

Despite the evidence of effectiveness and the legislative framework public access to waste information has, in practice, been slow to materialise. Godfrey

(Godfrey 2007) comments that an Internet search of Integrated Waste Management Plans (IWMPs) in South Africa in June 2005, for example, yielded only three plans. Municipalities have typically been slow to include communities in the IWMP process and to make IWMPs available to the public for consultation and comment, thereby undermining the potential for communities to participate in the waste planning process.

Even the history of the current consultation has been controversial in this regard. The enactment of the National Environmental Management: Air Quality Bill; proposed amendments to the Bill were a result of civil society organisations requesting the Portfolio Committee on Environment and Tourism in February 2004, to hold back the Bill and request the DEAT to amend the Bill. On Thursday 12 August 2004, DEAT presented the amendments to the Portfolio Committee on Environment and Tourism as requested. However, DEAT included additional clauses 26-28 that would allow for the incineration of hazardous waste without input from civil society. (GroundWork 2006)

Godfrey (Op Cit 2007) identified the top priority waste information needs of national, provincial and local government and highlighted "public access to information" as the 2nd and third highest priorities with only "*planning*" being consistently higher:

The top 5 needs of national/provincial and local government

National and provincial government	Local government
1. Planning	1. Planning
2. Compliance and enforcement	2. Public access to information
3. Public access to information	3. New development initiatives
4. Decision-making	4. Human resource and operations management
5. Policy development	5. Budgeting, billing and financial management

Godfrey did comment that a shift in the Government's approach to waste information was encouraging but that "*the focus on waste disposal …and the need for information on landfill remains entrenched within Government*".

It is regrettable also that the opportunity presented by this consultation to present a detailed and up to date assessment of the waste situation in South Africa has not been grasped. Rather than the melange of www reports which bulk up the COWI and SINTEF documents a focus on providing good country specific and relevant data would have been far more useful. Even the specific data provided on cement kilns, though helpful because it was not previously available, is still very limited in scope given that the consultants had travelled to each of the sites as part of the project.

Data extracted from the permits of the existing cement kilns is included in Annex 6 of this report but it will be seen that even basic information necessary to calculate pollutant burdens such as the gas flow rates has been removed from the permits. This would not be acceptable practice in Europe of the United States and it is vital that the provision of information like this should be significantly more open than it has been to date.

POPs Control in South Africa

Bouwman (Bouwman 2003) says that the Stockholm Convention has brought to the fore the lack of data and information on the environmental chemistry and ecotoxicology of POPs in developing countries - including South Africa.

Whilst South Africa has sources and uses of POPs comparable with developed countries, it also has conditions and considerations that are distinctly different.

Unfortunately very few data are available on environmental levels of dioxins, dibenzofurans and PCBs, but they have been found in breast milk – albeit at relatively low levels (see below).

Bouwman argues that the lack of data could hamper the power of the negotiation positions of developing countries, when compared with developed countries that have more data and information to motivate their agendas.

More recently Bouwman (Bouwman, Polder et al. 2007) reports finding HCB, DDTs, HCHs, chlordanes and PCBs at detectable levels eggs from African darter, cattle egret, reed cormorant, African sacred ibis, as well as single eggs from some other species. They say the presence of mirex in all species was unexpected, since this compound was never registered in South Africa. Worryingly eggshell thinning was detected in the African darter, and was associated with most of the compounds, including DDE and PCBs.

They warn that given the scarcity of water and the high biodiversity in Southern Africa, climate change will exert strong pressure, and any additional anthropogenic contamination at levels that can cause subtle behavioural, developmental and reproductive changes, can have serious effects. The reduction of hazard in waste and chemicals policy is the most appropriate and effective response to these threats.

The development of any strategy for Hazardous Wastes treatment and disposal should, in any case, be in accordance with the provisions of the National Implementation Plan ('NIP') for the Stockholm Convention[7]. Unfortunately South Africa has not yet submitted such a plan even though the deadline was 17th May 2006[8]. This is another powerful reason to delay the development of the current incineration oriented strategy.

[7] In spite of receipt of a GEF grant of $499,000 for this work http://www.gefonline.org/projectDetails.cfm?projID=1785

[8] http://www.pops.int/documents/implementation/nips/submissions/default.htm

Annex 3 -The Literature reviews

The literature review reports prepared for this consultation are unfortunately of poor quality and cannot reasonably be considered to be fit for purpose. They have, no doubt, been profitable exercises for COWI and SINTEF whose consultants appear to have largely copied their previous work mixed with reports from the www in an unstructured and uncritical fashion. There is a disappointing lack of attention or relevance to the South African context of either text to the current project.

Perhaps more seriously both reports demonstrate a worrying bias towards incineration and co-incineration in their approach. This is a particular problem with the SINTEF contributions which draw very heavily on their earlier incarnations as lobby documents for the "Cement Sustainability Initiative" ('CSI') funded by the World Business Council on Sustainable Development (see, for example, (Karstensen 2006)). It is surprising to see a governmental consultation so closely aligned to the lobbying of the cement industry. Although the CSI documents are wide-ranging in scope and contain much useful data they certainly present the arguments from strongly pro-industry, pro-waste burning perspective and, significantly, omit some data which is not helpful to that case. The current consultation documents are similarly aligned.

The COWI report (Lauridsen 2007) is remarkably short of detail on the historic development of the strategy or the South African policy context saying only:

"Over the past years South Africa has developed several waste management policy documents and strategies, including:
• the Integrated Pollution and Waste Management Policy (IP&WM),
• the National Waste Management Strategy the Minimum Requirements for Waste disposal by Landfill and more recently
• the Waste Minimisation and Management Bill, that indicate the countries support of managing waste through the waste hierarchy concept."

The text is incorrect in any case (unless punctuation is missing in the second bullet point). The *Minimum Requirements for Waste Disposal by Landfill* was published in two editions the 1st Edition in September 1994 and the 2nd edition in September 1998 but by the Department of Water Affairs and Forestry (DWAF). This pre-dated the National Waste Management Strategy which was, at that stage, still being formulated, as a joint venture between the Department of Water Affairs & Forestry, the Department of Environment and Tourism, and DANCED (Republic of South Africa Department of Water Affairs and Forestry 1998)

Rather surprisingly for a literature review on hazardous waste in South Africa there is no other reference to the National Waste Management Strategy and none at all to the "Minimum Requirements for the Classification, Handling and Disposal of Hazardous Waste, 2nd edition, published in October 1998".

The conclusions of the literature review by COWI claim to present the overall advantages and disadvantages of incineration of hazardous waste. There is considerable confusion in the style and presentation of this document and it alternates between hazardous and domestic/ municipal wastes without any apparent logic and with no explanation.

Much of the review also appears to be simply 'padding' with little relevance to the development of policy in South Africa. Why, for example, is Annex 3 (the Republic Act of the Philippines) included when this is, like so much of the rest of the 'review' largely copies verbatim from www sites without comment or context?

So much of the review is copied from other sources without citation that it is difficult to establish what, if any remains as commentary on the different data sources.

The essence of the review from the conclusions is that whilst there may historically have been some problems with incineration these have largely been overcome and that modern incinerators are an acceptable waste management option. These conclusions have been reached, however, without proper consideration of the objections, the alternatives and the South African policy context. Solutions which may be common in cold Scandinavian countries with large budgets; well established regulatory and licensing regimes; multiple, well equipped laboratories capable of analysing minute concentrations of complex organic compounds in all media; and urban infrastructure based around large heating networks. South Africa lacks most or all of these circumstances.

It is clearly not practical to pick up all the issues arising from the hundreds of pages published by DEAT for this consultation. Instead several key points have been explored in more detail. These comments are fully referenced to the recent peer reviewed literature and it is hoped that they will be useful to DEAT in assessing how thorough the work undertaken by their consultants has been in practice.

The Economics of Thermal Treatment:

The COWI review says that one of the advantages presented in favour of incineration is "*cost effectiveness*". This is strange because there is no sustainable argument that incineration is anything but an expensive option. The Wold Bank (Rand, Haukohl et al. 1999) said that "*capital and operating requirements for these plants are generally an order of magnitude greater than required for landfills*".

UNEP (United Nations Environment Programme and Calrecovery Inc 2005) agrees and more recently stated "*incineration has a serious disadvantage in the form of the substantial cost of controlling and managing its pollutant emissions*".

Compared with those of the World Bank the UNEP estimates indicate a slightly smaller - but still very significant margin over landfill and, importantly, more environmentally benign and appropriate options for South

Africa such as composting:

	Low Income	Middle Income	High Income
Open dumping (US$/Mg)	0.5 to 2	1 to 3	Not applicable
Sanitary landfill (US$/Mg)	5 to 25	15 to 30	30 to 100
Composting (US$/Mg)	5 to 25	15 to 40	30 to 80
Incineration (US$/Mg)	30 to 60 (Note 5)	30 to 80 (Note 4)	70 to 100 (Note 4)

Notes:
1. The above sanitary landfill costs are for cities of over 500,000 people, or over 250 tonnes/day, in order to capture economies-of-scale. For smaller cities, costs could be higher.
2. The higher range of costs for sanitary landfill is for systems with plastic membrane bottom liners and leachate collection and treatment systems; while the lower range of costs is for natural attenuation landfills, where site conditions do not require leachate management.
3. The higher range of costs for composting is for systems with mechanised classification, pulverisation, and forced aeration, while the lower range of costs is for systems with hand sorting, trommel screening, and simple turned windrows.
4. The higher range of costs for incineration is for systems with modern air pollution control and ash handling systems, while the lower range of costs is for systems with limited air pollution control equipment and no specialised ash handling equipment.
5. Limited air pollution control equipment and no specialised ash handling.

On the basis of this, and together with waste composition considerations which have been discussed above, UNEP concluded that:

"*High costs, limited infrastructure, and the composition of the waste stream suggest that incineration is an inappropriate technology for most African cities*".

Whilst reliable, and particularly peer reviewed, data on actual costs of projects is relatively rare Tsilemou et al. (Tsilemou and Panagiotakopoulos 2006) recently published a review of European data and included a helpful summary table:

Table 1: Cost data for WTE facilities in Europe[a].

Country/region	Capacity (10^3 tons year^{-1})	Type of energy recovery	Initial capital investment (10^6 €)	Operating cost (€ ton^{-1})	Annual total cost* (€ ton^{-1})
France	18.70	electricity	11.80–13.30 [1, 2]	74.00–79.00 [3, 4]	129.00–141.00
Greece	36.50	electricity	23.57–27.03 [5]	182.03–188.08	
France	37.50	electricity	18.07–21.06 [1, 2]	44.00–48.00 [3, 4]	102.00–113.00
France	37.50	heat	17.20–21.51 [1, 2]	59.00–66.00 [3, 4]	105.00–120.00
Sweden	40.00	heat	13.34	34.80	71.40
Sweden	40.00	co-generation	24.25	46.65	113.20
Denmark	40.00		26.00	48.80	
Europe	50.00		25.00 [6]	19.00 [7]	
Germany	50.00	electricity			230.00 [8]
France	75.00	electricity	33.55–39.57 [1, 9]	52.00–56.00 [3, 4]	91.00–102.00
Greece	100.00		35.00 [10]		
Germany	100.00				140.00 [8]
UK	100.00		56.62	36.25 [11, 12]	92.50 [6, 8]
Europe	100.00		45.00 [6]	17.50 [7]	
UK, Ireland	120.00		67.20	42.00	
France	150.00	co-generation	72.26–89.47 [1, 13]	48.00–52.00 [3, 4]	90.00–104.00
Belgium	150.00	electricity	59.49 [1]	38.79	82.57 [14]
Belgium	150.00	electricity	63.80 [1]	40.00	86.88 [14]
Germany	200.00	electricity	121.93 [15]	57.66 [16]	105.00 [8]
Ireland	200.00		84.24 [17]	25.93 [17]	
UK	200.00		81.62	29.01 [11, 12]	69.65 [11, 12]
Europe	200.00		90.00 [6]	20.00 [7]	
Denmark	230.00		128.80	36.50	
Italy	300.00		146.81 [18]	60.73 [20]	127.53
Sweden	300.00	heat	52.49	19.29 [21]	38.50
Sweden	300.00	co-generation	95.49	24.17 [21]	59.10
Germany	300.00				85.00 [8]
Netherlands	450.00		463.50	67.00	
UK, Ireland	420.00		180.60		
Europe	500.00		160.00 [6]	13.60 [7]	
Italy	584.00		200.00 [19]		
Germany	600.00				65.00 [8]

* As reported in the Literature; see Section B (a) in the text.

These costs confirm the UNEP estimates but shows that for smaller capacity units the operating costs can rise significantly higher – to as much as € 140/tonne. It should also be considered that these data are inevitably historic and that current costs are likely to be higher in any case.

The European Commission Best Practice Reference Note ('BREF') (European Commission 2005) for incineration also includes some cost data:

Cost structure	Incineration plant for	
	Municipal waste with a capacity of 250 ktonnes/yr in EUR 10^6	Hazardous waste with a capacity of 70 ktonnes/yr in EUR 10^6
Planning/approval	3.5	6
Machine parts	70	32
Other components	28	28
Electrical works	18	20
Infrastructure works	14	13
Construction time	7	7
Total investment costs	**140**	**105**
Capital financing cost	14	10
Personnel	4	6
Maintenance	3	8
Administration	0.5	0.5
Operating resources/energy	3	2.5
Waste disposal	3.5	1.5
Other	1	0.5
Total operational costs	**29**	**12.5**
Specific incineration costs (without revenues)	**Approx EUR 115/tonne**	**Approx EUR 350/tonne**
Note: The data provides an example in order to illustrate differences between MSWI and HWI. Costs of each and the differential between them vary		

These data also shows that costs may be expected to be higher than UNEP estimated with at total costs for a 250,000 tpa incinerator being estimated to be 60 % higher than the maximum cost for incineration given by UNEP ($162/tonne vs. $ 100 tonne). Whilst the costs of hazardous waste incineration will vary significantly depending upon the wastes to be incinerated a working estimate of three times greater than for municipal waste is provided in the BREF.

Autret et al. (Autret, Berthier et al. 2007) provide a recent example of the costs of upgrading plant to the more recent European standards in France. They showed that capital investment requirements rose from € 2.6m per t/h capacity in 1993 to approximately € 4.0m per t/h capacity in 2003. Global incineration cost, which takes into account the amount of the investments and the global operating cost, was estimated to be between €70 and € 90 per tonne of waste treated.

Even the peripheral expenses not reflected in these reviews can be enormous. A current controversy in Dublin, Ireland, has arisen over the money spent by the local authority to promote an incineration-based solution in an effort to convince the public of the acceptability of the proposals. The authorities have spent € 19 million to date just on promotion of incineration (Dublin People Group of Newspapers 2007).

The very high capital costs necessarily require the security associated with long-term waste contracts in order to protect the banks or financier's investments. Such contracts effectively monopolise waste management for quarter of a century or more and require that guaranteed minimum tonnages of waste are supplied to the incinerators with tight specifications on the suitability of the waste for combustion (such as calorific value, water content, contamination levels etc). Penalty payments are often required if such conditions are not met. This security makes waste incinerators particularly attractive to vendors, not least because the contracts are normally with governments or local administrations and are thus considered relatively secure. The World Bank (op cit) warned *"project developers armed with rosy financial forecasts can be found in all corners of the globe encouraging municipal officials to consider incineration"*. It is therefore vital that the overall economics and the total costs over the operating life of a proposed project are scrutinised carefully. The literature reviews provided to DEAT have, unfortunately, completely failed to do this – but the limited information financial information which is provided strongly supports the case against thermal treatment as a viable option for South Africa.

COWI appear to propose, for example, at s8.2 p34 that 10 million tonnes of MSW could be incinerated in South Africa saying "*If only half of the SA municipal waste was incinerated (e.g. [sic] 10 million tonnes)"*. The basis for the claim that there are 20 million tonnes of MSW produced in South Africa is challenged above - but for the moment let us assume that the estimate is reasonable.

The capital costs of implementing this proposal are, oddly, not explicitly presented by COWI. If they had been it would have been obvious that what is proposed would be enormously expensive. COWI says:

" One kiln (sic) like the biggest in Europe (sic) has been build near Copenhagen and costs about 100 mill Euros, incinerate 35 tons per hour, 8000 hours/year, and produces 179,000 MWh/year electricity and 670,000 MWh/year heat /39/."

This would mean that 280,000 tpa capacity costs €100 million on their own figures. It should be noted that these costs are rather low compared with those presented from the independent sources above, but for the purposes of this exercise they will be used here.

The COWI prices mean that their proposal to incinerate 10,000,000 tonnes of waste would require a capital investment of € 3.5 Billion ($ 4.9 Billion or R 35 Billion). This equates, for example, to the entire health service budget for South Africa for about three years but in fact the real cost would be likely to be even higher.

In addition to these enormous costs the external costs need to be considered.

External Costs and Benefits:

"*External costs*" or "*externalities*" are essentially economic side effects that represent market failures. They are costs or benefits arising from an economic activity that affect somebody other than the people engaged in the economic activity and are not reflected fully in prices. Environmental impacts are a common example of externalities and occur when an activity has an impact on the environment, whether positive or negative, and the monetary cost or value of that impact is not included in the transactional cost of that activity. Those who suffer from external costs do so involuntarily, while those who enjoy external benefits do so freely.

Because external costs and benefits are often not included in the calculations of the people making decisions concerning some economic activity, they are a form of market failure that will lead to an inefficient use of resources. If the externality is beneficial, the market will provide too little; if it is a cost, the market will supply too much.

Externality theory (Pigou 1932) can therefore make an important contribution to the design of public policies to protect the environment. In essence it says that price is not an optimal policy unless it reflects the full social marginal costs and benefits.

COWI (COWI s 10.4 page 47) show that the externalities of MSW incineration are approximately €40/tonne. About half of this (€21) comes from emissions of hazardous chemicals.

This would means that the <u>annual</u> externality for their proposals, as above, of incinerating 10,000,000 tonnes of MSW would total <u>€400,000,000 (c R 4 billion)</u> for South Africa. Over a 25 year operating life this would total <u>€10 billion (c R 100 billion)</u>. Operating costs are about 20% of the capital costs which are estimated above at € 3.5 billion, total 'private' costs would therefore be c € 4.2 billion.

The total private and environmental costs of following the COWI recommendations would therefore be more than <u>€14 billion (c R 140 billion)</u> over 25 years. This equate to the entire budget for the South African health service for more than 12 years.

The Norwegian study cited by COWI is not unusual in reaching the conclusions that incineration has high external costs. Several studies have calculated the total social cost of incineration and landfill, and their findings show that most of the time incineration costs are much higher than landfill.

Indeed COWI prepared an economic assessment of benefits/ disbenefits for the EC (COWI 2000) about which the current review is silent.

In that report COWI had calculated that the incineration of waste to the earlier European incineration Directive standards had an overall net environmental cost of between 16 and 84 Euros/tonne with a most likely value of 34 Euros/tonne.

They also calculated that, due to the displaced electricity and heat production, that an incinerator operating to the current Waste Incineration Directive standards AND generating electricity and heat with an efficiency of 83% (which is very rate in practice – and would certainly not apply in South Africa or even for the vast majority of Europe) would have a net environmental cost of between -72 and -9 Euros/tonne (i.e. an environmental benefit) with a most likely figure of -43 Euros/tonne.

Since that review the environmental cost attributed to emissions have increased as it has been recognised that harm from air pollution is far more extensive and serious than was thought even until very recently.

Other studies finding similar results include, but are certainly not limited to:

1. Eunomia, A Changing Climate for Energy from Waste?, Final report for Friends of the Earth, 03/05/2006. (Hogg and Eunomia Research & Consulting Ltd 2006).

2. Rabl, A., J. V. Spadaro, et al. (2007). "Environmental Impacts and Costs of Solid Waste: A Comparison of Landfill and Incineration." Waste Management & Research **in press**. (Rabl, Spadaro et al. 2007).

3. Holmgren, K. and S. Amiri (2007). "Internalising external costs of electricity and heat production in a municipal energy system." Energy Policy **35**(10): 5242-5253. (Holmgren and Amiri 2007)

4. Eshet, T., O. Ayalon, et al. (2006). "Valuation of externalities of selected waste management alternatives: A comparative review and analysis." Resources, Conservation and Recycling **46**(4): 335-364. (Eshet, Ayalon et al. 2006)

5. HM Customs & Excise (2004). "Combining the Government's Two Health and Environment Studies to Calculate Estimates for the External Costs of Landfill and Incineration, December 2004." (HM Customs & Excise 2004)

6. Turner, G., (Enviros Consulting), D. Handley, (Enviros Consulting), et al. (2004). Valuation of the external costs and benefits to health and environment of waste management options Final report for DEFRA by Enviros Consulting Limited in association with EFTEC, DEFRA. (Turner, Handley et al. 2004)

An independent study by Dijkgraaf (Dijkgraaf and Vollebergh 2004) concluded:

"The net private cost of WTE (waste-to-energy) plants is so much higher than for landfilling that it is hard to understand the rational behind the current hierarchical approach towards final waste disposal methods in the EU (European Union). Landfilling with energy recovery is much cheaper, even though its energy efficiency is considerable lower than that of a WTE plant."

This conclusion is similar to that reached by the OECD (Organisation for Economic Co-operation and Development (OECD) 2007) this year following their review of waste Management in the UK and the Netherlands:

"In both countries, there is currently a strong preference given to incineration compared to landfilling of waste – as reflected e.g. in the landfill taxes they apply. A similar preference underlies the Landfill Directive of the European Union, which fixes upper limits for the amounts of biodegradable waste member states are allowed to landfill.

