BZL Kommunikation und
Projektsteuerung GmbH
Lindenstr. 33
D – 28876 Oyten
Tel. ++49 4207 91763-10
Fax. ++49 4207 91763-12
info@bzlgmbh.com
http://www.bzlgmbh.com

BZL Kommunikation und Projektsteuerung GmbH

Ecodumping by Energy Recovery

A Report on Distortions of Environmental
Standards between Disposal and Recovery
and approaches to overcome them

Client:
European
Environmental
Bureau (EEB)

January 2001

Foreword

Energy recovery is burning waste and using it as a substitue fuel in order to generate heat or electricity. Without strictest pollution control it is a highly polluting activity, releasing considerable amount of hazardous substances into the environment or into the products resulting from the recovery operations.

Operators of the energy recovery sector and their clients have launched one of the most aggressive campaigns in Europe to increase their market shares. They fight downstream and upstream and they successfully manipulate politicians and high level Commission officials by misleading messages.

The downstream fight is easy. The recovery industry lets a distorted market work: Due to local protest many operators of municipal waste incineration plants have moved their emission control much beyond legal compliance in order to find a minimum public acceptance. As a result waste incineration has become an expensive disposal option and waste streams are getting diverted from incineration and go towards cheaper energy recovery. Many recovery operators do not only do normal business, but they earn the regulatory dividend from considerably weaker pollution control. It is the most haevily polluting ones, who make the best business. In order to even strengthen their competitive advantage over disposal operation, recovery operators want to change the waste definition: they want to get rid of administrative controlls, which are necessary to monitor the flows of potentially hazardous substances.

The upstream fight is more demanding. Revovery industries fight ambitious policies for recycling with the arguments of cost effectivity and climate protection. Recovery can for the time being credibly claim to be cheaper than recycling in the short run, but recycling will catch up. The climate change argument however is misleading: the environmental performance of recycling is generally much better than for energy recovery, especially as regards climate protection. This is the result of a recent literature review done for the EEB.[1]
This report now highlights a forgotten dimension of recovery: the release of hazardous substances into the environment or into the products. With health becoming a priority of EU environmental policies next to climate change, those releases must be of major concern. An environmental policy needs careful design to prevent shifting of environmental problems. The neglected toxics dimension of recovery is a case in point.

---

[1] Assessment of Plactic Recovery Options, Wollny, Volrad, Schmided, Martin, EEB publication 008/2000, March, available from the EEB website: www.eeb.org

The problem of ecodumping of recovery activities urgently needs to be addressed. As long as recovery industries make business with ecodumping, they are no credible alternatives to disposal and recycling.

The EEB fully supports the twin strategy suggested by the author of the study, Dr. Uwe Lahl, to overcome the problem: establishing fuel specifications for wastes to be accepted for recovery and harmonising pollution control requirements between disposal and recovery operations. The Art. 18 of the IPPC directive offers a strong legal basis for this option.

Since many waste streams are very heterogenous as regards their contamination levels, fuel specifications cannot be used as an argument for the deregulation of the waste definition. A control over the life-cycle from waste to recovery is necessary

Dr. Christian Hey
EU Policy Director

Table of contents

FOREWORD I

1 INTRODUCTION 1

2 THE PROBLEM 1

3 DESCRIPTION OF WASTE MATERIALS IN TERMS OF THEIR POLLUTANT IMPACT 2

3.1 Hazardous wastes 3

3.2 Domestic wastes 5

3.3 Production-specific industrial wastes 9

3.4 Packaging wastes (*Grüner Punkt* or "Green Dot") 11

3.5 Conclusion regarding waste qualities 12

4 DISPOSAL METHODS 13

4.1 Thermal disposal of wastes 13
  4.1.1 Thermal disposal in incinerating plants for hazardous waste 14
  4.1.2 Thermal disposal in conventional waste incineration plants (WIPs) 17
  4.1.3 Conclusion regarding disposal 19

4.2 Waste recovery 20
  4.2.1 Material recycling 20
  4.2.2 Energy recovery 22
  4.2.3 Feedstock recycling 30
  4.2.4 Conclusion regarding recovery 33

5 SOLVING THE PROBLEM 34

5.1 The dual nature of recycling and disposal 34

5.2 The EU Incineration Directive - a partial solution 37

5.3 Solving the problem by imposing requirements with regard to substitute fuel 37

5.4 Article 18 of the IPPC directive 39

6 OVERALL CONCLUSION 40

7 REFERENCES 41

1 Introduction

In the EU Member States, waste is often recycled in facilities with a lower environmental protection standard than applies to waste disposal. This is even more true for wastes which are not included in the waste regime and are, for example, intended for use as products taking the form of a substitute fuel.

The different standards applied to (recycling/disposal) plants are creating an ecological and economic divide and a trend towards plants subjected to a lower emission control standard. **This phenomenon is referred to in the literature as "ecodumping".**

The present study seeks to document and examine the ecological impact of this phenomenon and different strategies to address the problem, namely quality specifications for waste to be recovered and the role that Article 18 of the IPPC Directive could play in eliminating the aforementioned divide.