However, estimates in both countries indicate that the environmental harm caused by a modern landfill and a modern incineration plant are of a similar magnitude, while *the costs of building and operating an incinerator are much higher than the similar costs for a landfill. Hence, the total costs to society as a whole of a modern incinerator seem significantly higher than for landfilling - which indicates that some reconsideration of the current preference being given to incineration could be useful."*

And:

"Analyses of the negative environmental impacts of landfilling and incineration in both countries suggest, however, that the foundation for the present preference for incineration is questionable from the point of view of total social costs".

It should be noted that the *"social costs"* of waste management include the respective *private costs i.e.* the costs to society of building and operating the various management options together with the external environmental costs.

Disamenity Impacts from incinerators

Incinerators are extremely unpopular in most countries and they generally have to be forced upon an unwilling population. Whilst the main concerns probably relate to health risk there are also important concerns about the disamenity of incinerators. Kiel and McClain assessed these impacts of incinerators with an hedonic pricing study in Massachusetts, USA (Kiel and McClain 1995; Kiel and McClain 1995). The study examines the progression of house prices over the life of an incinerator, from rumour and construction and through to operation.

Consultants acting for DEFRA in the UK (Turner, Handley et al. 2004) converted their result to £/tonne of waste based on information on the case study site by that could be gleaned from publicly. The study had found that after four years of operation the effect on house prices within 3.5 miles of the site has stabilised at £10,055 per mile (£,2003), which is essentially a distance decay function, i.e. starting from 3.5 miles from the site, at every mile approaching the site house prices drop by an average of £10,055. The outcome of the analysis is that £10,055 (R 143,000) per mile is equivalent or £21 or c R 300/tonne of waste for the disamenity effect on local communities.

The fact that the study is from the US is likely to affect the accuracy of this figure in the South African context but in the absence of better data or local studies it is a useful starting point of the measure of local disamenity of incinerators on a "willingness to pay" basis.

Incineration Taxes

Although the COWI review promotes the Scandinavian use of incineration enthusiastically the report comments only briefly on incineration taxes in Norway – and not at all on the taxation regime it the other countries.

Eriksson (Ericsson and Nilsson 2004) reported in 2004 that in Denmark, Norway and the Netherlands there is a tax on burning waste. (In the Netherlands the tax has been introduced administratively but the tax rate is still zero). An incineration tax has since been introduced in Sweden. This tax consists of two parts (Sahlin, Ekvall et al. 2007): the energy tax of 150 SEK/tonne (€ 16.5 /tonne) fossil coal and the CO_2 tax of 3374 SEK/tonne (€ 371/tonne) fossil coal. Heat-only boilers are levied full tax while combined heat-and-power (CHP) production plants pay tax only on the proportion of energy which is for heating purposes.

Furthermore Erikson et al. (Ericsson and Nilsson 2004) added that in Germany and the Netherlands biofuels and waste have difficulty in competing with fossil fuels partly because environmental taxes on carbon based fossil fuels are much lower than in Sweden and Denmark. The market for incineration is thus distorted in Denmark and Sweden by the taxation system. Clearly this needs to be corrected in the light of the more recent research (also not reported by COWI) on the climate impacts of incineration above.

2006	Denmark (Euro/ton)	Sweden (Euro/ton)	Norway (Euro/ton)	Iceland (Euro/ton)	Faroe Islands (Euro/ton)	Finland (Euro/ton)
Incineration - with energy recovery	44	10	9	0	0	0
- without energy recovery		48	42		0	
Landfill	50	47	51 - 66	0	0	30

Sources:

NRF, 2005: "Rammebetingelser for energiutnyttelse av avfall i Norge", Rapport nr 2/2005, Arbejdsgruppe for energiutnyttelse

In a report for the Swedish Defence Agency Björklund et al. (Björklund, Johansson et al. 2003) confirmed that the introduction of a waste incineration tax was likely to result in environmental improvements. They suggested that a waste incineration tax should be accompanied by an increased landfilling tax, in order to ensure that landfilling is avoided. The environmental improvements are partly accomplished by diverting materials from landfills to recycling as a result of the increased landfill tax, and partly by diverting materials from incineration to recycling.

They concluded that although the studied alternative of a waste incineration tax of 400 SEK/ton (€ 44 /tonne) is likely to lead to environmental improvements, the improvements are small compared to the potential improvements available through the more visionary scenarios developed to make recycling more attractive.

This is clearly important because the evidence available shows that large quantities of recyclable materials are currently incinerated in Scandinavian countries. A recent analysis of waste delivered to a Swedish incinerator by Petersen (Petersen, Berg et al. 2005) showed, for example that of the waste evaluated, 40.3% was recyclables, of which 4.6% was non-combustible recyclables. An additional 33.0% was biowaste, that is, material that can be composted or anaerobically digested. Thus based on its characteristics, 73.3% of the household waste incinerated was suitable for material recycling (including 4.6% non-combustibles) or biological treatment.

The European Incineration BREF (European Commission 2005) confirms that in Denmark, the tax on incineration is especially high. Hence, although underlying costs tend to be low (owing primarily to scale, and the prices received for energy), the costs net of tax are of the same order as that of several other countries where no tax is in place. This tax along with a landfill tax were adopted in Denmark to promote waste treatment in compliance with the waste hierarchy. This has resulted in a large shift from landfill to recycling, but with the percentage of waste being incinerated remaining constant. This demonstrates, inter alia, how difficult it is to divert waste from incineration once investments have been made – no matter how important it may be for environmental reasons.

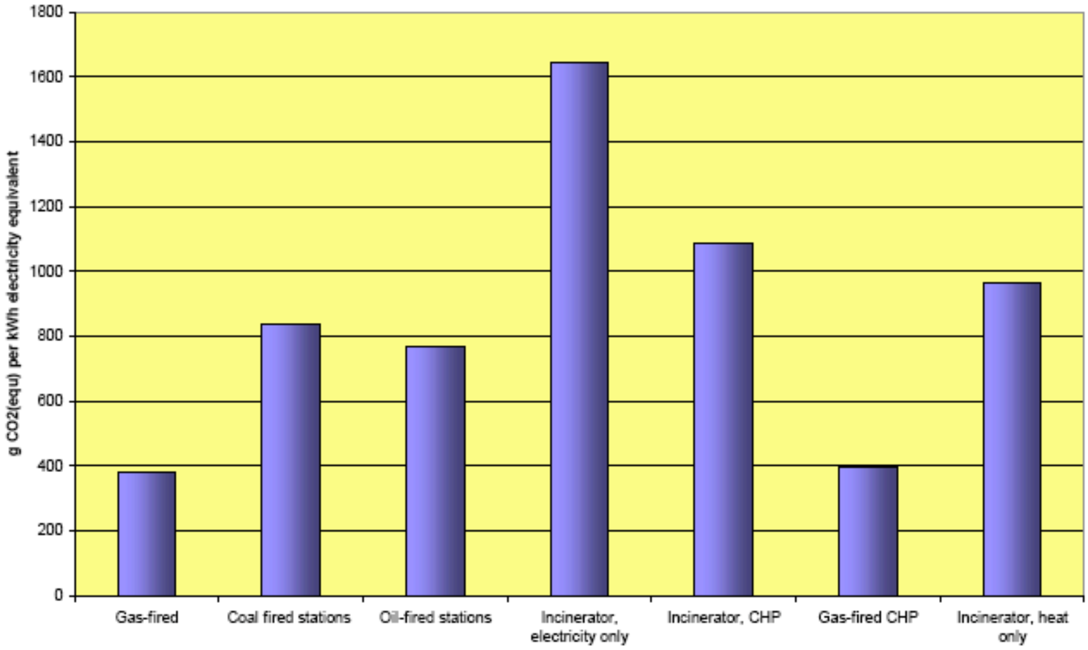
The Danes, like the other Scandinavian countries do not represent a good advert for incineration instead they clearly demonstrate how countries can become trapped in a cycle of incineration undermining recycling – even when the evidence shows that recycling is better and even incineration taxes are relatively powerless to change the situation once it has arisen.

Climate Change and Incineration:

Climate change is a major threat and it is important to consider the role of incineration in relation to the challenge we face. There are conflicting claims made about the total emissions of greenhouse gases from incinerators and the literature reviews do not consider this important issue in very much detail. Certainly no resolution is reached.

The graph below, from research by Eunomia (Hogg and Eunomia Research & Consulting Ltd 2006) for Friends of the Earth shows how electricity only incinerators produce about twice as much carbon dioxide per kWh as coal fired power stations.

Figure 3: Includes CO_2 from Biogenic Carbon, Heat=0.4 x Electricity

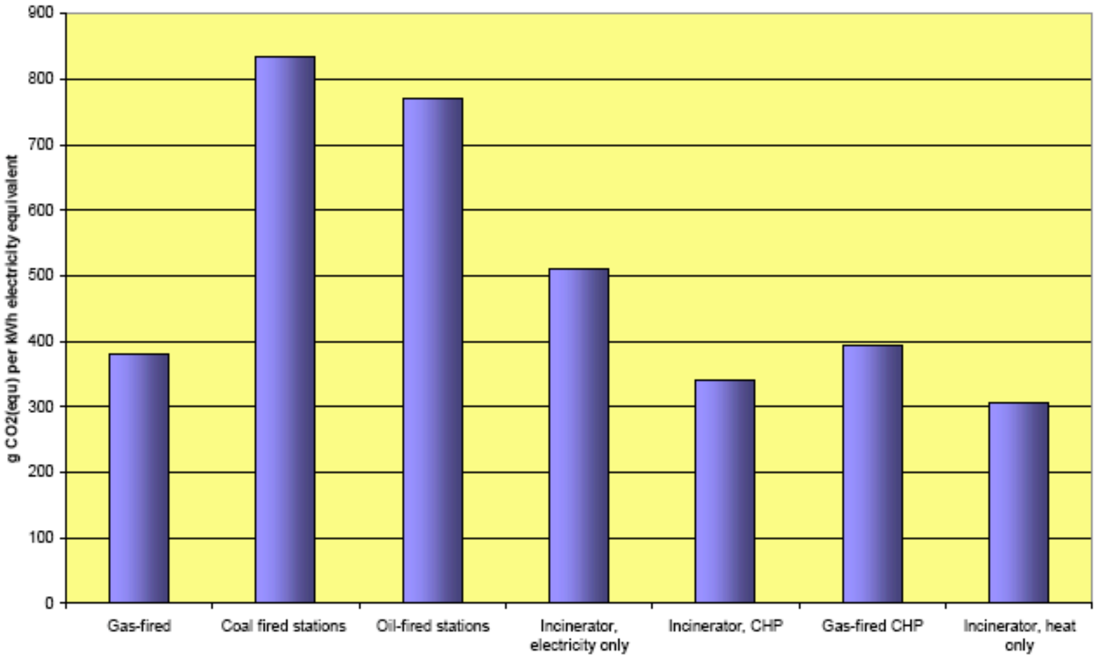


Combined Heat and Power CHP schemes have significant benefits over those that only generate electricity. The UK Environment Agency IPPC Guidance (Environment Agency 2004), for example, shows that waste heat for CHP or district heating has the potential to increase overall thermal efficiencies from approx. 20% to 75%. This, in turn has a very great impact on total carbon dioxide emissions. However incinerators still do rather badly even as CHP or heat producers - producing more than 2.5 times as much carbon dioxide as gas fired CCGT stations - but much better than when the extra heat is just dumped into the atmosphere.

For completeness it should be this graph includes biogenic carbon. This is the appropriate approach to adopt when accounting for incinerator emissions. The incineration industry, and some consultants, ignore this element of the emissions claiming that it is 'climate neutral' but that would only be valid in an incineration life cycle assessment if the climate change impacts of a biogenic carbon dioxide molecule was different from any other carbon dioxide molecule. Furthermore a recent editorial in the International Journal of Life Cycle Assessment by Rabl and other leading LCA experts (Rabl, Benoist et al. 2007) confirms the appropriate approach is to include this component.

Even if biogenic carbon is excluded most incinerators still produce more carbon dioxide per unit of electricity than gas fired power stations:

Figure 1: Excludes CO_2 from Biogenic Carbon, Heat=0.4 x Electricity



Incinerators that utilise the heat effectively for district heating or CHP can be marginally more efficient in carbon dioxide terms than combined cycle gas turbines power generation. This is consistent with the COWI review which shows that the use of heat that would otherwise be wasted in district heating or combined heat and power schemes is essential to the economics and efficiency of incineration schemes.

There are several reasons to question the appropriateness of heat recovery systems similar to those cited in the review in the particular context of South Africa.

Firstly, Karlsson et al. (Karlsson and Gustavsson 2003) raised significant doubts about whether district heating/ CHP schemes are the most efficient way to deliver space heating in any case, even in Europe.

Karlsson used a systems approach to compare different heating systems from a consumer perspective. The whole energy system was considered from natural resources to the required energy services. District heating, electric heat pumps, electric boilers, natural gas, oil or pellet-fired local boilers were considered when supplying heat to a detached house. The district heat production included wood-chip-fired and natural-gas-fired cogeneration plants. Electricity other than co-generated electricity was produced in wood-chip and natural-gas-fired stand-alone power plants. The analysis included four tax scenarios, as well as the external cost of environmental and health damage arising from energy conversion emission based on the ExternE study of the European Commission. The most cost-efficient systems when the external cost and taxes were excluded were the natural gas and oil boiler systems, followed by the heat pump and finally the district heating systems.

It is also shown by Ertesvag (Ertesvag 2007) that some, but not all, CHP cases are exergetically[9] beneficial to separate generation.

Specifically their results indicate that CHP systems with low temperature heat delivery (as many waste incinerators) have marginal or no benefits compared to separate generation of heat and electricity.

One of the reasons that CHP/ DH schemes are not always environmentally advantageous is the relatively high transmission losses. Comakli et al. (Comakli, Yuksel et al. 2004) found that even in a relatively advanced and modern district heating system on a university campus the exergy losses forming during heat distribution were about 16% of total exergy in the system.

A final consideration is that the heat from incineration could, in principle, be used by absorbtion chillers for air conditioning applications in South Africa. The COWI review accepts that these options are "*in general poorly exploited*". It does not, however, explain the reasons for this which include the very low efficiencies of these chillers. Also important is the fact that absorbtion chillers alone cannot return water at a low enough temperature and so must be used with an air or water-cooling system which dumps the heat to atmosphere.

In conclusion it is considered that CHP/ District heating is unlikely to be a viable option for most of South Africa and thus any incinerators would be fare worse than conventional electricity generation for climate change impacts. Recycling is a far more effective way of addressing the challenges of climate change, A recent report by the UK Government sponsored Waste Resources Action Programme 'WRAP' (Wenzel 2006) concluded:

"Further analysis by WRAP of the research findings has provided an assessment of the relative greenhouse gas savings associated with current UK levels of recycling for paper/cardboard, glass, plastics, aluminium and steel.

Again, the results are clear and positive. The UK's current recycling of those materials saves between 10-15 million tonnes of CO_2 equivalents per year compared to applying the current mix of landfill and incineration with energy recovery to the same materials. This is equivalent to about 10% of the annual CO_2 emissions from the transport sector, and equates to taking 3.5 million cars off UK roads."

[9] the exergy of a system is the maximum work possible during a process that brings the system into equilibrium with a heat reservoir

Economic Instruments and Alternative Policy Measures for South Africa:

A draft policy paper on the possible use of economic instruments, 'EIs', for fiscal reform (National Treasury 2006), and two documents on the possible use of EIs in waste recycling and health care waste management (Department of Environmental Affairs and Tourism 2006; Department of Environmental Affairs and Tourism 2006), seem to suggest that the use of such instruments is being considered by government for solid waste management (Godfrey and Nahman 2007).

EIs should rather be seen as policy instruments driving behaviour, and any revenues generated should be subjected to the normal fiscal process (National Treasury, 2006).

It is true that some authors (Bell and Russell (2002), Russell and Vaughan (2003)) argue that the required level of institutional capacity is currently lacking in most developing countries. For example, in South Africa, as in other developing countries, they say that there is insufficient capacity for the monitoring and billing of waste services. Many municipalities, for example, don't bill for the disposal of waste to landfill, due to a lack of resources, or fear of an increase in illegal dumping due to a lack of the necessary monitoring and enforcement capacity. It is argued that EIs are unlikely to be effective in these circumstances.

It is, however, vital for South Africa to develop an effective regulatory and reporting regime and the establishment of this regime, incorporating appropriate EIs as discussed above is likely to be significantly more straightforward, and quicker, than developing the complete "command and control" regime, together with associated technical and scientific support. It has been necessary to use taxation regimes to restrict the growth of incineration and landfill in Europe and it is unlikely that South Africa will manage without some fiscal control mechanisms in the regulatory basket also. Taxes raised it his manner could usefully be hypothecated to environmental regulation and control.

Cost sensitivity of disposal

When considering the cost of off-site hazardous waste disposal generators clearly have to consider disposal fees and shipments costs. However with an appropriate regulatory structure based upon the "polluter pays" principle generators of hazardous waste can also be held liable for the cost of cleanup if the waste disposal site contaminates the environment after closure or abandonment of a production or disposal site. Alberini et al. (Alberini and Frost 2007) empirically examined the sensitivity of individual hazardous waste generators to these categories of costs, exploiting the variation across states in factors influencing disposal costs, and in the structure of the liability imposed on waste generators by state laws. They modelled the scenarios to predict the waste management method (incineration or landfill disposal) and the state of destination for shipments of halogenated solvent waste used for metal cleaning in manufacturing and reported in the Toxic Release Inventory in 1988-1990. Their conclusions were that waste generators respond to transportation costs and to proxies for current disposal costs. They also reported that generators find the concurrent presence of strict and joint-and-several liability a deterrent – and said that this deterrent effect does not vary with the wealth of the firm or the volume of the waste shipped.

Similarly the econometric analysis presented by Sigman (Sigman 1996) suggests that firms' generation of chlorinated solvent waste is very sensitive to waste management costs. Despite large elasticity estimates, however, the analysis predicts only a small effect of state taxes on waste generation because the taxes are low relative to total waste management costs. The econometric analysis also suggests that state taxes alter facilities' waste management choices. In particular, high taxes on disposal reduce reliance on disposal relative to treatment of wastes.

Emissions from Incineration and Potential Health Impacts

Section 24 of the Constitution of the Republic of South Africa (Act 108 of 1996) states that the people of South Africa have a right to an environment that is not detrimental to human health, and imposes a duty on the state to promulgate legislation and to implement policies to ensure that this right is upheld (South African Department of Environmental Affairs and Tourism (DEAT) 1999)

COWI, citing the National Research Council (National Research Council 2000) say:
"Although emissions from newer, well-run facilities are expected to contribute little to environmental concentrations and to health risks, the same might not be true for some older or poorly run facilities."

This is hardly reassuring given the low level of certainty expressed considered together with the experience of how badly incineration facilities in South Africa have been run in the recent past.

Emissions from Municipal Waste Incineration

In fact there are a huge range of emissions from even municipal incineration systems - and the possible impacts of most of these are poorly, if at all, understood. Jay (Jay and Stieglitz 1995) found, for example, concentrations of about 250 compounds[10] in the order of 50 ng/Nm^3 in the emissions of a municipal waste incinerator.

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[10] K. Jay and L. Steiglitz, "Identification and Quantification of Volatile Organic Components in Emissions of Waste Incineration Plants," CHEMOSPHERE Vol. 30, No. 7 (1995), pgs. 1249-1260 identified the following volatile organic chemicals emitted from a municipal waste incinerator: pentane; trichlorofluoromethane; acetonitrile; acetone; iodomethane; dichloromethane; 2-methyl-2-propanol; 2-methylpentane; chloroform; ethyl acetate; 2,2-dimethyl-3-pentanol; cyclohexane; benzene; 2-methylhexane; 3-methylhexane; 1,3-dimethylcyclopentane; 1,2-dimethylcyclopentane; trichloroethene; heptane; methylcyclohexane; ethylcyclopentane; 2-hexanone; toluene; 1,2-dimethylcyclohexane; 2-methylpropyl acetate; 3-methyleneheptane; paraldehyde; octane; tetrachloroethylene; butanoic acid ethyl ester; butyl acetate; ethylcyclohexane; 2- methyloctane; dimethyldioxane; 2-furanecarboxaldehyde; chlorobenzene; methyl hexanol; trimethylcyclohexane; ethyl benzene; formic acid; xylene; acetic acid; aliphatic carbonyl; ethylmethylcyclohexane; 2-heptanone; 2-butoxyethanol; nonane; isopropyl benzene; propylcyclohexane; dimethyloctane; pentanecarboxylic acid; propyl benzene; benzaldehyde; 5-methyl-2-furane carboxaldehyde; 1- ethyl-2-methylbenzene; 1,3,5-trimethylbenzene; trimethylbenzene; benzonitrile; methylpropylcyclohexane; 2- chlorophenol; 1,2,4-trimethylbenzene; phenol; 1,3-dichlorobenzene; 1,4-dichlorobenzene; decane; hexanecarboxylic acid; 1-ethyl-4-methylbenzene; 2-methylisopropylbenzene; benzyl alcohol; trimethylbenzene; 1-methyl-3-propylbenzene; 2-ethyl-1,4-dimethylbenzene; 2-methylbenzaldehyde; 1-methyl-2-propylbenzene; methyl decane; 4-methylbenzaldehyde; 1-ethyl-3,5-dimethylbenzene; 1-methyl-(1-pro-penyl)benzene; bromochlorobenzene; 4-methylphenol; benzoic acid methyl ester; 2-chloro-6-methylphenol; ethyldimethylbenzene; undecane; heptanecarboxylic acid; 1-(chloromethyl)-4-methylbenzene; 1,3- diethylbenzene; 1,2,3-trichlorobenzene; 4-methylbenzyl alcohol; ethylhex anoic acid; ethyl benzaldehyde; 2,4- dichlorophenol; 1,2,4-trichlorobenzene; naphthalene; cyclopentasiloxanedecamethyl; methyl acetophenone; ethanol-1-(2-butoxyethoxy); 4-chlorophenol; benzothiazole; benzoic acid; octanoic acid; 2-bromo-4- chlorophenol; 1,2,5-trichlorobenzene; dodecane; bromochlorophenol; 2,4-dichloro-

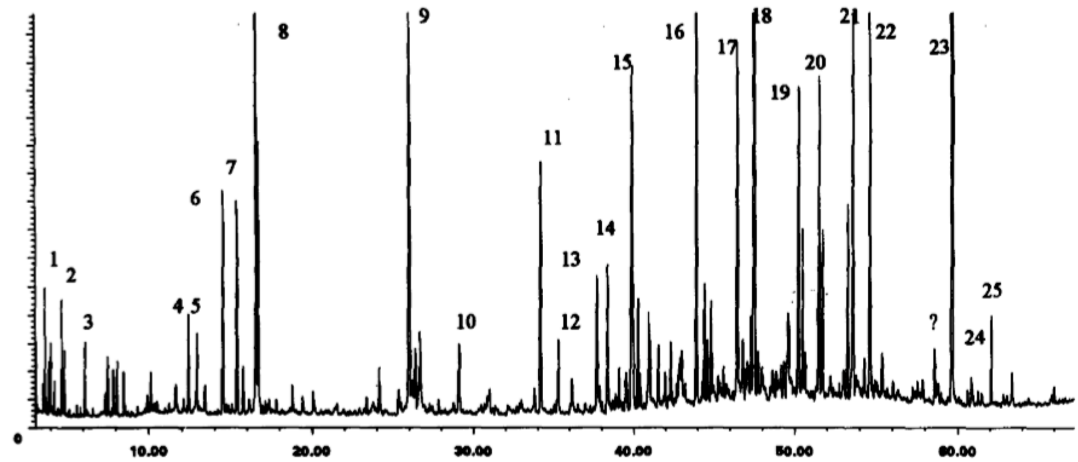


Fig. 3: Total Ion Chromatogram of the Condensate of 428 l of Offgas from Incineration Plant A.

The most intense peaks on the chromatograph are: (1) benzene, (2) chloroiodomethane, (3) toluene, (4) elemental iodine, (5) chiorobenzene, (6) ethyl benzene, (7) xylene, (8) diiodomethane, (9) diiodoethene, (10) chloroiodopentane, (11) diiodochloromethene, (12) hydroxybenzaldehyde, (13) undecane, (14) diiodobromomethane, (14) napththalene, (16) benzoic acid, (17)trichlorobenzene, (18) triiodomethane, (19) methyl naphthalene, (20) biphenyl, (21) chloroiodoethylbenzene (-xylene), (22) dibenzofurane+ pentachlorophenol, (23) diiodostyrene, (24) phenanthrene, (25) hexadecanoic acid, (27) octadacanoic acid, (27) tetracosane (4.46 pg), (28) bis-(2-ethylhexyl) phtlalate.

Worryingly 58% of the compounds could in the flue gas could not even be identified.

6-methylphenol; dichloromethylphenol; hydroxybenzonitrile; tetrachlorobenzene; methylbenzoic acid; trichlorophenol; 2- (hydroxymethyl) benzoic acid; 2-ethylnaphthalene-1,2,3,4-tetrahydro; 2,4,6-trichlorophenol; 4- ethylacetophenone; 2,3,5-trichlorophenol; 4-chlorobenzoic acid; 2,3,4-trichlorophenol; 1,2,3,5- tetrachlorobenzene; 1,1'biphenyl (2-ethenyl-naphthalene); 3,4,5-trichlorophenol; chlorobenzoic acid; 2-hydroxy- 3,5-dichlorobenzaldehyde; 2-methylbiphenyl; 2-nitrostyrene(2-nitroethenylbenzene); decanecarboxylic acid; hydroxymethoxybenzaldehyde; hydroxychloroacetophenone; ethylbenzoic acid; 2,6-dichloro-4-nitrophenol; sulphonic acid m.w. 192; 4-bromo-2,5-dichlorophenol; 2-ethylbiphenyl; bromodichlorophenol; 1(3H)- isobenzofuranone-5-methyl; dimethylphthalate; 2,6-di-tertiary-butyl-p-benzoquinone; 3,4,6-trichloro-1-methyl- phenol; 2-tertiary-butyl-4-methoxyphenol; 2,2'-dimethylbiphenyl; 2,3'-dimethylbiphenyl; pentachlorobenzene; bibenzyl; 2,4'-dimethylbiphenyl; 1-methyl-2-phenylmethylbenzene; benzoic acid phenyl ester; 2,3,4,6- tetrachlorophenol; tetrachlorobenzofurane; fluorene; phthalic ester; dodecanecarboxylic acid; 3,3'- dimethylbiphenyl; 3,4'-dimethylbiphenyl; hexadecane; benzophenone; tridecanoic acid; hexachlorobenzene; heptadecane; fluorenone; dibenzothiophene; pentachlorophenol; sulphonic acid m.w. 224; phenanthrene; tetradecanecarboxylic acid; octadecane; phthelic ester; tetradecanoic acid isopropyl ester; caffeine; 12- methyltetradecacarboxylic acid; pentadecacarboxylic acid; methylphenanthrene; nonedecane; 9-hexadecene carboxylic acid; anthraquinone; dibutylphthalate; hexadecanoic acid; eicosane; methylhexadecanoic acid; fluoroanthene; pentachlorobiphenyl; heptadecanecarboxylic acid; octadecadienal; pentachlorobiphenyl; aliphatic amide; octadecanecarboxylic acid; hexadecane amide; docosane; hexachlorobiphenyl; benzylbutylphthalate; aliphatic amide; diisooctylphthalate; hexadecanoic acid hexadecyl ester; cholesterol.

Emissions from Hazardous Waste Incineration

EPA reports (United States Environmental Protection Agency 2001) research to identify the types and quantities of organics emitted from hazardous waste combustion facilities (EPA 1998e; Ryan and others, 1996 and 1997; Midwest Research Institute and A.T. Kearney 1997; Lemieux and others 1999). These research efforts indicate frequent detection of volatile and semi volatile organics including chloro-, bromo-, and mixed bromochloro-alkanes, alkenes, alkynes, aromatics, and polyaromatics, D/Fs, PAHs, PCBs, phthalates, nitrogenated and sulphonated organics, and short-chain alkanes (such as methane and propane). EPA reports frequent detection of chlorinated and brominated alkanes and alkenes (such as chlorinated ethenes), and suggests that chlorinated ethenes can serve as potential indicators of D/F formation (EPA 1998e). EPA supports ongoing research to improve the identification and quantification of organic emissions.

EPA concludes (United States Environmental Protection Agency 2001) with the rather worrying comment:

"However, uncertainty remains regarding the full suite of organic emissions from hazardous waste combustion facilities and the potential risks associated with those emissions."

The importance of the Total Organic Emissions determination for site-specific risk assessments cannot be over-emphasized. Studies (EPA 1976; Pellizzari and others 1980) have shown that analyses based strictly on target analyte lists may account for less than 20% of the total organic material in an emission sample.

Without a Total Organic Emissions determination, a final risk assessment report cannot explain how much of the total stack emissions have been evaluated for risk, significantly complicating the risk management decision.

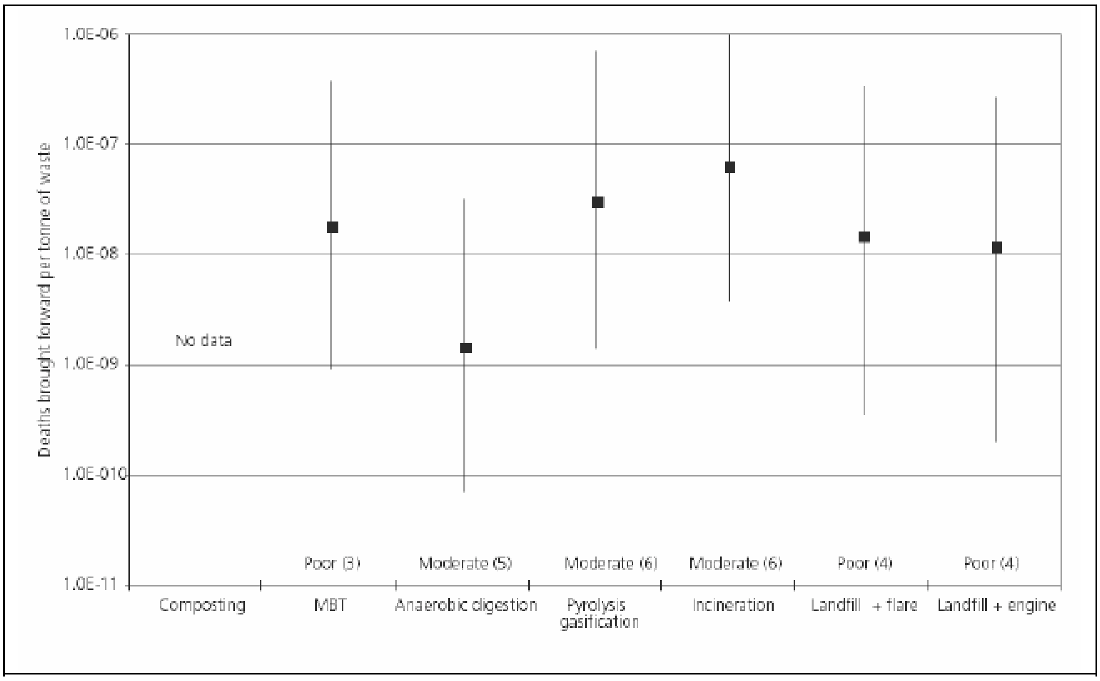
EPA reported in 2001 (United States Environmental Protection Agency 2001) that Linak has documented PCC exit total hydrocarbon levels in excess of 10,000 ppm during very intense transient puffs arising from batch feed operations at a pilot-scale unit, and has performed chemical analysis to show that the puffs can contain numerous hazardous compounds, even though adequate DREs (>99.99%) may be achieved (Linak and others 1987).

The concern with these compounds is that they are likely to be emitted as, or transported by, ultra-fine particles and inhaled. The respirable fraction, ($PM_{2.5}$ and ultrafine $PM_{1.0}$, $PM_{0.1}$) can then enter the non-ciliated alveolar regions and deposit deep within the lungs (Cormier, Lomnicki et al. 2006) where the hazardous chemicals can be passed directly to the blood stream thus exerting effects are very low concentrations – particularly, for example, if the receptor is pregnant or ill.

Relative Health Impacts of Waste Management Options:

A review undertaken for DEFRA of the health effects of waste management by consultants Enviros (and others historically sympathetic to incineration)

(Enviros Consulting Ltd., University of Birmingham et al. 2004) concluded, so far as it is possible to do so given the uncertainty of the data, that incineration had the highest impact in terms of deaths brought forward compared with other waste management options:



There is good reason to believe that this report seriously understates the damage associated with incineration as it has assumed compliance with permit conditions, has not taken into account upset conditions or start-up emissions; does not include the latest health based data on particulate impacts and has considered only limited emissions.

Fine particulate matter (PM) and ultrafine PM, which have been documented to be related to cardiovascular disease, pulmonary disease, and cancer, have more recently become the focus of research. Cormier et al. (Cormier, Lomnicki et al. 2006) wrote:

Fine PM and ultrafine PM are effective delivery agents for PAHs, CHCs, and toxic metals. In addition, it has recently been realized that brominated hydrocarbons (including brominated/chlorinated dioxins) , redox-active metals, and redox-active persistent free radicals are also associated with PM emissions from combustion and thermal processes.

Clearly there are a vast number of contaminants in the emissions of incinerators (and cement kilns) as described above. All of these can be carried into the body by particulates as described by Cormier.

Another concern about most existing health studies is that they have looked at more serious endpoints such as cancer etc. There are many other effects of concern which maybe caused by exposure to emissions from thermal treatment which have been less carefully reviewed. Recent work by Miyake (Miyake, Yura et al. 2005)in Japan, for example, concluded:

The findings suggest that proximity of schools to municipal waste incineration plants may be associated with an increased prevalence of wheeze, headache, stomach ache, and fatigue in Japanese children

The National Research Council on Health:

The National Research Council report cited by COWI above is an important review by an arm of the National Academy of Sciences which was established to advise the U.S. government. It concluded that it was not only the health of workers and local populations that could be affected by incinerators. The NRC reported that populations living more distantly from incinerators are also likely to be exposed to some incinerator pollutants. For example,

"*Persistent air pollutants, such as dioxins, furans and mercury, can be dispersed over large regions – well beyond the local areas and even the countries from which the sources first emanate.... Food contaminated near an incineration facility might be consumed by people close to the facility or far away from it. Thus, local deposition on food might result in some exposure of populations at great distances, due to transport of food to markers. However, distant populations are likely to be more exposed through long-range transport of pollutants and low-level, widespread deposition on food crops at locations remote from a source incineration facility*."

and,

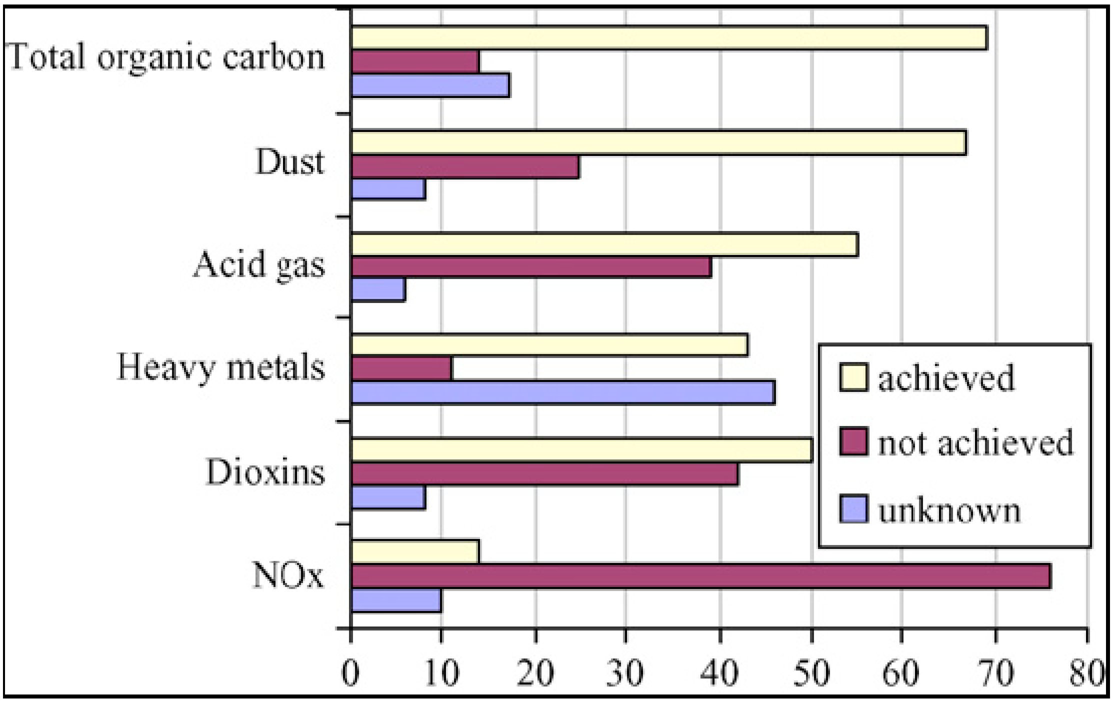
"*The potential effects of metals and other pollutants that are very persistent in the environment may extend well beyond the area close to the incinerator. Persistent pollutants can be carried long distances from their emission sources, go through various chemical and physical transformations, and pass numerous times through soil, water, or food. Dioxins, furans, and mercury are examples of persistent pollutants for which incinerators have contributed a substantial portion of the total national emissions. Whereas one incinerator might contribute only a small fraction of the total environmental concentrations of these chemicals, the sum of the emissions of all the incineration facilities in a region can be considerable The primary pathway of exposure to dioxins is consumption of contaminated food, which can expose a very broad population. In such a case, the incremental burden from all incinerators deserves serious consideration beyond a local level*."

Compliance:

The NRC emphasises the importance of facilities being well run if there is to be any reassurance about possible health impacts and the COWI review gives the impression that incinerators in Europe always operate to the standards in the Waste Incineration Directive. The reality is that this is often not the case. In the UK, for example, no incinerators have operated in complete compliance with their operating permits. When Greenpeace (Greenpeace 2001) reviewed the performance of these incinerators for 1999/2000 it was found that there were a total of 546 self-reported breaches of permit conditions:

Incinerator	dioxin	HCl	SO2	NOx	CO	Part	Total
Dudley	0	67	8	2	3	0	80
Wolverhampton	0	32	21	1	12	2	68
Cleveland	0	1	0	0	5	5	11
Coventry	0	19	8	12	46	5	90
Tyseley, Birmingham	0	9	0	4	2	0	15
Nottingham	0	13	14	24	1	1	53
Sheffield	0	33	12	11	99	1	156
Stoke	0	28	11	3	4	0	46
Edmonton, London	0	7	1	0	9	2	19
Lewisham, London	0	4	2	2	0	0	8
Total	0	213	77	59	181	16	546

In France a large proportion of incinerators do not comply with NOx , dioxin and acid gas emission standards as illustrated below (Autret, Berthier et al. 2007). Emission limit values (ELV) of acid gas are not achieved by 39% of French incinerators, dioxin ELV by 42% and NO*x* ELV by nearly 80%. The authors conclude that these figures "*strongly suggest that comprehensive flue gas treatment works need to be done*" (!).



The following list ranks additional the individual legal requirements that are not achieved by French incinerators as of June 2003 (Autret, Berthier et al. 2007):

• 95% incineration plants are concerned by Article 6.3: plants shall have and operate an automatic system to prevent waste feed;
• 70% incineration plants are concerned by Article 10: controls and monitoring of NO*x*, conditions and mass concentrations of emissions of NO*x* into air;
• 70% incineration plants are concerned by Article 8.7: storage capacity shall be provided for contaminated water arising from spillage or fire-fighting operations;
• 50–60% incineration plants are concerned by Article 6: each line of the incineration plan shall be equipped with at least one auxiliary burner;
• 42% incineration plants are concerned by Article 7: incineration plants shall be designed, equipped, built and operated in such a way that the emission limit value of dioxins is not exceeded in the exhaust gas.

When incinerators in Europe, with long established regulatory regimes are so badly and regularly out of compliance there can be no reassurance that plants in South Africa can operate safely.

Health Reviews:

This section of the response has touched upon some of the issues associated with emissions and health it is not, however, the place for a detailed analysis of the potential health impacts which may arise from exposure to emissions from incineration. There are, in any case, two good reviews which are strongly recommended for consideration as part of the consultation process:

1) Allsopp, M., P. Costner, et al. (2001). Incineration and Human Health - State of Knowledge of the Impacts of Waste Incinerators on Human Health, Greenpeace Research Laboratories, University of Exeter, UK. (Allsopp, Costner et al. 2001; Allsopp, Costner et al. 2001)

2) Thompson, J. and H. Anthony (2006). The Health Effects of Waste Incinerators Moderators: Dr Jeremy Thompson and Dr Honor Anthony. 4th Report, British Society for Ecological Medicine. (Thompson and Anthony 2006) (and currently being updated).

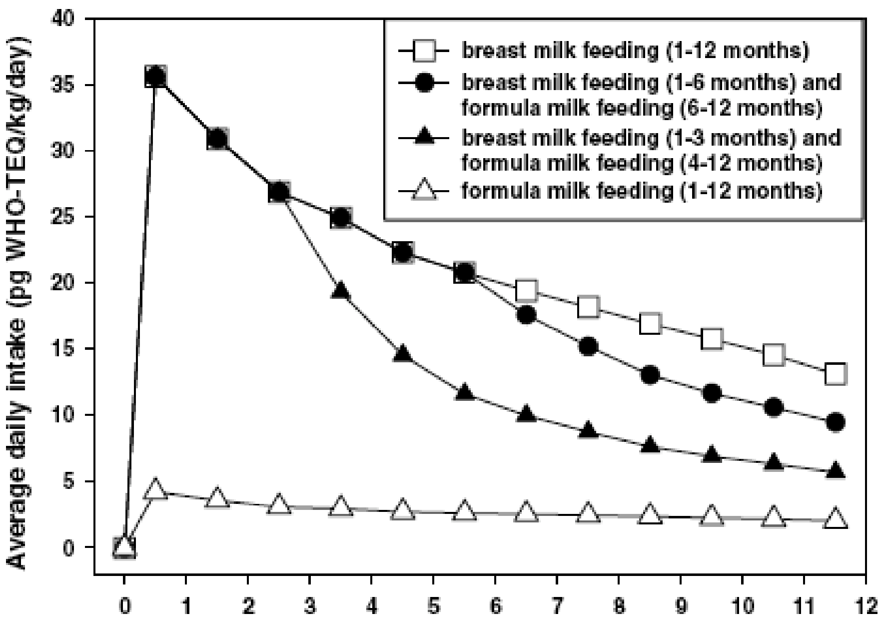
Dioxins and PCB Emissions

Until very recently municipal solid waste incinerators were the largest source of dioxin emissions to air in Europe, the US and Japan (Kulkarni, Crespo et al. 2007). A 1995 emission inventory for the UK, for example, estimated annual releases between 560 and 1100 g I-TEQ. The review confirmed that municipal solid waste (MSW) incinerators were responsible for up to 80% of these emissions (Douben 1997).

These high emission levels have resulted in a large proportion of the population exceeding acceptable daily intakes for dioxin like compounds.

The WHO defined in 1998 a tolerable daily intake of 1 - 4 pg TEQ/kg body weight (including dioxin-like PCBs), meaning that a large part of European citizens is currently exceeding the tolerable daily intake value. [LfU 2002] (Sander, Tebert et al. 2007).

A very recent study by Bilau et al of dietary intakes in Flanders (Belgium) for example, (Bilau, Matthys et al. 2008) reports the median (95th percentile) estimated intakes of dioxin-like contaminants were 2.24 (4.61), 2.09 (4.26), and 1.74 (3.53) pg CALUX TEQ/kgbw/d for, respectively adolescents, mothers and adults. They comment that these data are in the same range as those found in other European studies. The CALUX-TEQ results of respectively 59.8%, 53.7% and 36.2% of the adolescent, mother and adult population exceed the tolerable weekly intake (TWI) of 14 pg WHO-TEQ /kgbw/w, as derived by the Scientific Committee on Food. The exposure of breast fed babies is very much higher still – Hsu (Hsu, Guo et al. 2007), for example, showed that exposure to new-born babies for the first month of breast feeding can be more than 17 times the TDI:



Bouwman (Bouwman 2003) quoting work by Schecter in 1990 (Schecter, Startin et al. 1990) reports that the only published environmental data on chlorinated dioxins and dibenzofurans were an analysis done on breast milk. This showed for black rural South Africans (n=6) and white urban South Africans (n=18), that the mean dioxin levels were 279.8 and 355.6 ng/kg in milk fat, respectively. For the dibenzofurans the levels were 20.4 and 23.1 ng/kg in milk fat, respectively. As I-TEQs the results were 8.3 and 12.6 ng/kg which encouragingly were the lowest results reported. Schecter said that these were not necessarily representative samples of the populations and that caution should be exercised in light of the small number of women sampled and the small number of specimens analysed.

It is, however, notable by contrast that in Japan, where reliance on incineration has been particularly heavy has some of the highest breast milk contamination levels in the world (Tanabe and Kunisue 2007). Furthermore Kunisue reported last year (Kunisue, Muraoka et al. 2006) that the concentrations of organochlorines such as dioxins and related compounds in human breast milk were comparable to or slightly higher than the data obtained during 1998, indicating that the levels of these contaminants in Japanese human breast milk have not decreased since 1998

The fact that existing levels of human exposure to dioxin are already too high is not included in the COWI (or SINTEF) reviews. The basic thrust of the COWI paper is rather that the incineration industry has now "*solved*" the dioxin problem. This claim merits careful consideration and a short historical review may be helpful.

Whilst dioxins were first found in incinerator emissions by Olie in 1977 (Olie, Vermeulen et al. 1977) it was originally it had been asserted that anything so small as a few nanograms of dioxins couldn't possibly be a problem. That was proved to be badly wrong because dioxins bio-accumulate – particularly in cattle and milk, see, for example (Webster and Connett 1989).

It was then argued that since dioxins break down at temperatures above 800ºC or 1000ºC that as long as the combustion temperatures were kept high the problem would be solved.

That approach failed because the majority of dioxins are created by a process of *de novo* synthesis when the exhaust gases cool down – particularly over the 200ºC-400ºC range (Altwicker and Milligan 1993; Stanmore 2004).

Next, it was said that "*modern air pollution control equipment*" - rapid quenches and carbon injection - had solved the problem. But that is not correct either. It has now been established that the injection of activated carbon increase the availability of carbon and catalysts (i.e. $CuCl_2$, $FeCl_2$, etc.) in the cake on fabric filters and is at a temperature that allows de novo synthesis. Thus activated carbon injection significantly increases the total dioxin formation (Chang and Lin 2001).

Unfortunately the need to recover heat from incinerators to improve the economics and to balance the environmental and economic impacts of their emissions tends to increase dioxin generation. In a typical waste heat boiler the PCDD/F concentration at boiler inlet is 1 ng-TEQ/Nm3 and at boiler outlet is 5 ng-TEQNm3 due to the de novo synthesis of PCDD/Fs in the boiler section (Buekens and Huang 1998).

So while dioxin emissions to air can be reduced this is often at the expense of increasing the total releases of dioxins produced by an incinerator. This data is also based on the assumption that the incinerators operate under steady state conditions continuously. That is not a reasonable assumption, as is shown below. Firstly though it is important to consider what happens to the dioxin in the residues.

The landfill disposal of the highly dioxin contaminated residues, particularly the fly ash, can result in exposures at some distance from the incinerator. Recent research has shown, for example, that dioxin contaminated ash blown from landfill sites can presents a dioxin risk to local children (Macleod, Duarte-Davidson et al. 2006). The authors wrote "*Preliminary modeling suggested that indirect exposures from PCDDs/PCDFs at the 95th percentile level for the site where APC deposition rates were highest could potentially exceed the tolerable daily soil intake (TDSI) but this warrants further study given the model limitations*." No further study has yet been undertaken.

An integrated approach to sustainable waste management should take the occurrence of PCDD/F in all emissions into account. A comprehensive recent review by Vehlow (Vehlow, Bergfeldt et al. 2006) compiles published data on concentration ranges of PCDD/F and the related compounds polychlorinated biphenyls (PCB), chlorinated benzenes and phenols, as well as polyaromatic hydrocarbons (PAH) in solid residues from waste incineration in grate furnaces and their development since 1985. COWI make no reference to this review in their literature search.

The inventory data are based on steady state operations but this does not reflect the real emissions because the majority of dioxins are emitted during:

- start-up and shut-down when filters are often bypassed in any case)(Tejima, Karatsu et al. 1993; Gass, Wilken et al. 2003; Hunsinger, Seifert et al. 2003; Nordsieck, Neuer-Etscheidt et al. 2003; Wilken, Marsch et al. 2003; Neuer-Etscheidt, Nordsieck et al. 2006; Tejima, Nishigaki et al. 2007; Wang, Hsi et al. 2007); and
- "*upset*" or, more euphemistically, "*transient*" conditions i.e. when the steady-state combustion is perturbed.

The COWI report included the comment:

"*In future regulatory decision-making, greater consideration should be given to emission levels achieved in actual performance of incinerators, including process upset conditions (described earlier). In monitoring for compliance or other purposes, data generated during the intervals in which a facility is in start-up, shutdown, and upset conditions should be included in the hourly emission data recorded and published. It is during those times that the highest emissions may occur, and omitting them systematically from monitoring data records does not allow for a full characterization of the actual emissions from an incineration facility.*"

This is sound advice and was copied verbatim from the National Research Council (National Research Council 2000) review on Waste Incineration (even including the '*described earlier*' – NSC had done so COWI hadn't). Unfortunately neither did COWI explore the implications of the NRC warning for dioxin emissions from modern incinerators.

It is now well established that transient, non-steady-state conditions in the incinerator systems can induce dramatic concentration increases of products of incomplete combustion (PIC's) such as dioxins (De Fre and Rymen 1989; Halonen, Tuppurainen et al. 1997; Hart 2001; Zimmermann, Blumenstock et al. 2001; Gullett, Touati et al. 2006; Neuer-Etscheidt, Orasche et al. 2007) Elevated PCDD/PCDF formation levels in the raw gas have been observed during and after transiently disturbed operation conditions at municipal waste incineration plants (Tejima, Karatsu et al. 1993; Zimmermann, Blumenstock et al. 2001; Hunsinger, Jay et al. 2002; Weber, Sakurai et al. 2002). In many of these cases so called memory effects could be observed.

Because incinerator operators and regulators avoid measuring emissions during those problem stages (sampling normally takes place only during stable operating conditions. (Lothgren and van Bavel 2005)); and they are exempt from compliance with emission standards under many regulatory regimes, including that in Europe; it is not possible to be confident how much dioxin would be emitted from any plant in practice.

Two very recent papers (Tejima, Nishigaki et al. 2007) and (Wang, Hsi et al. 2007) published in Chemosphere give some indication of the likely emissions that can be released during start-up periods.

Tejima tested a modern Japanese incinerator equipped sophisticated dioxin abatement equipment. It was found that just a single incinerator start-up released more dioxins to air than operating the incinerator in steady state conditions non-stop for over 2 months. Contamination levels of ash were also increased. If an incinerator was started more than four times a year the majority of the dioxin emissions are likely to come from the unregulated start-up emissions.

Wang (Wang, Hsi et al. 2007) investigated the PCDD/F characteristics of incinerators during start-up of a continuous MSW incinerator for two years. The elevated PCDD/F emissions of the MSWI during start-up could reach 96.9 ng I-TEQ N m^3 (nearly 1,000 times the EU limit of 0.1 ng/m^3) and still maintained a high PCDD/F emission (40 times higher than the Taiwan emission limit) even 18 h after the injection of activated carbon, indicating the memory effect.

From the four MSW incinerators they studied the estimated annual PCDD/F emission from normal operational conditions was 0.112 g I-TEQ. However they calculated that one start-up procedure can generate 60% of the PCDD/F emissions for one whole year of normal operations. Furthermore the PCDD/F emission from the start-ups of some incinerators was <u>at least two times larger than that of a whole year's normal operations</u>. This was even without consideration for the PCDD/F emission contributed by the long lasting memory effect.

There are still few good data showing the levels and frequency of releases during combustion upsets but the emissions are likely to be significant and potentially very high. As an example - some testing of the 1983 Columbus Ohio incinerator in the early 1990s (Lorber, Pinsky et al. 1998) showed that absolutely enormous quantities of dioxins can be released when operations went wrong. This single incinerator released more dioxins to air (c 1,000 g) that the entire emissions of the UK or West Germany according to the dioxin inventories at that time.

It is not only start ups which can cause problems in modern incinerators (or cement kilns). In order to reach the desired high levels of incineration efficiency as well as plant reliability, optimized operation of an MSW incinerator through a sophisticated and intelligent process control is required. The optimization of such a process is a complicated task due to the inherent instability of the MSW incineration. Indeed, the fluctuation of waste composition leads to large and frequent disturbances with the associated negative impact on the incineration process, mainly in terms of emissions and steam production. Avoidance of disturbances is the main goal of the control system of a MSW incinerator. (El Asri and Baxter 2004)

Blumenstock et al. (2000) found an increase in PCDD/F levels after a period with bad operating conditions in a pilot scale incinerator. This was later confirmed by several other authors (Gullett et al., 2000; Zimmermann et al., 2001; Gass et al., 2002). Gass et al. (2002) investigated the emissions from a full scale incinerator and obtained the same results as earlier were shown in pilot scale. They showed that during the oil burner operation concentrations in the raw gas up to 250 ng I-TEQ/Nm^3 could be detected, leading to a long lasting memory effect in the wet scrubber downstream and consequently in the clean gas as well. (Lothgren and van Bavel 2005)

Hunsinger (Hunsinger, Jay et al. 2002) found that under disturbed combustion conditions characterized by high CO concentrations in the raw gas, high amounts of PCDD/F are able to pass the combustion chamber and lead to high concentrations in the raw gas (F=D > 1).
• Incomplete flue gas burnout (especially during disturbed combustion conditions) will contaminate the boiler surface with soot particles. This will cause PCDD/F formation reactions by de-novo synthesis (F=D   1) even under efficient stationary combustion conditions.
• If the cleaning of the boiler is insufficient, the formation of PCDD/F from old fly ash deposits takes place over a very long period of time (>24 h). These memory effects must be recognized when interpreting PCDD/F raw gas data. (Hunsinger, Jay et al. 2002)

In South Africa the emissions from stat-up and upset conditions are currently likely to be exempt from regulation. The Chief Air Pollution Control Officer (CAPCO) issues registration certificates on the basis of information provided on a registration form and individual discussion and reviews of the process. A criterion for issuing the registration certificate is that the operation must be capable of being operated continuously without emitting dark smoke. Allowances are made, however, for '*unavoidable*' emissions caused at start up, shut down or upset conditions (Fischer 2005).

Whilst the COWI review is again silent on the matter the best way to establish the total dioxin emissions from incinerators would be to continuously monitor the flue gases. Unfortunately the concentrations involved are so small that this is not yet possible. There are, however, now two commercially available systems of continuous sampling of dioxins which collect the emissions over an extended period, normally two weeks, for subsequent laboratory analysis. These are the AMESA system[11] and Dioxin Monitoring Systems[12] ('DMS').

There are other systems which measure surrogates (such as chlorophenols) and which claim to be indicators of dioxin emissions. The surrogate samplers are far less reliable and lack the experience and regulatory approvals of the continuous samplers.

Work published by (De Fré and Wevers 1998) in Belgium clearly indicates that the consequence of the higher start up and upset emissions are that the standard dioxin monitoring as required in the UK to date is likely to significantly underestimate actual emission levels. In their tests incinerator emissions were monitored using the AMESA system for continuous sampling over approximately two-week periods. They showed that a standard emission measurement according to the European standard method EN 1948 during a period of 6 hours resulted in an emission concentration of 0.25 ng TEQ/Nm^3, while the average over 2 weeks in the same period was 8.2 to 12.9 ng TEQ/Nm^3. This illustrated that the standard measurement could underestimate the average emission by a factor 30 to 50[13].

As a result of these findings doubts have risen over the actual emission of the incinerators, and the special commission on incineration asked all incinerators in the Flemish region to use the continuous sampling system in order to establish their compliance with the emission limits. This has now been made a legal requirement.

AMESA has now been installed in almost 100 applications. The majority are in Europe but four systems are installed in Japan and one system was installed in Taiwan for an EPA test. The system is a mandatory requirement in Flanders and has been approved by the German EPA (Mayer, Linnemann et al. 2000).

The uncertainties associated with actual dioxin emissions, combined with the still urgent requirement to reduce the levels of dioxin in the environment presents a powerful argument for the use of the 'AMESA' (or similar) semi-continuous dioxin measuring system.

The Air Quality Guide for Europe of the World Health Organisation (WHO) underlines the importance of controlling known sources as well as to identify new sources due to the potential importance of the indirect contribution of PCBs in air to total human exposure. [WHO 2000a] (Sander, Tebert et al.

[11] http://www.becker-messtechnik.de/eng/index.htm
[12] http://www.westechinstruments.com/appspage.asp?samplingApplication=Dioxin%20Monitoring#Lit
[13] This plant had a wet scrubbing system which may have a particular 'memory' effect. A similar effect could be generated from the carbon in the boiler of a plant with a semi-dry scrubber. In any case a range of similar data has demonstrated that AMESA results are far more comprehensive than conventional sampling.

2007).

<u>In the event that the advice given in this submission is not acted upon and a policy of thermal treatment is developed for South Africa it is strongly recommended that a pre-requisite should be the requirement to continuously sample for dioxins using one of these systems. This should apply both to purpose built incinerators and a to cement kilns.</u>

Brominated and other halogenated dioxins

The literature reviews do not mention it but it is important to note that the current dioxin monitoring refers only to the <u>chlorinated</u> species. There are over 5,000 mixed halogenated dioxins and furans any or all of which could be produced by incinerators or cement kilns.

The European Committee on Toxicity, Ecotoxicity and the Environment (CSTEE), has considered, inter alia, the risks of exposure to brominated dioxins and furans from incinerators. ENDs reported[14]:

"The most incendiary part of the Cstee review is a warning about the risks of human and environmental exposure to brominated dioxins and furans created by incinerating deca-containing plastics in end-of-life appliances.

The Committee concluded[15]:

"The presence of bromine may even decrease the apparent level of chlorine-derived dioxins and furans... suggesting that emission limits are being met while the real level of harmful dioxins and furans is higher and unnoticed."

Weber and Greim (Weber and Greim 1997) report that:

Brominated dibenzo-p-dioxins and dibenzofurans can be formed under laboratory conditions by pyrolysis of flame-retardants based on polybrominated biphenyls and biphenyl ethers. Their occurrence in the environment, however, is due to combustion processes such as municipal waste incineration and internal combustion engines. As these processes generally take place in the presence of an excess of chlorine, predominantly mixed brominated and chlorinated compounds have been identified so far in environmental samples.

The reference to internal combustion engines refers to the historic use of brominated fuel additives which has now been stopped. Heeb et al. (Heeb, Dolezal et al. 1995) found that:

"Incineration of municipal waste yields a variety of halogenated phenols including chlorinated, brominated and mixed chlorinated phenols in raw and stack gas. A total of 14 chlorinated, 3 brominated and 31 mixed brominated and chlorinated phenols could be characterised by high resolution gas chromatography high resolution mixed

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[14] EU scientists question deca risk assessment ENDS Environment Daily 1331, 18/11/02
[15] EU scientists question deca risk assessment ENDS Environment Daily 1331, 18/11/02

spectrometry."

They continued:

"The growing commercial production of brominated organics and their widespread application as flame retardants and fuel additives are suspected to contribute increasingly to environmental pollution. Incineration of bromine containing products will lead to substantial formation of mixed brominated and chlorinated aromatics. Upon thermal treatment of halogenated material bromine radicals do form preferentially compared to chlorine radicals. Already a moderate molar fraction of bromine in the halogen load of a flue gas has been found to reduce the amount of chlorinated aromatics significantly and to favor the formation of mixed brominated and chlorinated aromatics. Compared to the accumulated knowledge about polychlorinated aromatics only little is known about the fraction of mixed halogenated aromatics produced"

Dioxin Mass Balance

COWI claim that modern incinerators are net dioxin destroyers. As in so many other cases no evidence is cited to support this claim, however. When critically reviewed the evidence is, at best, equivocal.

Abad (Abad, Adrados et al. 2002) found different results in two tests on the same plant, largely related to the difference in dioxin concentrations of the input which he reported were difficult to establish effectively:

Dioxin mass balance

	Input (g I-TEQ/yr)	Output (g I-TEQ/yr)	Balance (g I-TEQ/yr)
1st sample collection	1.33	4.64	3.31
2nd sample collection	9.62	1.92	−7.70

Burnley (ENDS 1997) reported that according to his best estimate, a modern incinerator produces about 15 times as much dioxin as that in the incoming wastes (see table below). Using pessimistic assumptions, the overall dioxin loading could be increased 170-fold. Even on optimistic assumptions, the incinerator remains a net dioxin source:

Main Risks of Incineration Plants

The literature review is silent on the main risks associated with incineration plants even though COWI has previously produced (COWI 2000) a list of the most likely accidents and failure modes:

Table 1.9 The main risks of accidental and sudden occurrences at incineration plants.

Potential risk	Description and consequences
Contact with auxiliary materials	Occupational health and safety risk to workers at the incineration plant. Risk of dermal contact, and associated health effects.
Fire in the silo	Occurs relatively frequently and is extinguished using water canons permanently installed in the silo. Causes an increase in emissions to air, until fire is extinguished.
Fire in the dioxin filter	May occur if glowing particles reach the filter. Results in fine contaminated carbon particles being emitted to air (e.g. in the order of a few tonnes), requiring the installation of a new filter.
Leaks from high pressure feed-water and steam system	Occupational health and safety risk to workers at the incineration plant. Risk of dermal contact and associated health effects.
Overheating	Overheating of the boiler may cause damage and outlets of steam in the boiler. Results in temporary reduction or stop in plant operation and energy recovery.
Explosive matter in the waste	Waste may contain explosive matter such as gas bottles that can explode in the boiler, silo, or shredder. Explosions can result in temporary reduction or stop in plant operation and energy recovery.
Leak of ammonia	A sudden leak of ammonia, used to remove NOx, is acutely dangerous. However, even small leaks are easily detected by smell long before dangerous concentrations are reached. The main risks relate to occupational health and safety.
Contact with flue gas residues	Occupational health and safety risk to workers at the incineration plant. Risk includes dermal contact and inhalation of fugitive dust emissions, and associated health effects.

Source: Reto Hummelshøj, pers. comm.

Annex 4 – Cement Kiln Specific Issues

Proposed AFRs:

The proposed wastes for cement kilns are an "Exclusive rather than inclusive list of AFRs" (Crous 2007):

- Scrap tyres & rubber waste
- Hydrocarbon waste (e.g. used oil, oil-contaminated general waste & soil, coal fines)
- Plastic waste
- Biomass (e.g. paper waste, sawdust, wood chips)
- De-water, treated sewage sludge pellets
- Spent pot lining & boiler ash
- Blended waste"

Excluded Waste Streams

The list of waste streams proposed to be excluded can be compared with the excluded waste streams in the BAT/BEP guidelines (Stockholm Convention 2006) and the Holcim/GTZ guidelines (Holcim and GTZ 2006):

South Africa (Crous 2007)	BAT-BEP	Holcim
Anatomical hospital waste	Infectious medical waste	Infectious and biologically active medical waste
Asbestos containing waste	Asbestos-containing waste	Asbestos
Unsorted electronic scrap	Electronic waste	Electronic waste
Bio-hazardous waste		
Entire batteries	Entire batteries	Entire batteries
Explosives	Explosives	Explosives
Mineral acids	Mineral acids	Mineral acids and corrosives[16]
Radioactive wastes	Nuclear waste	Radioactive wastes
Unsorted municipal waste	Unsorted municipal garbage	Unsorted municipal waste
	other waste of unknown composition.	
	High-concentration	

[16] The guidance adds (A23) "Beside mineral acids, substances that can cause
severe damage by chemical reaction to living tissue, or freight, or the means of transport are prohibited, as are all corrosive substances. Well known examples are aluminium chloride; caustic soda; corrosive cleaning fluid; corrosive rust remover/preventative; corrosive paint remover. These types of materials should be excluded from co-processing due to the upstream collection,
transport risks and handling hazards."

	cyanide waste	
	Chemical or biological weapons destined for destruction	

	Enrichment of pollutants in the clinker	Emission values	OH&S	Potential for recycling	Landfilling as better option	Negative impact on kiln operation
Electronic waste	X	X		X		
Entire Batteries	X	X		X		X
Infectious & biol. active medical waste			X			
Mineral acids and corrosives		X	X			X
Explosives	X		X			X
Asbestos			X		X	
Radioactive waste	X		X			
Unsorted municipal waste	X	X		X		X

Table 4: List of waste material not suited for co-processing and the main reasons for the exclusion from co-processing

It will be noted that the current SA list does not meet the standards expected by the BAT-BEP guidance nor even those established through the industry driven Holcim GTZ process which represent the minimum standard that should be expected.

There are particular concerns about the rather loose term *"unsorted electronic scrap"*. Both the BAT_ BEP and Holcim guidance are much more specific on this. The BAT_BEP definition, for example, says:

"Electronic waste is composed of computer and accessories, entertainment electronics, communication electronics, toys and also white goods such as kitchen devices or medical apparatus. The average composition shows that electronic waste contains, on the one hand, substances harmful to health and the environment such as Cl, Br, P, Cd, Ni, Hg, PCB and brominated flame retardants in high concentrations, often higher than threshold limit values. On the other hand, electronic waste contains such a high scarce precious metal content that all efforts have to be undertaken to recycle it. Coprocessing of the plastic parts of electronic waste would be an interesting option, but requires disassembling and segregation first (after Holcim, 2006)."

Performance Requirements of Cement Kilns:

The cement industry and SINTEF, as one of their strongest claim that the conditions in cement kilns are well suited to the burning of hazardous wastes. It is interesting to consider the comparison provided in the consultation:

	Requirements		Performance	
	EU	USA	Dedicated incinerators	Cement kiln
Temperature	850 -1100 °C	850 – 1600 °C	900 –1200 °C	1450 – 2000 °C
Residence time	≥ 2 seconds	≥ 2 seconds	0,3 – 4 seconds	4-8 seconds
Oxygen availability	3 – 6 %	2 – 3%	> 4 %	> 4%
Turbulence/mixing	Yes	Yes	Yes	Yes
Thermal stability	Auxiliary burners	Auxiliary burners	Auxiliary burners	Thermal buffer
Exit gas cleaning	ELVs	ELVs & DRE	Advanced	EP/bag etc & lime scrubbing

From (Karstensen 2007)

Firstly the temperature in cement kilns is claimed to be between 1450 and 2000 °C with a residence time of 4-8 seconds

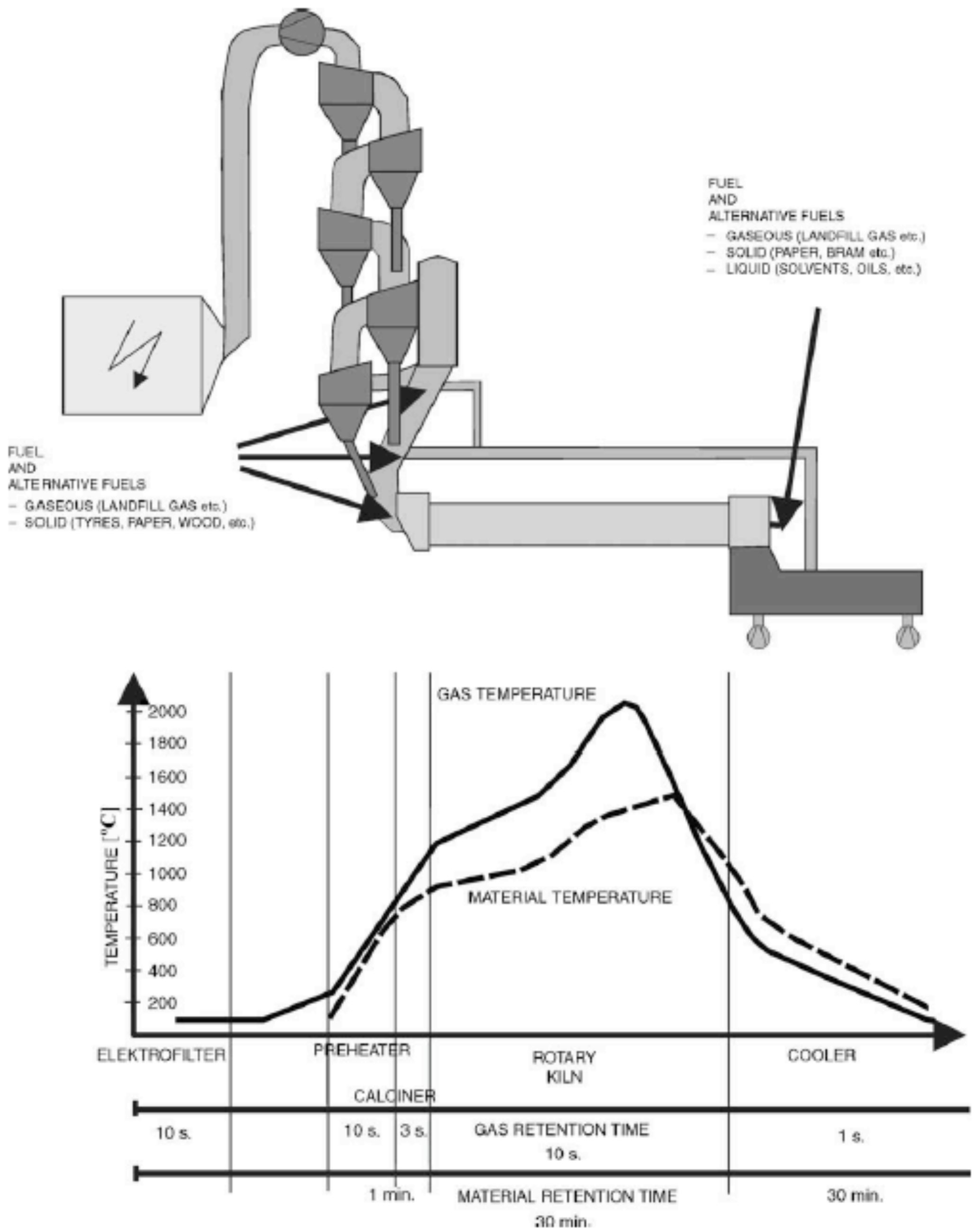
The vital qualifier for this claim, often omitted, is that this requires the wastes to pass through the main body of the kiln. In fact waste is often not added to the burner end of the kiln for a variety of operational, engineering and practical reasons but is added either at the pre-heater or pre-calciner stage – and sometimes even with the raw meal. In these circumstances the temperatures claimed above are not achieved. It is unlikely to achieve the minimum EU and US residence times of 2 seconds at 850°C in some of these circumstances.

Secondly, oxygen availability is claimed at > 4%

The usual levels of excess oxygen in a dedicated incinerator are much higher than in a cement kiln. Environment Canada (Environment Canada 2004) says that although a kiln could be operated with as little as 0.5% kiln exhaust oxygen level, typically the kiln operators strive for an oxygen level of 1 to 2% to ensure the desired oxidizing conditions in the kiln burning zone. In an incinerator the oxygen concentration is normally kept in a determined range (usually between 8 and 12 vol %) which ensures stable and tolerated concentrations of the gaseous emissions. (El Asri and Baxter 2004)

Thirdly the exit gas cleaning is very different

It is reasonable to describe the exit gas cleaning in modern hazardous waste incinerators as advanced. For cement kilns a more appropriate description is rudimentary. Not only to most still rely on rather crude electrostatic precipitators but, as is shown below, these ESPs trip rather frequently and depend upon unreliable power supplies. The bag filters used are little better. Instead of a quench to quickly reduce the temperature over which *de novo* synthesis of dioxin and other PICs is likely the kilns then have a significant period in the 450 to 200 °C range over which the flue gases cool in a high particulate environment.



From (Mokrzycki, Uliasz-Bochenczyk et al. 2003)

Test Burns

The test burn in Vietnam (Karstensen, Kinh et al. 2006) is cited as a successful example of how kilns can burn waste pesticides. It is widely accepted that kilns proposing to burn hazardous wastes should already be compliant with domestic regulations before hazardous waste is burned yet the Vietnam kiln was not (for NOx – see table below). Yet in spite of this the a collection of the worlds leading experts continued with the test burn and then de-stabilised the kiln to the point that the NO_2 levels were nine times higher than the EU Waste Incineration Directive standards because they, or the laboratory, miscalculated the calorific values of the wastes.

Table 3 – Gaseous compounds (mg/N m^3)			
	Baseline	Test burn	ELV Vietnam
HCl	2.1	2.4	90
HF	<0.21	<0.23	4.5
NH_3	<1.0	<0.44	45
CO	99	131	225
O_2 (%)	5.24	5.21	–
SO_2	1.8	2.0	225
NO_2	21	40	–
NO	760	1220	–
NO_x expressed as NO_2	1180	1910	1000

The report says "*The reason for the high NOx levels during the test burn was due to high heat input through the main flame due to wrong information about heat content of the insecticide mix prior to the test. The coal feed was approximately 1 tonne higher than required. The easy burnability of the solvent of the insecticide mix compared to hard coal probably caused a more intense flame in the main burner as well as added 31 kg of nitrogen per hour. The consequence of this inadequate compensation was higher temperature in the kiln and higher NO_x levels*".

The report also admits that "*the NO_x level was however higher than the ELV also under the baseline measurements (under investigation)*". But gives no explanation of why the test was continued when the kiln was operating unlawfully already.

If these experts, including SINTEF, could cause such a major breach of permit conditions on a sensitive test burn then it is very likely that other, less expert, operatives, will have similar or worse problems.

Municipal Waste:

The South African kilns cannot reasonably be considered as a potential "solution" to the disposal of municipal waste. The introduction of large amounts of unprocessed MSW into cement kilns is not practical because the additional kiln volume required is too great; the large amounts of ash generated would affect the cement clinker quality; and it would be difficult to sustain the required very high clinkering temperature of 1500 °C with large quantities of low calorific value MSW (Cheung, Lee et al. 2007).

Emissions from Cement Kilns

Whilst some attention if paid to the stack emissions from cement kilns in the review literature there is much less paid to some of the other emission sources. These include:

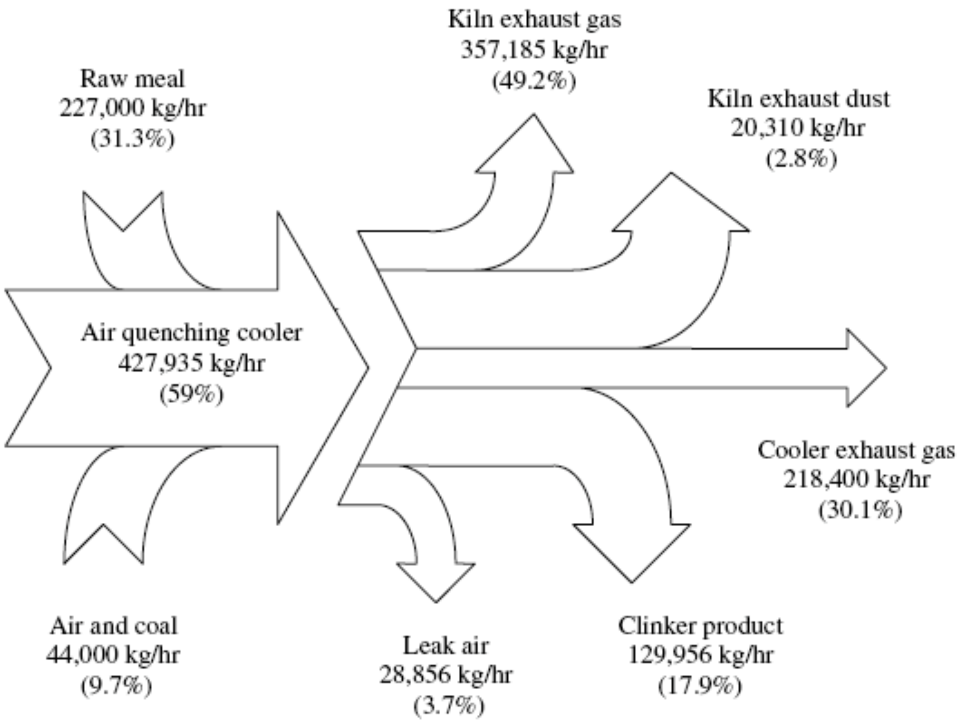
ESP Trips

Switching off of the ESPs leads to unabated particulate releases from the kiln. ESPs are switched off during start up from cold (when there is a risk of gasses condensing and shorting out the high tension electrics) and if carbon monoxide, 'CO', levels within the system become too high, typically to >0.5% by volume (when there is a risk of explosion).

The unplanned shut-downs, called CO trips, can be caused by unsteady state operation of the combustion system. This sometimes occurs when feeding solid fuels (European Commission 2000), so solid-fuel feeding systems must be designed to prevent surges of fuel into the burner. The latest draft of the EU IPPC BREF (European Commission 2007) gives examples from Ireland in 2006 where CO emissions above 60 and up to 130 mg/Nm^3 (half hourly average values) have been reported with frequencies of between one to six times per month. Of these, ESP trip-outs of between 1 – 13 minutes/trip and a total duration of up to 184 minutes have been reported. The BREF also reports how frequencies of CO trips were minimised at German cement plants and gives examples of total duration ranges of between 1 – 29 minutes per year. It is unlikely that these German examples could be considered representative of kiln operations in Africa – the levels of emissions reported in Ireland, or higher, are much more likely to reflect the African situation.

Cement Kiln Fugitive Emissions:

Rasul et al. (Rasul, Widianto et al. 2005) illustrated that the cement kiln unit is a particularly 'leaky' environment and estimated a leakage equivalent to about 3.7% of the input mass. Fugitive emissions also escape from kilns. Sometimes, due to poor maintenance or operation, this can be much more Rasul expected. Staff at the Cemex kiln in Rugby, England, for example, found a cement kiln door hanging off its hinges and tried to force it shut. Despite knowing the door was not secure, Cemex restarted the kiln, which was experiencing operating difficulties. This resulted in the release of about seven tones of cement kiln dust into the residential area around the plant . This kiln was rated as "*well managed*" under the UK Environment Agency's operator pollution and risk appraisal (EP OPRA) system.(ENDS 2006)



(Rasul, Widianto et al. 2005)

The leakage air from this kiln is approximately equivalent to the volume of total stack emissions from a 37,000 tpa MSW incinerator and is likely to have a significant cooling effect in parts of the process.

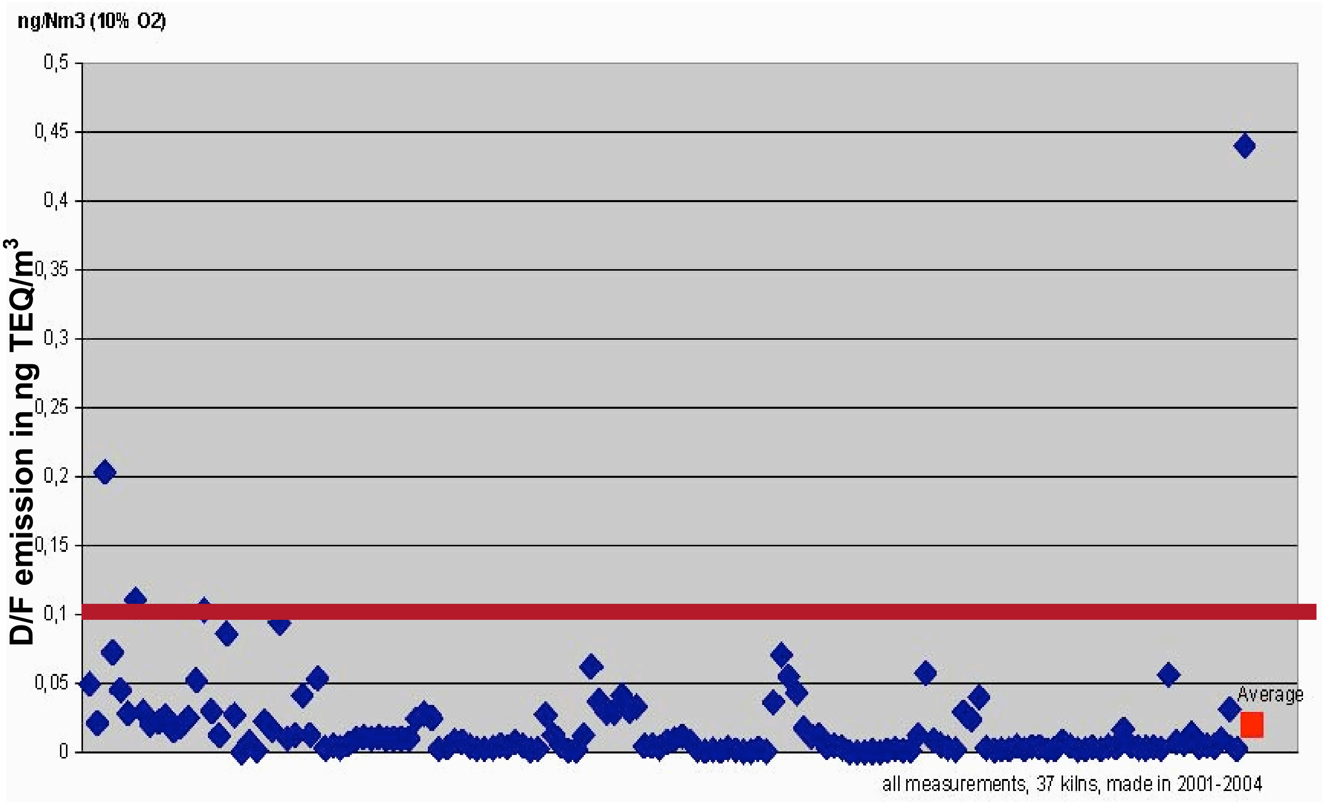
Abdul- Wahab (Abdul-Wahab 2006) assessed the impact of fugitive particulate emissions from a cement plant on a nearby community using high volume samplers were used for the determinations of total suspended particulate (TSP) concentrations. The 24-average dust concentrations for each house were compared to the World Health Organization guideline value of 120 μg/m3 (WHO, 1999). The results indicated that the measured average TSP concentrations at the three houses sampled exceeded the WHO guideline. They concluded that their results "*revealed that the cement plant activities had impact on the air quality of the nearby residential houses. Such concentrations would be expected to be higher when worst atmospheric and stability conditions occurred especially if this coincided with the increase of the cement plant production rate*".

The releases of dust of this nature are incompatible with the treatment of hazardous wastes for the reasons explained in the previous annex.

Dioxin Emissions from Cement Kilns

According to the European Commission's BREF (European Commission 2000) on the cement industry any chlorine input in the presence of organic material may potentially cause the formation of dioxins/furans during the combustion process, and dioxins/furans can be formed in a preheater or afterwards and in an air pollution control device if chlorine and hydrocarbon precursors from the feed materials are available.

The results presented by Kare Karstensen at the October Stakeholder meeting are superficially reassuring. He includes, for example, a table purporting to show the dioxin emissions recorded in 152 PCDD/F measurements from 37 Heidelberg kilns over the period from 2001-2004 :



The inference is that only two of the results significantly exceed 0.1 ng/m3 and that the highest emission recorded is under 0.45 ng/m3.

I am aware that one Heidelberg Kiln operated by Castle Cement at Padewsood, Wales, UK was operating in 2004 with extremely high emissions. This has been referred to in a recent paper by Dr Karstensen (Karstensen 2008):

The International POPs Elimination Network claim that the PCDD/PCDF emissions in 2004 from a long dry kiln in the UK reached 136 ng TEQ/m3 and averaged more 50 ng TEQ/m3 over the year with total emissions of more than 40 g TEQ. The kiln, now closed, was operating with relatively high temperatures in the electrostatic precipitator and used raw material with high organic content together with waste pulverised fuel ashes. This information cannot be confirmed in scientific literature, but is referred in UNEP (2007).

Whilst the data "*may not be in the scientific literature*" (largely because Heidelberg have tried to hide it) it is certainly on the Court record which is an even more reliable source. The company was prosecuted by the British Environment Agency and found guilty on a total of nine charges, three for exceeding dioxin emission levels; three for failing to report dioxin emissions and three for not sampling when required.

The dioxin emissions from that one kiln were higher than claimed for the entire European Cement Industry for that year.

It is not clear why no reference has been made to these higher values in the review for DEAT or why they have been omitted from the graph above – especially as it is included in the other publication prepared by Dr Karstensen. It is true that the kiln is now closed but it is similar to the long dry kilns operating in South Africa and was use alternative raw materials.

Other recent data raises concerns that cement kilns may still be relatively major dioxin sources. Chen (Chen 2004), for example, found that cement kilns and electric arc furnaces for steels also produced significant portion (both >10%) of dioxins into the environment. It is difficult to tell what the current situation is in South Africa as there is an almost total lack of dioxin data for kiln emissions to air and none publically available for dioxin levels within the process.

Possible Dioxin Formation in the Clinker Cooler

There are recently renewed concerns that dioxin formation may be significant in the clinker cooler. Dr Karstensen (Karstensen 2008) wrote:

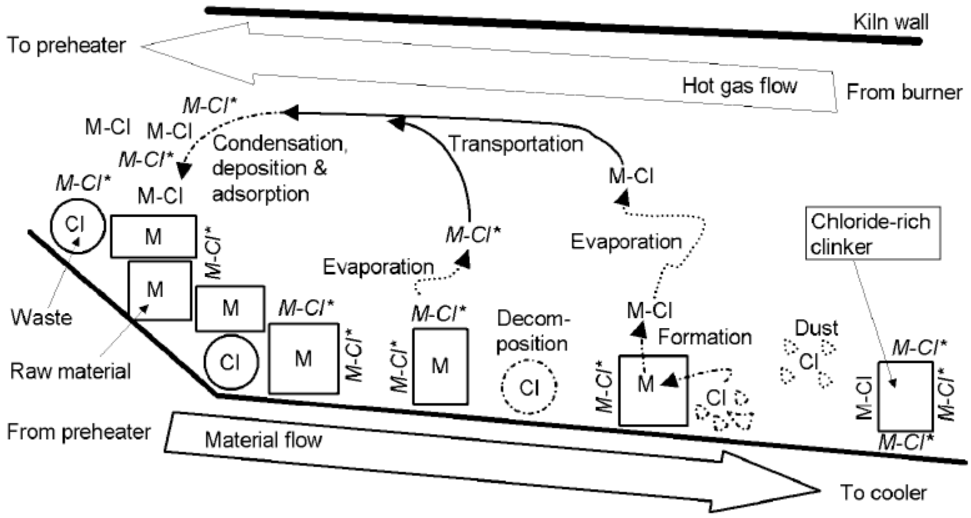
"The slightly higher concentration of PCDD/PCDF found in clinker than in cement when analysing the CSI samples in 2005 was a surprise (see Table 4). Cement is often mixed with CKDs and a higher PCDD/PCDF concentration was expected in cement than in clinker due to normally higher concentrations in CKD, not the opposite. The concentration in clinker was expected to be low; because none has identified PCDD/PCDF in clinker earlier (CKD, 1995; Federal Register, 1995) and because of the high material temperatures inside the kiln (1450 °C). One possible explanation could be that the clinker samples had been contaminated through ambient air in the cooling process. Thousands of cubic meter of ambient air are used for cooling and investigations from 8 EU countries have shown concentrations from 1 to 705 fg TEQ/m3 for urban and rural air (Fiedler, 2003). A second possible explanation could be contamination through adsorption of dust and material residues in the cooler. Depositions from ambient air have shown concentrations up to 464, 517 and 14800 pg TEQ/m2 for rural, urban and contaminated air, respectively (Fiedler, 2003). A third possibility, which cannot be ruled out for the time being, is possible contamination during the preparation for analysis. Clinker is hard spheres which are difficult to crush and contamination during sample preparation in the laboratory is not unlikely."

This misses the fourth, and perhaps more obvious explanation, that the dioxins can be formed de novo in the clinker cooler by De Novo synthesis as described by Kikuchi et al (Kikuchi, Mukherjee et al. 2006):

This year Yin (Jin, Lee et al. 2007) reported dioxin emission factors for CKD of up to 47.6 μg/tonne cement.

De novo synthesis occurs at temperatures ranging from 200– 400°C (Refs. 9 and 16). It takes c.30 min to cool the clinkered materials from 1200 to 80°C in a clinker cooler (see Fig. 1b); that is, it takes over 5 min to pass through the critical temperature zone (200 to 400uC).

Assuming that factors such as the critical temperature and presence of catalytic compounds, organic materials, and HCl and H_2O are met, Kickuchi considered that there is a strong possibility that dioxins/furans may form and adhere to the clinker and/or kiln dust. In industrial practice, the bulk of this kiln dust (filter ash) is returned to the production process as part of raw meal and/or a grinding additive (i.e. mixed with cement) and is also used as fertiliser, sub-base in roads, backfill material in



Countercurrent principle and chlorine behaviour in clinker kiln for cement production

The results proved the considerable leaching of Cl from the waste co-incineration pieces. Furthermore, the conclusion derived from these results suggests that chloride bearing waste containing the chloride levels studied here may add dioxin-like pollutants (e.g. chlorinated organic compounds) to the clinker and/or kiln dust during co-incineration. This means that the amounts of the dioxin-like pollutants are comparatively low in the flue gas because the major portion of those pollutants is mixed with clinker product or transported to the other application fields. Based on this finding, it was concluded that waste from combustible residues containing high chloride levels is unfit for co-incineration in a clinker kiln because it may cause the qualitative degradation of cement and the formation of dioxin-like pollutants.

They also concluded that "*although waste co-incineration in a clinker kiln and cement production are scarcely considered to be great emission sources of dioxins/furans, there would still seem to be significant uncertainty about this subject*".

Cement Kiln Dust and Cement Quality Issues

Most cement kilns require that a portion of the CKD be removed from the kiln system rather than returned to the kiln. This is done to bleed the kiln system of alkali materials that build up as they circulate which would otherwise contaminate product and damage the kiln lining (USEPA 2006).

Surprisingly it appears that little cement kiln dust is produced in South Africa – the majority of it being blended into product. This raises several concerns as the CKD is likely to be one of the most contaminated outputs from a cement kiln – whether burning wastes or conventional fuels.

This was shown for example, by Guo (Guo and Eckert 1996) who analysed data from a kiln equilibration for heavy metal outputs from a cement kiln co-fired with hazardous waste fuels. Metal outputs from stack emissions, cement kiln dust and cement clinker were considered and equations were derived for predicting all three metal outputs at any hazardous waste feed rate under steady state conditions. Measured concentrations of arsenic, beryllium, cadmium, chromium, and lead in waste kiln dust, at the highest intended hazardous waste feed rates to the kiln, were 68, 10, 72, 18, and 68 times those predicted for feed rates with no hazardous waste. In addition, the intermediate, non-steady state segment of the equilibration test was analysed. If metals are assumed not to accumulate in the kiln, the intermediate metal concentrations in cement clinker were predicted to be substantially higher than those at the final steady state

Guo et al (Guo 1997) developed a mathematical leaching model for assessing potential increases of lead and chromium in drinking water from using cement-mortar-lined pipes. The model considered the initial wetting process, dissolution, diffusion, and advection of metals in the lining, accumulation of metals in the static pipe water and dilution of metals by the flowing water. Based on the modelled results, the authors concluded that (US) drinking water standards were likely to be exceeded when using cement with lead solubility larger than 70 ppb or chromium solubility larger than 540 ppb.

For one cement kiln studied, it was recommended that cement kiln dust should not be fully recirculated when hazardous waste fuel had the maximum allowable amount of lead. It was also recommended that the maximum allowable amount of chromium in HWF be lowered. No data has been provided with the SINTEF review to assess what concentrations of contamination are currently being fired in cement kilns and whether the subsequent contamination of cement is a concern in South Africa.

There is little doubt that the use of wastes changes the quality of the clinker and the cement . Kikuchi (Kikuchi, Mukherjee et al. 2006) found that the Cl content (0.36%) of clinker in the waste co-incineration test was 18 times greater than that (0.02%) of clinker in the blank test. When a leaching test was applied to a concrete sample from the cement The results suggest that chlorine was not sufficiently fixed in concrete produced by waste co-incineration. Indeed it was observed that free chloride ions easily flow out to the surroundings.

Acternbosch (Achternbosch, Brautigam et al. 2005) identified and quantified the input pathways of trace elements into cement and concrete and estimated the extent to which trace element concentrations in cement may change due to waste utilisation. Not surprisingly primary raw materials represented the most important input pathway for trace elements into cement, but the contribution from wastes was not negligible. The use of waste led to a slight increase of the concentrations of cadmium, antimony and zinc in cement. For cobalt, lead and vanadium, this increase was less distinct and for all other trace elements considered, the effect of the use of wastes on trace element concentrations in cement could not be demonstrated clearly. The trace element content of concrete was governed by the aggregates for most elements considered. However, for arsenic, cadmium, lead and zinc, both cement and the additive coal fly ash contributed noticeably to the total trace element concentration in the concrete.

Table 1: Average values (AV) of selected input materials compiled from miscellaneous sources. Input materials cited by the German Cement Works Association (VDZ 2001).

Data in ppm		As	Cd	Co	Cr	Cu	Ni	Pb	Sb	Sn	V	Zn
Limestone	AV	3	0.2	3	14	11	18	18	1	4	26	30
Clay	AV	14	0.2	20	85	43	63	25	2	5	130	78
Marl	AV	6	0.3	5	28	12	16	12	4	3	20	48
Sand	AV	11	0.2	11	19	10	13	10	7	3	50	25
Iron works waste	xMin[a]	74	29	149	600	1076	254	481	10	81	229	2262
Iron ore	AV	37	6	144	495	1520	331	350	26	25	256	3288
Foundry sand	AV	3	0.3	90	290	28	92	62	0.8	40	150	75
Hard coal	AV	9	1.0	9	14	18	23	27	1	4	39	63
Brown coal	AV	0.8	0.2	1	3.6	1.8	3	3	0.8	4	10	10
Oil coke	AV	0.5	1	2.5	4.3	2.4	263	13	0.6	0.3	758	16
Used tyres	AV	1.6	7	30	137	68	90	125	136	15	19	6100
Waste oil	AV	2.4	0.8	1	12	51	20	151	1	6	2	700
Scrap wood	AV	3.4	1.2	10	27	24	13	222	8	6	3	440
MCIW fuel	AV	3	2.5	4	51	138	25	74	25	20	7	331
Blast-furnace slag	AV	0.8	0.7	4	25	5.2	5	6	2	5	30	38
Coal fly ash	AV	79	2.6	74	172	247	196	257	14	10	345	504

[a] Average minimum values (xMin) were used (see text). AV, average; MCIW fuel, fractions from municipal, commercial and industrial waste.

Table 2: Trace element concentrations of Portland cement, 'mixed cement' and "normal cement". A comparison of calculated average values using the top-down approach to the ranges of data found from literature.

Data in ppm		As	Cd	Co	Cr	Cu	Ni	Pb	Sb	Sn	V	Zn
Portland cement 'top-down'	AV	9	0.8	10	46	39	42	40	5	8.0	66	153
Portland cement 'literature'[a]	Min	2	0.03	3	25	14	14	5	0.5	1	15	21
	Max	117	6	21	712	98	97	254	18	14	144	679
	AV	8	0.6	11	68	38	45	27	5	3	74	164
'Mixed cement' 'top-down'	AV	7.7	0.7	9	42	34	36	35	4	7.4	59	133
'Normal cement' (VDZ 2000)	AV	6.8	0.4	10	40	25	24	27	6	4.6	56	140

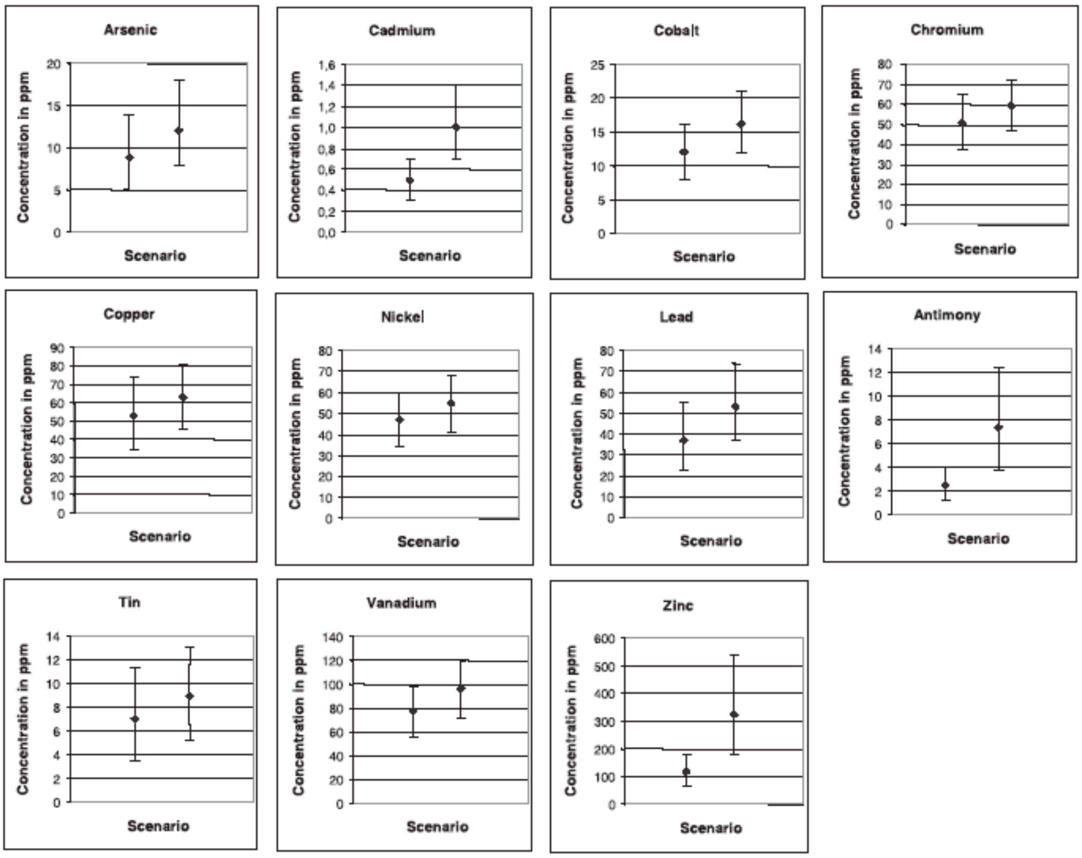
[a] Selected sources: Hillier *et al.* (1999), Murat & Sorrentino (1996), van der Hoek & Comans (1994), Sprung & Rechenberg (1993). AV, average.

Table 3: Contribution (%) from input classes to the trace element concentrations, and to the mass, in Portland cement in 1999.

	As	Cd	Co	Cr	Cu	Ni	Pb	Sb	Sn	V	Zn	Mass
Primary raw materials	78	48	65	71	52	76	70	62	78	74	38	85
Primary fuels	4	8	4	2	2	9	3	2	5	15	3	6
Secondary fuels	1	12	5	4	6	3	8	28	5	0	37	1.5
Secondary raw materials	14	29	24	21	37	11	16	6	11	9	20	1.5
Interground additives	3	3	2	2	3	1	3	2	1	2	2	6

Scenario A
Only primary input materials (raw meal 1) and regular fuels were used. The primary materials in combination with different types of fuels were chosen such that the resulting trace element concentrations in cement were as low as possible. For most elements this was the case for brown coal.

Scenario B
This scenario represents combinations of raw materials and fuels, which resulted in the highest concentration of trace elements in cement; hence a 'worst case' but realistic scenario. For all trace elements, this scenario consisted of raw meal 2 and different fuel variants.



ig. 2: Average values and ranges of trace element concentrations in Portland cement in scenario A (left) and B (right).

A slight increase of the trace element concentration of cement due to the use of waste as an input material was found for antimony, cadmium, and zinc, as revealed by calculations for different realistic scenarios. For lead, cobalt and vanadium the concentrations also increased when using waste as an input material, but this increase was less distinct.

After the end of service life, crushed concrete weathering is accelerated due to the enlarged surface area. The way re-utilization was managed is of decisive importance for the potential environmental risk that may be caused by the trace elements.

The long-term behaviour of trace elements in crushed concrete could not be predicted reliably under this project as it was concluded that scientific knowledge is still insufficient.

Health Concerns Associated with Cement Kilns:

Many of the health concerns associated with cement kilns are similar to those discussed in the last Annex and are covered in the references provided. There are, however, some omissions from the literature review that should be corrected and these papers for which the abstracts are provided, whilst not a comprehensive list, are a few of those that should also be considered in relation to concerns about health impacts form cement kilns:

Abdel-Halim, A. S., E. Metwally, et al. (2003). "Environmental pollution study around a large industrial area near Cairo, Egypt." Journal of Radioanalytical and Nuclear Chemistry 257(1): 123-124. (Abdel-Halim, Metwally et al. 2003)

Neutron activation analysis is one of the most extensively used methods for environmental studies due to its high sensitivity, precision, versatility and multielemental character. Cement factories at Helwan, south of Cairo, contribute substantially to environmental pollution. Determination of minor and trace-elements in dust particulates from the cement industrial areas has been performed to assess the air quality from an environmental and human health point of view. Soil-7 standard reference material from IAEA and SRM-1571 from NBS were used for quality assurance testing. The data obtained indicate there is an indication that the pollution could be hazardous to people living in and around the area surveyed.

Porto, M. F. d. S. and L. d. O. Fernandes (2006). "Understanding risks in socially vulnerable contexts: The case of waste burning in cement kilns in Brazil." Safety Science 44(3): 241-257. (Porto and Fernandes 2006)

This article proposes a qualitative approach for understanding occupational and environmental risks in countries with high-social vulnerabilities. We use waste burning in cement kilns as a qualitative case study in order to illustrate how social (population and institutional) vulnerabilities influence the context of risk situations and events in a developing country such as Brazil. The vulnerability analysis was based on the reconstitution of the trajectory of this risk problem in a Brazilian State and its impacts, which mobilised several social and institutional actors. The methodology used interviews with different actors and an analysis of the documents, including mostly technical reports from various participating institutions. One objective of contextualising risk problems and vulnerabilities is to encourage professionals, decision-makers, and other social actors to discuss safety and health promotion in their different dimensions and to develop new strategies for intersectorial and participatory public policies. This point is important not only for developing countries even in more developed countries where legislation, social protection, and labour relations are more organised. We suggest that the need for knowledge integration, participation by all stakeholders, and empowerment of vulnerable groups exposed to risks are important principles to promote safety and health through the reduction of vulnerabilities.

Ballal, S. G., H. O. Ahmed, et al. (2004). "Pulmonary effects of occupational exposure to Portland cement: a study from eastern Saudi Arabia." Int J Occup Environ Health 10(3): 272-7.(Ballal, Ahmed et al. 2004)

A cross-sectional study was conducted in a randomly selected factory producing Portland cement in eastern Saudi Arabia to determine the prevalence of respiratory symptoms and diseases and chest x-ray changes consistent with pneumoconiosis in the employees. A sample of 150 exposed and 355 unexposed employees was selected. A questionnaire about respiratory symptoms was completed during an interview. Chest x-rays were read according to the ILO criteria for pneumoconiosis. Dust level was determined by the gravimetric method. Concentrations of personal respirable dust ranged from 2.13 mg/m3 in the kilns to 59.52 mg/m3 in the quarry area. Cough and phlegm were found to be related to cigarette smoking, while wheezing, shortness of breath, and bronchial asthma were related to dust levels. It is recommended that engineering measures be adopted to reduce the dust level in this company, together with health monitoring of exposed employees.

Al-Neaimi, Y. I., J. Gomes, et al. (2001). "Respiratory illnesses and ventilatory function among workers at a cement factory in a rapidly developing country." Occup Med (Lond) 51(6): 367-73. (Al-Neaimi, Gomes et al. 2001)

Chronic exposure to Portland cement dust has been reported to lead to a greater prevalence of chronic respiratory symptoms and a reduction of ventilatory capacity. The seriousness of pulmonary function impairment and respiratory disease has not been consistently associated with the degree of exposure. Regular use of appropriate personal protective equipment, if available at the worksite, could protect cement workers from adverse respiratory health effects. For a variety of reasons, industrial workers in rapidly developing countries do not adequately protect themselves through personal protective equipment. This study explores the prevalence of chronic respiratory symptoms and ventilatory function among cement workers and the practice of use of personal protective equipment at work. An interviewer-administered questionnaire was used to collect information on sociodemographic characteristics, smoking profile and history of respiratory health among workers at a Portland cement plant (exposed) and workers occupationally unexposed to dust, fumes and gases (unexposed). Pulmonary function was assessed and pulmonary function impairment was calculated for the exposed and the unexposed workers. A higher percentage of the exposed workers reported recurrent and prolonged cough (30%), phlegm (25%), wheeze (8%), dyspnoea (21%), bronchitis (13%), sinusitis (27%), shortness of breath (8%) and bronchial asthma (6%). Among the unexposed, prevalences of these symptoms were 10, 5, 3, 5, 4, 11, 4 and 3%, respectively. Ventilatory function (VC, FVC, FEV(1), FEV(1)/VC, FEV(1)/FVC and PEF) was significantly lower in the exposed workers compared with unexposed workers. These differences could not be explained by age, body mass index (BMI) or pack-years smoked. Ventilatory function impairment, as measured by FEV(1)/FVC, showed that 36% of the exposed workers had some ventilatory function impairment compared with 10% of those unexposed. Certain jobs with greater exposure to cement dust had lower ventilatory function compared with others among the exposed workers. It was concluded that adverse respiratory health effects (increased frequency of respiratory symptoms and decreased ventilatory function) observed among cement workers could not be explained by age, BMI and smoking, and were probably caused by exposure to cement dust.

Carrasco, F., N. Bredin, et al. (2002). "Gaseous Contaminant Emissions as Affected by Burning Scrap Tires in Cement Manufacturing." Journal of Environmental Quality, 31: 1484–1490. (Carrasco, Bredin et al. 2002)

We studied the environmental impact (gaseous emissions) of using scrap tires as a fuel substitute at a cement plant that produces one million tons of cement per year. Using a combination of tires and coal as opposed to only coal caused variations in the pollutant emission rate. The study recorded a 37% increase in the rate of emission for CO, a 24% increase for SO_2, an 11% decrease for NO_x, and a 48% increase for HCl when tires were included. The rate of emission for metals increased 61% for Fe, 33% for Al, 487% for Zn, 127% for Pb, 339% for Cr, 100% for Mn, and 74% for Cu, and decreased 22% for Hg. On the other hand, the emission rate of organic compounds dropped by 14% for polycyclic aromatic hydrocarbons, 8% in naphthalene, 37% in chlorobenzene, and 45% in dioxins and furans. We used a Gaussian model of atmospheric dispersion to calculate the average pollutant concentration (1-h, 24-h, and annual concentrations) in the ambient air at ground level with the help of the ISC-ST2 software program developed by the USEPA. When tires were used, we observed (i) a 12 to 24% increase in particulate matter, this range considering the concentration variation depending on the average used (1-h, 24-h, and annual basis), 31 to 52% in CO, 22 to 34% in SO_2, 39 to 52% in HCl, 12 to 27% in Fe, -3 to 8% in Al, 30 to 37% in Zn, and 270 to 885% in Pb; (ii) a decrease of 8 to 13% in NO_x, 9 to 13% in polycyclic aromatic hydrocarbons, 6 to 7% in naphthalene, 32 to 39% in chlorobenzene, and 32 to 45% in dioxins and furans. The results obtained showed that the maximum ground-level concentrations were well within the environmental standards (for operation with only coal as well as for operation with a combination of coal and tires).

Legator, M. S., C. R. Singleton, et al. (1998). "The health effects of living near cement kilns; A symptom survey in Midlothian, Texas." Toxicology and Industrial Health 14(6): 829-842. (Legator, Singleton et al. 1998)

Cement kilns are major sources of toxic air emissions. Regulations based on demonstrated concentrations of specific chemicals, and risk assessments with inherent limitations and uncertainties, are the current methods of preventing exposure to 'unsafe' emission levels. Monitoring data are frequently incomplete. These limitations mandate that residents residing near cement kilns be evaluated for adverse health effects. This study reports findings from a symptom survey conducted in Midlothian, Texas, which adds to the limited but growing body of knowledge showing that persons living near cement kilns are experiencing increased respiratory effects. This cross-sectional study uses randomized sampling and an extensive health questionnaire, covering 12 physiological systems, to determine differences in reported health symptoms between the study community (Midlothian, Texas, n = 58) and the reference community (Waxahachie, Texas, n = 54). Findings indicate significant elevations in reported respiratory symptoms in the study community (p-value 0.002). Although the comparatively small sample size is a limitation, the fact that only 'respiratory effects' were highly significant supports the efficacy of this investigation. Respiratory effects would be the major anticipated outcome from the known exposures under investigation. This specificity of response (i.e., elevation in respiratory symptoms only), indicates that 'response bias' was not a significant factor in this study.

Performance of Existing Kilns

The conclusions of the review of existing cement plants in South Africa (Karstensen 2007) gives cause for concern.

This report confirms that "*Kiln systems with 5 cyclone preheater stages and precalciner are considered standard technology for ordinary new plants*". The conclusions are careful not to completely undermine the older kilns but they concentrate only on multi-stage pre-heater, pre-calciner kilns as being the only kilns with the technological advantages to overcome the many problems of waste burning.

It is also clear, even though the conclusions are carefully worded, that many of the existing kilns do not meet modern standards:

"Compared with "international" technology, for example in Europe, many of the South African kilns, especially the long dry without preheating or exit gas conditioning, are old with low energy efficiency and low environmental performance. It is doubtful if it's economical feasible to upgrade these kilns and improve the performance significantly."

But even amongst the more modern pre-calciner kilns none have bypasses or other features which would be standard in a BAT kiln.

Of even greater concern is the comment on p40 that "*Some of the long dry kilns have no exit gas conditioning or cooling before the gas enters to the air pollution control device (electro static precipitator), implying that the temperature will be in the range of 200-400 0C, which under unfavorable conditions may contribute to the formation and release of dioxins; this should be checked*". This rather under-states the possible hazards – it was conditions like these that have been responsible for many of the historically high emissions of cement kilns with emission levels of 50 ng/m3 and sometimes even higher of dioxins. <u>It is vital that action is taken to follow up these concerns.</u>

It is claimed that "*Most of the "new" South African kilns are comparable to "international" performance standards, i.e. equipped with preheaters (and calciner), efficient clinker coolers and raw mills, exit gas conditioning, sufficient air pollution abatement capacity, on-line emission monitors, and independent measurements of for example dioxins*".

Yet this is demonstrably not the case for the kilns reviewed as can be seen from the summary abstracts below. Few have actually been sampled for dioxin (and there is no suitable lab in South Africa in any case) but most do not have the basic emission monitoring equipment that would be required for European Kilns. Incredibly several of these kilns are already burning wastes but the quantities are claimed not to be available (!).

The report says:

"*All the plants recive (sic) electricity from the grid, i.e. Escom. Most of the plants said they experience dips in power with subsequent process and air pollution control instability*". Yet the summary reports, copied below in Annex 4, shows that all claim, incorrectly, to have a reliable and adequate electricity supply. Presumably this has been 'moderated' because it is recognised that the unreliability of the electricity supply dramatically increases the risks associated with the treatment of hazardous wastes in cement kilns.

Whilst it is suggested that "It would probably be economic (sic) feasibile to upgrade all of the "new" South African kilns to comply with for example the EU emission limit values" no indication is given of the costs of doing so or what improvements would be required

The conclusions say that whilst the kilns visited "*would, from a technical standpoint, be able to co-process AFRs and treat hazardous wastes*." (subject to upgrading to European standards at an unspecified cost if dual standards are not to be operated) the " *"Inherent" kiln features, as high temperatures and long residence time, is however not enough to be qualified to co-process AFRs and treat hazardous wastes adequately*".

In addition the plant "need qualified and skilled employees to manage AFRs and hazardous wastes, as well as health, safety and environmental issues; they will need adequate emergency and safety equipment and procedures, and regular training; they will need authorised and licensed collection, transport and handling "systems"; they will need safe and sound receiving, storage, preparation and feeding facilities; they will need adequate laboratory facilities and equipment for AFR and hazardous waste acceptance and feeding control; and they would need to demonstrate the destruction performance of hazardous wastes through test burns." Given that these requirements are not already in place it begs the question why the burning of wastes is currently being permitted in the South African kilns. All current waste burning should be stopped until at least these basic minimum requirements are met.

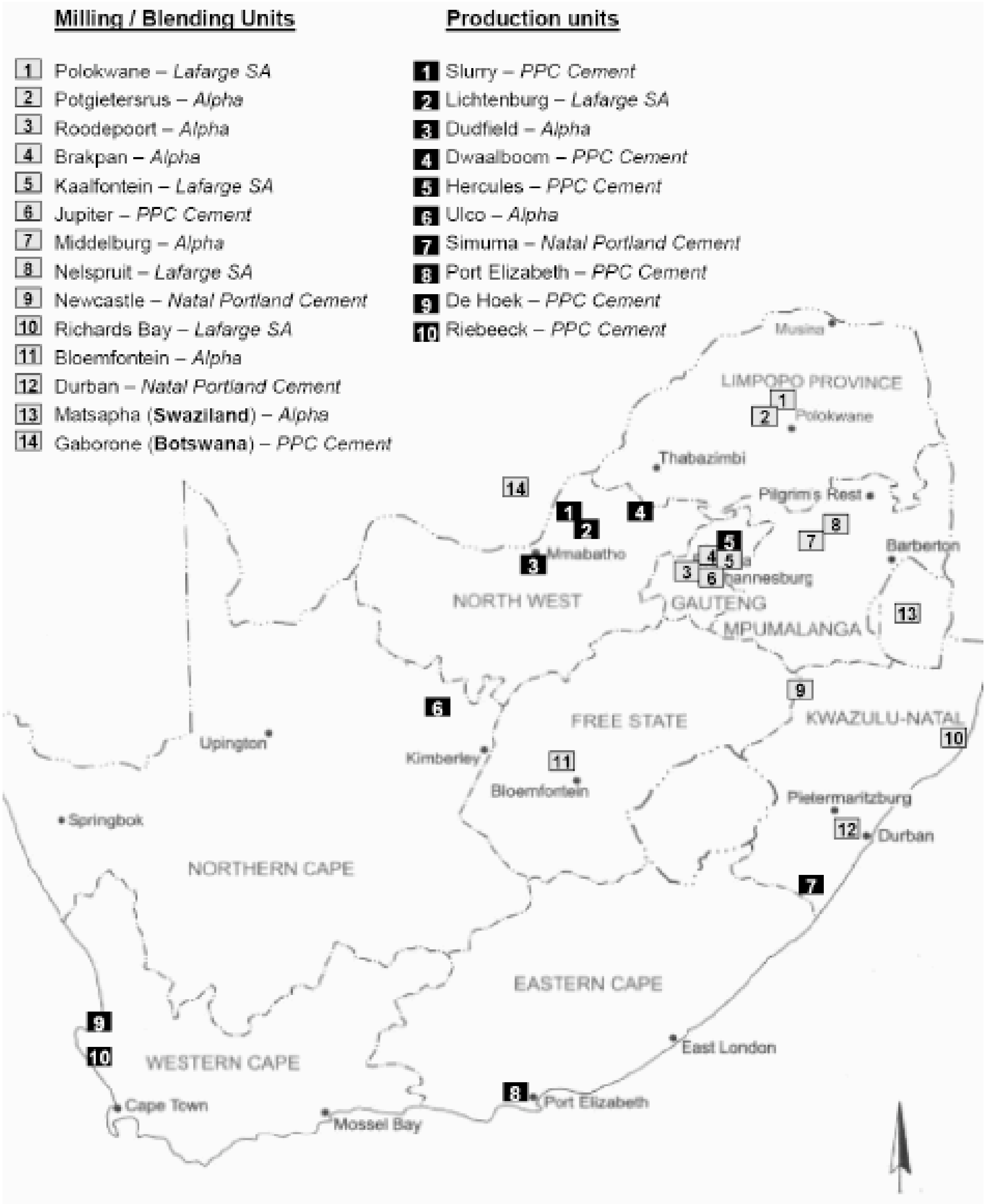
The Holcim GTZ guidelines (Holcim and GTZ 2006) say:

"Co-processing should only be applied if not just one but all tangible pre-conditions and requirements of environmental, health and safety, socio-economic and operational criteria are fulfilled."

It is clear from the information provided in this consultation that this situation does not currently apply to the wastes being burned in cement kilns in South Africa and is unlikely to do so in the foreseeable future.

Company	Afrisam			NPC-Cimpor		Lafarge	
Plant location/name	Dudfield		Ulco	Simuma		LIC	
Kiln #	#2	#3	#5	# 1	# 2	# 2	# 3
Clinker production (t/y)	~780000	~1100000	~130000	587153	uc	664 983	675 349
Coal consumption (t/y)	~130000	~160000	~170000	74793		109552,0	109248,8
Electricity consumption (MWh/y)	~150000		~110000	43804		214 874	
Energy consumption (MJ/t clinker)	<5.000	<4.000	<4.000	3,52		3924	3825
Kiln type / Process technology	FLS/DS2	FLS/PC4	Polysius PC4	4 PH	4 PH/PC	air through	air separator
Exit gas cooling/conditioning	Conditioning tower	Conditioning tower	Conditioning tower	Yes	Yes	135°C	140°C
By-pass	No	No	No	No	No	no	no
Air Pollution Control Device's)	Bag Filter	Bag Filter	EP	ESP	Bag house	Oldham EP1000	Oldham EP1000
Temperature in APCD / stack (°C)	~160/~150C	~160/~150C	~160/~150C	130		112°C	139°C
Dust recovery(?)	99,997%	99,997%	>98%	Yes, back to kiln		Recovered dust fed back into process.	
On-line emission gas monitoring (system and parameters)	Opsis/Durag	Opsis/Durag	Opsis/SICK	yes		not available	not available
Emissions: Dust (mg/Nm_3) - Average value and number of measurements	14 (CEM)	9 (CEM)	129 (CEM)	70 - continuous		73 daily	95- daily
NO_x (mg/Nm3) - Average value and number of measurements	590 (CEM)	450 (CEM)	680 (CEM)	540 - continuous		1000 (weekly)	950 (weekly)
SO_2 (mg/Nm3) - Average value and number of measurements	40 (CEM)	8 (CEM)	3 (CEM)	2.8 - continuous		0 (weekly)	0 (weekly)
VOC / TOC (mg/Nm3) - Average value and number of measurements	4.6(CEM)	3 (CEM)	2 (CEM)	25 - once off in 2003		Not measured	
HCl (mg/Nm3) - Average value and number of measurements	9.7 (CEM)	10.8 (CEM)	13 (CEM)	0 - once off in 2002		Not measured	
HF (mg/Nm3) - Average value and number of measurements	n/a	<1 (CEM)	<1 (CEM)	0 - once off in 2002		Not measured	
PCDD/PCDF (ng TEQ/Nm_3) - Average value and number of measurements	0,0023	0,0016	0,0065	.001 once off in 2002		Not measured	
PCBs (ng TEQ/Nm3) - Average value and number of measurements	0,0000	0,0013	0,0013	001 - once off in 2002		Not measured	
Heavy metals (µg/Nm3) - Average value and number of measurements	See attachment	See attachment	See attachment	336 - once off in 2002		Not measured in gas but dust.	
Co-processing AFR and/or mineral substitutes (types and volumes t/y)	Nil	Nil	Nil	No		No AFR	
Infrastructure and equipment for AFR-handling, pre-treatment and feeding	Limited	Limited	Limited	No		No AFR	
Environmental management system, e.g. ISO 14001	Certified	Certified	Certified	edited for ISO 14001 in 2004		Lafarge environmental standards.	
Reliable and adequate electricity supply (?)	Yes - Eskom	Yes - Eskom	Yes - Eskom	Yes		Yes, Eskom supply	
Reliable and adequate water supply (?)	Yes - Own	Yes - Own	Yes - Own	Yes		Yes, Boreholes	
Laboratory for quality control	Yes	Yes	Yes	Yes		yes	
Laboratory for control of AFR (?)	Partial	Partial	Partial	No		No AFR	

Plant location/name	Slurry				Hercules		Jupiter	De Hoek		Dwaalboom		Port Elizabeth	Riebeeck	
Kiln #	# 5	# 6	# 7	# 8	#4	#5	#3	#5	#6	#1	#2	#4	#1	#2
Clinker production (t/y)	155000	155000	295000	776000	169000	357000		357000	450000	621000	1024000	197000		
Coal consumption (t/y)	274000				110000			120000		250000		50000		
Electricity consumption (MWh/y)	130000				80000			90000		130000		28000		
Kiln type / Process technology	Long Dry	Long Dry	1 St PH	4 St PH	1 St PH	4 St PH		4 St PH	4 St PH	5 St PH	6 St PC (ILC)	Long Dry Kiln		
Exit gas cooling/conditioning	No	No	No	Yes	Yes	Yes		Yes	Yes	Yes	Yes	No		
By-pass	No	No	No	No	No	No		No	No	No	No	No		
Air Pollution Control Device's)	ESP	ESP	ESP	ESP	ESP	ESP		ESP	ESP	ESP	Bag House	ESP		
Temperature in APCD / stack (^0C)	250	250	318	120	130	130		125	112	150	80	270		
Dust recovery(?)	Yes	Yes	Yes	Yes	Yes	Yes		Yes	Yes	Yes	Yes	Yes		
On-line emission gas monitoring (system and parameters)	Dust	Dust	Dust	Opsis	Dust	Opsis		Dust	Opsis	Dust	Opsis	Dust		
Emissions: Dust (mg/Nm^3) - Average value and number of measurements	250	250	100	80	200	120	Not considered due to the fact that the kiln will not use Secondary Fuels	150	150	150	150	200	Not considered due to the fact that the kiln will not use Secondary Fuels	
NO_x (mg/Nm3) - Average value and number of measurements	1400	1400	800	700	1400	1200		900	800	1400	1000	1400		
SO_2 (mg/Nm3) - Average value and number of measurements	200	200	130	<10	10	10		180	180	1,7	1,7	30		
VOC / TOC (mg/Nm3) - Average value and number of measurements	Not available				Not Available			Not Available		Not Available		Not Available		
HCl (mg/Nm3) - Average value and number of measurements	Not available			<1	Not Available			2	2	6	Not Available	12		
HF (mg/Nm3) - Average value and number of measurements	Not available			<0.4	Not Available			<0.1	<0.1	0,4	Not Available	<0.5		
PCDD/PCDF (ng TEQ/Nm_3) - Average value and number of measurements	Not available				Not Available			Not Available		Not Available		Not Available		
PCBs (ng TEQ/Nm3) - Average value and number of measurements	Not available				Not Available			Not Available		Not Available		Not Available		
Heavy metals (µg/Nm3) - Average value and number of measurements	Not available				Not Available			Not Available		Not Available		Not Available		
Co-processing AFR and/or mineral substitutes (types and volumes t/y)	None	None	SPL Volume N/A	SPL Volume N/A	SPL Volume N/A	SPL Volume N/A		None	None	SPL Volume N/A	SPL Volume N/A	SPL Volume N/A		
Infrastructure and equipment for AFR-handling, pre-treatment and feeding	None	None	Feeding	Feeding	Feeding	Feeding		Not applicable		Feeding	Feeding	Feeding		
Environmental management system, e.g. ISO 14001	ISO 14001				ISO 14001			ISO 14001		ISO 14001		ISO 14001		
Reliable and adequate electricity supply (?)	Reliable - Power outages 1 per month				Reliable			Reliable		Reliable		Reliable		
Reliable and adequate water supply (?)	Reliable				Reliable			Reliable		Reliable		Reliable		
Laboratory for quality control	Yes				Yes			Yes		Yes		Yes		
Laboratory for control of AFR (?)	Integrated into plant Lab				Integratd			Not applicable		Integratd		Integratd		


Milling / Blending Units
1 Polokwane – Lafarge SA
2 Potgietersrus – Alpha
3 Roodepoort – Alpha
4 Brakpan – Alpha
5 Kaalfontein – Lafarge SA
6 Jupiter – PPC Cement
7 Middelburg – Alpha
8 Nelspruit – Lafarge SA
9 Newcastle – Natal Portland Cement
10 Richards Bay – Lafarge SA
11 Bloemfontein – Alpha
12 Durban – Natal Portland Cement
13 Matsapha (Swaziland) – Alpha
14 Gaborone (Botswana) – PPC Cement
Production units
1 Slurry – PPC Cement
2 Lichtenburg – Lafarge SA
3 Dudfield – Alpha
4 Dwaalboom – PPC Cement
5 Hercules – PPC Cement
6 Ulco – Alpha
7 Simuma – Natal Portland Cement
8 Port Elizabeth – PPC Cement
9 De Hoek – PPC Cement
10 Riebeeck – PPC Cement
Musina
LIMPOPO PROVINCE
Polokwane
Thabazimbi
Pilgrim's Rest
Barberton
Mmabatho
NORTH WEST
GAUTENG
MPUMALANGA
FREE STATE
KWAZULU-NATAL
Upington
Kimberley
Bloemfontein
Pietermaritzburg
Durban
Springbok
NORTHERN CAPE
EASTERN CAPE
East London
WESTERN CAPE
Cape Town
Mossel Bay
Port Elizabeth

PPC CEMENT (PTY) LTD DE HOEK	
Certificate Number	35/3
Issued	24 February 1999
Period of validity	Not stated
Situation	Farm Rietfontein No 184, district Piketberg (1338,62 ha)
Nature of Process	Cement Process (No 22) Limestone and shale/latorite are mined and crushed in a quarry adjoining the plant. Together with sand and iron ore/filter dust granules (FDG) these raw materials are mixed in computer-controlled ratios and fed to two raw mills. The raw meal is homogenised and stored in silos from where it is fed into two kilns fired with pulverised coal. One kiln (No 5) is a 1150 ton per day (nominal) FL Smidth kiln with a four-stage pre-heater. The other kiln (No 6) is 1450 ton per day (nominal) Polysius kiln with a four-stage preheater. After leaving the kilns the cement clinker is cooled and stored in clinker silos. When required the clinker is finely ground in any of two cement mills where about 5% of gypsum and about 9% limestone is added. The unblended cement is then stored in a silo. The unblended cement is mixed with about 15% slag in a blender and stored in silos. (The milled slag is delivered to De Hoek in rail trucks and is stored in a storage silo.) The blended product is then packed/palletized and dispatched. (*Note: percentages have been crossed out and new figures written in – 4% gypsum, 9% limestone, 21% slag, respectively. Limestone has been annotated with the term NDM, which is defined as being non-deleterious material).*
Raw Materials	Limestone, shale, sand, iron ore, gypsum, laterite, filter dust granules, milled slag
Products	Portland Cement, 1 000 000 tons *Note: 1 million tons crossed out and replaced with 1.5 million tons.*

Appliances and measures to prevent air pollution	<u>Quarry</u>
	1. Water tankers are used to spray roads. Calcium chloride is added to the water to make it more effective.
	2. Dust suppression units are fitted to drilling rigs
	3. Water spray at primary and secondary crushers as well as transfer points on the conveying system
	<u>Factory</u>
	1. Water sprays are installed at the crushing stations and at transfer points on the conveying systems.
	2. Bag filters, having filtration velocities of less than 1.5 minute, control dust emission from-
	    1. raw meals transport and storage;
	    2. clinker transport;
	    3. cement transport and storage;
	    4. cement packers and bulk loading.
	3. Each kiln is equipped with a four-stage preheating system and a conditioning tower in which the temperature of the exist gases is reduced to 150°C before entering the electrostatic precipitators. Each precipitator consists of two chambers, each having two fields with each field having its own power pack.
	    The dust emission from No 5 plant shall be less then 350 mg/m3.
	    The dust from No 6 plant shall be less then 200 mg/m3.

	4. Exit gases from the two cement mills are passed through electrostatic precipitators. The dust emissions shall not exceed 200 mg/m3. Both mills exhaust through 18m high stack. 5. The rail truck tippler for offloading coal, iron ore and FDG equipped with a system of automatic water sprays for dust control. (*Note: iron ore crossed out)* 6. Exhaust gases from No 6 sand kilns are monitored continuously with a photo-electric opacity meters. (*Note: No 6 amended to No 5 & 6, sand deleted)* Note: All emissions quoted as mg/m3 shall be corrected to 0ºC and 760 mm HG.
Disposal of effluents from purification equipment	No effluents

PRETORIA PORTLAND CEMENT COMPANY LTD ***(DWAALBOOM)***	
Certificate Number	A 1326/1
Issued	2 September 2005
Period of validity	36 months
Situation	Remaining extent of Portion 2 of farm Scoongezight 238 KP Thabazimibi municipality, Limpopo Province (925.384 ha)
Nature of Process	Cement Manufacturing Processes (No 22) A rotary kiln with preheater and precalciner, prate cooler, raw mill plant and cool mill plant, all equipped with exhaust gas cleaning equipment, will be used to produce clinker from lime stone and other raw materials.
Raw materials and products	Limestone, lava or shale, iron or fines, spent pot lining (SPL), coal
Products	Clinker – Peak 1 204 500 tons/annum Normal 3 300 tons/day
Appliances and measures to prevent air pollution	<u>Raw mill and kiln:</u> 1. Dust (blended lime) from the raw mill and kiln is collected in a 6-compartment bag filter with the following specifications: a. Collection area: *(deleted)* m2; b. Air/cloth ratio: *(deleted)* m/min c. Emission flow rate: *(deleted)* Nm3/min (at 0ºC and 1 atmosphere) d. Exit temperature: 105ºC 2. The dust emission concentration emitted at a height of 120 metres above ground level does not exceed 80 mg/Nm3 as measured at 0º and 1 atmosphere pressure. 3. The final emission releases less than 7 grams/second of fluorine (measured as F) <u>Clinker cooler</u> 1. Clinker dust from the clinker cooler is collected in a 3-field, single chamber electrostatic precipitator with the following specifications: a. Collecting area: 8 400m2 b. Duct spacing: 400mm 2. The electrostatic precipitator handles a gas stream of *(deleted)* Nm3/min (at 0ºC and 1 atmosphere pressure) at an exit temperature of 305ºC. 3. The dust emission concentration does not exceed 80mg/Nm3 as measured at 0ºC and 101.3 kPa. 4. The final emission is at a height of 37 metres above ground level. <u>Coal plant</u> 1. Coal dust from the coal plant is collected in a bag filter with the following specifications: a. Collecting area: *(deleted)* m2 b. Air/cloth ratio: 1.25m/min 2. The bag filter handles a gas stream of *(deleted)* Nm3/min (at 0ºC and 1 atmosphere) at an exit temperature of 730ºC. 3. The dust emission concentration does not exceed 50 mg/Nm3 (at 0ºC and 1 atmosphere) <u>Dust from other sources</u> 1. Dust from conveying and handling systems (at transfer points, loading stations and storage silos) is kept to a minimum through the use of dedicated bag filters units to service these points. 2. Low level dust is controlled through the implementation of a grassing and paving programme. <u>General</u> 1. The main kiln stack will be provided with a continuous dust

	monitor. 2. All air abatement equipment will be available at the prescribed efficiency for 96% of the operational time per month.
Disposal of effluents from purification equipment	The disposal of all effluents will comply with the requirements of the relevant controlling authorities.

PPC CEMENT (PTY) LTD – JUPITER WORKS	
Certificate number	A146/1
Issued	1 April 2005
Period of validity	24 months
Situation	Potion 344 (portion of portion 89) of the farm Doornfontein No 92, IR, Germiston (15,6 ha)
Nature of process	Cement Processes (No 22) The manufacture of Portland cement utilising the following sections of the plant: 1. The unloading of Spoornet trucks containing various raw materials and the conveying of these raw materials to the raw material sheds 2. Milling of limestone into raw meal 3. Storage of raw meal in blending and homogenising silos 4. Burning of raw meal to clinker in a dry rotary kiln 5. Storing of clinker in a clinker shed 6. Milling of clinker into Portland cement 7. Conveying of materials by means of elevators, screws, belts and pneumatic means 8. Dispatch of bulk and bagged cement Clinker may also be imported to this site from other production facilities and then only milling, blending and dispatching will be done.
Raw materials	Limstone, slag, duff coal, gypsum, ash, sand, lime hydrate
Products	Portland cement, 580 000 tons/annum
Appliances and measures to prevent air pollution	1. Fugitive dust emissions in the tippler area, conveyor transfer points and clinker store will be improved by improving the control systems and enclosing the area where applicable. 2. The bagfilters on the transfer points and tippler will be in a fully operational condition 3. The electrostatic precipitators on the raw mills and the kiln will be overhauled and upgraded to ensure and emission level of 80mg/m3 at a control equipment availability of 98% 4. The cleaned off-gases from the kiln will be emitted to atmosphere at a height of 79m above ground level 5. Dust emissions from raw meal silos, transfer points, cement mills, cement transfer points, packing and bulk loading facilities and the palletiser are all controlled by extraction systems and bagfilters. 6. The emission to atmosphere of all the emission control equipment will be less than 80 mg/m3 as measured at 0ºC and 101,3kPa 7. Dust emissions from the operating area are kept to a minimum by keeping the area as clean as possible with the use of mechanical sweepers 8. The availability of all air pollution control equipment will not be less than 90% of the operating time per any continuous period of thirty days at the emission limits set in this registration certificate 9. When requested by this Directorate, the permit holder will within a reasonable time furnish any information required by law which is needed to determine compliance with the registration certificate.
Disposal of effluents form purification equipment	No effluents

PPC CEMENT (PTY) LTD *(RIEBEECK WEST)*	
Certificate number	34/3
Issued	19 March 1999
Period of validity	Not stated
Situation	Farm Ongegund, Annex 508 and 618, Riebeeck West (664,98 ha)
Nature of Process	Cement processes (No 22) The production of cement clinker in two kilns and the subsequent milling, packing and bulk loading of Portland cement. No 1 kiln: a rotary kiln with a capacity of 720 tons/day No 2 kiln: a rotary kiln with one stage of preheat capable of producing 840 tons/day
Raw materials	Limestone, shale and sandstone, gypsum, filter dust granules, coal
Products	Portland cement; *(deleted)* tons / annum
Appliances and measures to prevent air pollution	1. The exhaust gases form No 1 kiln pass through an electrostatic precipitator and are exhausted through a chimney 76.2 m high. The precipitator consists of two chambers, each having three fields with their own separate power packs. 2. No 2 kiln is equipped with a single stage feed preheater on leaving which the exhaust gases pass through a conditioning tower and an electrostatic precipitator consists of two chambers, each having two fields with their own separate power packs. 3. Each of the two raw mills, heated by cleaned exhaust gases form the kiln, is fitted with an electrostatic precipitator and a chimney 28.6m high 4. No 1 cement mill is ventilated through two electrostatic precipitators, coupled in series and a chimney 21,3m high 5. No 2 cement mill is ventilated through a bagfilter and a chimney 23.2m high] 6. Emissions from all electrostatic precipitators shall have a dust content of less than 120mg per cubic metre measured at 0ºC and 760 mm Hg 7. Dust from the blending plant and two plants is removed in high efficiency bag filters.
Disposal of effluents from purification equipment	No effluents

PRETORIA PORTLAND CEMENT COMPANY LIMITED – "SIRROCCO", PORT ELIZABETH	
Certificate number	148/1
Issued	24 April 1986
Period of validity	Not stated
Situation	"Sirrocco", of Old Grahamstown Road, Port Elizabeth; 30 ha
Nature of process	Limestone, clay, silica sand, crushed quartzitic sandstone and haematite are mixed and milled in ball mills. The product is calcined in a rotary kiln to produce cement clinker, which in turn is milled and mixed with gypsum to produce various grades of Portland cement. This is either delivered in bulk or packed in paper bags.
Raw materials	Limestone, clay, silica sand, quartzitic sandstone, haematite
Products	+- 270 000 tons/year
Appliances and measures to prevent air pollution	1. Raw mills 1 & 2: one electrostatic precipitator having two banks and three power packs. Stack height 15 *(illegible)*. Raw mix transport system: One "Intensiv" bagfilterand three small "Dalmatic" bagfilters. Kiln feed and transport system: "Intensiv" bagfilter. Cement mill: "Intensiv" bagfilter. Packing plant: "Intensiv" bagfilter 2. The kiln exhaust gases are passed through two cycles followed by an electrostatic precipitator. The e.s.p. consists of two parallel banks each of which has three chambers. The first chamber has its own power pack making it possible to link out individual chambers. The exhaust gases are discharged through a 73m high chimney. 3. The concentration of dust in the exhaust gases shall not exceed, on a 24 hour average, 200 mg/m3 measured at 0ºC and 760 mm Hg.
Disposal of effluents from purification equipment	No effluents

Note: a letter dated 10 March 2006 indicates that a new certificate was issued, but we were not furnished with a copy of this.

PPC HERCULES	
Certificate number	A 144/4
Issued	8 June 2004
Period of validity	Forty eight months
Situation	Remaining extent of portion 70 (Portland Estate) and remaining extent of Portion 93 (Les Marais) of the farm Daspoort No 319JR, district of Pretoria; +- 36 ha
Nature of Process	Waste Incineration Processes (No 39) Scrap tyres and sewage sludge will be incinerated as an alternative fuel to replace a percentage of coal in rotary kiln No 5.
Raw materials	Scrap Tyres and Sewage Sludge
Products	Products of incineration (products will be same as applicable to the normal cement manufacturing process).
Appliances and measures to prevent air pollution	1. A steady and accurate control of the tyres and sewage sludge feed rate will be maintained at all times. 2. On start-up the kiln will be taken up to full production with coal firing. The incineration of tyres and sewage sludge will only commence once stable conditions within 10% of production have been reached. 3. Trips on the coal feed activated by the kiln O2 and CO analyzers will also act on the tyres and sewage sludge feed. 4. Tyres and sewage sludge will be introduced at a point where the temperature is at least 800ºC 5. Complete incineration of tyres and sewage sludge will be maintained and no black smoke formed by products of incomplete combustion will be emitted. 6. The incineration process will meet all the requirements for class 1 incinerators as set out in the attached guideline document for Waste Incineration Processes (Process No 39) 7. The necessary monitoring and assessments will be done as required in terms of the Environmental Conservation Act. Results from emissions will be reported.
Disposal of effluents from purification equipment	No effluents

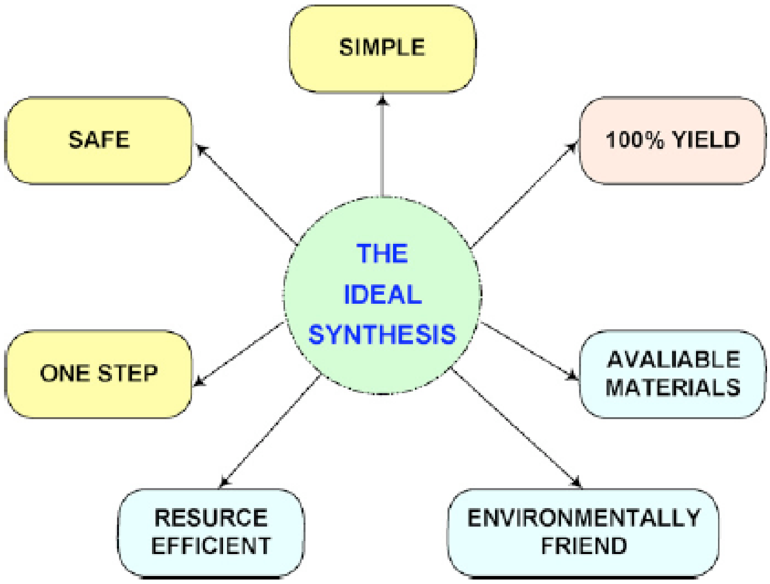
Annex 5 – Landfill Sites in South Africa: (Johannessen and Boyer 1999)

Table 4: Overview of Observations at Landfills Visited in South Africa

Region	KwaZulu/Natal	KwaZulu/Natal	KwaZulu/Natal	KwaZulu/Natal	North West	North West	Guateng	Guateng	Guateng
	Durban Bisasar Rd.	Durban Marianhill	Durban Shongweni	Durban Mobeni	Brits	Krugersdorp	Marie Louise Johannesburg	Goudkoppies Soweto	Boipatong
Landfill category	H+h (G:L:B+)	h+MSW (G:L:B+)	H+h	H+h	Regional landfill	Regional landfill	City landfill	City landfill	Township landfill
Waste types	MSW Low HZW	MSW	MSW and HZW	MSW and HZW	MSW	MSW HZW	MSW	MSW + sewerage sludge	MSW
Tonnes per day	2,400	300 (capacity 600 t/d)	MSW : 700 and 150m3 HZW	MSW: 1000 HZW (liquid): 200-250	25-100	Not known – estimated 500-1000	1900-2000	MSW: 1000 Sludge: 100	300
Operator	Municipality	Municipality	Privately owned and operated	Privately owned and operated	Co-operated by two municipalities	Municipality	Municipality- owned Privately operated (5-year contract)	Municipality- owned Privately operated (5-year contract)	Municipality owned Privately operated (5-year contract)
Tipping fee US$/tonne	MSW: 9 HZW: 42	MSW: 9	MSW: 11 HZW: 37-51	MSW: 11 HZW: 37-51	Waste registration– No tipping fees	None	12	12	MSW: 4-5
Disposal area	20 ha	1 cell: 5 ha	1 cell: 2.3 ha	5 ha	2.5 ha	15 ha	20 ha	10 ha	10 ha
Waste pickers	1 community of approx. 200 families, allowed to scavenge after 4:30 pm	No scavenging is allowed	Limited scavenging	None	Approx. 10-15 waste pickers living on-site	Extensive scavenging. 600 waste pickers living on and immediately off-site	None	None	100 registered waste pickers scavenging at the tipping front
Environmental setting	Gorge draining to adjacent river	Gorge draining to adjacent river	Hillside draining to adjacent river	Hillside/head of valley	Filling of old quarry in flat landscape	Filling of depression in landscape near old mine dump	Filling sloping land between old mine shafts and a stream valley	Filling of flat land draining to river	Filling of flat land (wet) draining to wetland
Climatic zone	Wet	Wet	Wet	Wet	Arid	Arid	Semi-arid	Semi-arid	Wet
Liner	Compacted clay liner	Multi-barrier liner	Multi-barrier liner with leak-detection layer	Multi-barrier liner with leak-detection layer	None	None	None	None	None
Leachate collection	Limited collection	Leachate collection and storage	Leachate drainage using old tires	Drains and leachate storage tanks	None	None	None	None	Diversion of run-on surface water and collection of leachate
Leachate treatment	Collected leachate discharged to municipal sewer	Discharge to municipal sewer	Storage and truck haul to nearest municipal sewer treatment plant	Municipal sewer	None	None	None	None	Leachate treated at sewage works. Sent via sewer pump station
Gas management	Active gas collection and flaring	None at present	None at present	Active gas collection and flaring	None	None	None	None	None
Operating techniques	Cell/area methods with down up compaction. HZW in trenches adding lime. Daily soil cover	Cell methods with down up compaction. Daily soil cover	Cell methods with daily soil cover	Comment: 1 cell has just collapsed and slid into new cell under construction	Grading of waste by bulldozer and random covering with soil	Grading and random compaction. Periodic soil covering	Cell methods operated with limited tipping front and daily soil cover	Cell methods operated with limited tipping front and daily soil cover	Cell methods operated with limited tipping front and daily soil cover
Equipment	4 weighbridges 3 compactors 2 bulldozers 1 payloader 2 excavators 2 dump tractors 1 tipper truck 2 water tankers Staff: 43	2 weighbridges 2 compactors 1 payloader 1 bulldozer 2 trucks Staff: 13	1 weighbridge 1 compactor 1 bulldozer 2 bucket loaders 1 dump tractor 1 excavator Staff: 32	N/a	No weighbridge 1 bulldozer	No weighbridge 2 compactors	2 weighbridges 1 compactor 1 excavator 1 bucket loader 2 tractors	2 weighbridges 1(2) compactor 1 bulldozer Staff: 28	1 weighbridges 1 compactor 1 front-end loader 1 bulldozer 1 water tanker Staff: 9

Annex 6 – Key Principles of Green Chemistry

Twelve principles of Green Chemistry (Garcia-Serna, Perez-Barrigon et al. 2007) to design environmentally benign products and processes or to evaluate the already existing processes are:



Towards the Ideal Chemistry.

(1) *Prevention*. It is better to prevent waste than to treat or clean up waste after it has been created.

(2) *Atom economy*. Synthetic methods should be designed to maximise the incorporation of all materials used in the process into the final product.

(3) *Less hazardous chemical syntheses*. Wherever practicable, synthetic methods should be designed to use and generate substances that possess little or no toxicity to human health and the environment.

(4) *Designing safer chemicals*. Chemical products should be designed to effect their desired function while minimising their toxicity.

(5) *Safer solvents and auxiliaries*. the use of auxiliary substances (e.g., solvents, separation agents, etc.) should be made unnecessary wherever possible and innocuous when used.

(6) *Design for energy efficiency*. Energy requirements of chemical processes should be recognized for their environmental and economic impacts and should be minimized. If possible, synthetic methods should be conducted at ambient temperature and pressure.

(7) *Use of renewable feedstocks*. A raw material or feedstock should be renewable rather than depleting whenever technically and economically practicable.

(8) *Reduce derivatives*. Unnecessary derivatization (use of blocking groups, protection/deprotection, temporary modification of physical/chemical processes) should be minimised or avoided if possible, because such steps require additional reagents and can generate waste.

(9) *Catalysis*. Catalytic reagents (as selective as possible) are superior to stoichiometric reagents.

(10) *Design for degradation*. Chemical products should be designed so that at the end of their function they break down into innocuous degradation products and do not persist in the environment.

(11) *Real-time analysis for pollution prevention*. Analytical methodologies need to be further developed to allow for real-time, in-process monitoring and control prior to the formation of hazardous substances.

(12) *Inherently safer chemistry for accident prevention*. Substances and the form of a substance used in a chemical process should be chosen to minimize the potential for chemical accidents, including releases, explosions, and fires.

The need for end-point engineering solutions to prevent pollution from being released into the environment is minimised when green chemistry principles are incorporated into feedstock and reagent selection, solvent use, and overall synthetic design.

A more detailed description of how each element of these guidelines may be applied in practice can be found in Warner et al (Warner, Cannon et al. 2004).

Annex 7 - Exclusionary Factors in Site Selection

The WHO (Sloan 1993)[17] has listed a number of exclusionary factors in site selection for hazardous waste management facilities. Again there was no reference to these factors in the literature reviews but they are important and long established. These site selection factors should therefore be included in any policy on hazardous waste and are:

1. Unstable or weak soils, such as organic soil, soft clay or clay-sand mixtures, clays that lose strength with compaction, clays with a shrink-swell character, sands subject to subsidence and hydraulic influence, and soils that lose strength with wetting or shock.

2. Subsidence owing to solution-prone subsurfaces, subsurface mines (for coal, salt and sulphur) and water, oil or gas withdrawal.

3. Saturated soils, as found in coastal or riverine wetlands.

4. Groundwater recharge, as in areas with outcrops of aquifers of significant or potential use, considering water availability and regional geology (where an impermeable or retarding layer shields the aquifer from the land surface, a specific site analysis should be conducted).

5. Flooding, as in flood plains or hydraulic encroachment, coastal or riverine areas with a history of flooding every 100 years or less, and areas susceptible to stream-channel or storm encroachment (even if not historically subject to flooding).

6. Surface water, which precludes sites above an existing reservoir or a location designated as a future reservoir, or above an intake for water used for human or animal consumption or agriculture and within a distance that does not permit response to a spill based on high-flow (most rapid) time of travel.

7. Atmospheric conditions, such as inversions or other conditions that would prevent the safe dispersal of an accidental release.

8. Major natural hazards, such as volcanic action, seismic disturbance (of at least VII on the modified Mercalli scale) and landslides.

9. Natural resources, such as the habitats of endangered species, existing or designated parks, forests and natural or wilderness areas.

10. Agricultural or forest land of economic or cultural importance.

11. Historic locations or structures, locations of archaeological significance and locations or land revered in various traditions.

[17] Table 2 page 34

12. Sensitive installations, such as those storing flammable or explosive materials, and airports.

13. Stationary populations, such as those of hospitals and correctional institutions.

14. Inequity resulting from an imbalance of unwanted facilities of unrelated function or from damage to a distinctive and irreplaceable culture or to people's unique ties to a place.

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