Art. 18 of the IPPC Directive says:
“ Acting on a proposal from the Commission, the Council will set emission limit values, in accordance with the procedures laid down in the Treaty, for:

- *the categories of installations listed in Annex I except for the landfills covered by categories 5.1. and 5.4 of that Annex and*
- *the polluting substances referred to in Annex III*

for which the need for Community action has been identified, on the basis, in particular, of the exchange of information provided for in Art. 16. “

This article allows for a harmonised emission control approach, if the Commission identifies its need. It should rely on the results of the Information Exchange Process organised to identify Best Available Techniques and associated emission and consumption levels. But it is not necessarily restricted to base its analysis on this information exchange process only.

So far the problem of waste streams moving towards less regulated waste management options has not been systematically discussed in the framework of the Information Exchange Process. This document has to be considered as a first systematic input to this debate.

2 The problem

Differing environmental protection standards can lead to distortions of competition. This is currently becoming a major problem in Europe's waste industry due to the very high standards for waste disposal and the mass of regulations governing, with the former in particular causing high disposal costs.

Under the guise of engaging in recycling which intrinsically is ecologically positive, waste owners and professional waste disposal firms are currently attempting to evade the strict waste regime and have material, energy or raw materials recycled in industrial plants that are less well-equipped in environmental terms.

In recent years this strategy geared towards evasion, what originally represented a growing problem in individual countries, has become a European issue, and there has been a clear increase in the exchange of waste for recycling across national borders.

To assess the situation, it is important to relate the respective types of waste to the destination routes (facilities), the key factor here being how the hazard potential of waste is dealt with. As a result, we shall start with the chemical characterization of each type of waste, then describe the capacity of the relevant disposal and recycling facilities to control pollution by hazardous substances before finally looking at the need to harmonize pollution control for disposal and recovery operations.

This study focussed on central European and Scandinavian facilities and data, an approach that is justified from the pan-European viewpoint because it underestimates rather than overestimates the environmental risks inherent in recovery. When considering other regions of Europe the gap between disposal and recovery in environmental technology may be higher. Moreover, in many countries the ecodumping described has not yet developed as far as is the case in Germany. However, it must be assumed that the situation will develop in the same way throughout Europe unless political steps are taken to counteract this trend.

3 Description of waste materials in terms of their pollutant impact

A very large number of waste materials is currently being considered as a fuel for recovery. A distinction has to be drawn between several categories:

- the large group of wastes particularly in need of monitoring ("hazardous wastes"),
- those falling under the general heading of domestic wastes (generated by households and businesses),
- product-specific industrial wastes and
- wastes collected separately for recycling, such as packaging waste .

3.1 Hazardous wastes

The following table shows the range of concentration of hazardous substances for selected hazardous wastes currently under discussion with a view to their recovery in the cement industry. As a rule, it is rather difficult to reprocess such wastes in order to reduce their contamination. . Where this is achieved, concentrations of pollutants are often reduced by mixing them with less-polluted batches or other fuels, such as sawdust.

The table clearly shows that high concentrations are to be expected where hazardous wastes are concerned. However, and this is part of the problem in assessing the situation, not every area of origin of the waste code (i.e. waste type) in question is necessarily associated with a high level of pollution. But this presentation of the data is intended to demonstrate precisely those high fluctuations that can extend as far as the per-thousand range for individual heavy metals. This statement is documented in the table below using wastes (or data) explicitly selected and conditioned for recycling in European cement works.

Table 1: Contamination of selected hazardous wastes intended for energy recovery (* = FS stands for 'fresh substance', meaning not converted to dry substance (as is often done in practice). MJ = megajoule, Mg = megagram, the new unit for 'tonne')

		Mixed hazardous wastes (Number of samples = 37)		Paint and lacquer sludges (Number of samples = 12)		Petroleum sludges (Number of samples = 43	
Parameter	Dimension in FS*	Mean value	Maximum value	Mean value	Maximum value	Mean value	Maximum value
Net calorific value	MJ/Mg**	10,532	16,000	10,140	27,420	14,410	30,100
Total chlorine	%	0.18	1.2	0.16	0.5	0.4	2
Antimony	mg/kg					4.9	6.6
Arsenic	mg/kg			2.5	2.5	5	5
Lead	mg/kg	309	1,700	2,569	15,700	276	1,182
Cadmium	mg/kg			2.9	10	6.6	27.7
Chromium	mg/kg	132	280	604	3,300	713	3,200
Cobalt	mg/kg					104	178
Copper	mg/kg	458	1,500	59.1	148	5,481	61,253
Nickel	mg/kg	131	450	15.3	35.8	376	1,416
Mercury	mg/kg			0.6	2.5	2.2	10
Vanadium	mg/kg					8.5	8.5
Zinc	mg/kg	2,396	11,000	4,513	20,800	2,706	16,811
Tin	mg/kg					17	17

3.2 Domestic wastes

The following two tables show pollution levels for residential wastes (Table 2 = household wastes, Table 3 = residential waste-like industrial wastes). The present discussion suggests the production of substitute fuels from these materials through mechanical reprocessing and fractionation. Facilities for producing such substitute fuels are generally referred to as either mechanical waste treatment plants (MWTPs) or mechanical-biological waste treatment plants (MBWTPs).

Table 2: Average contamination of domestic waste (residual wastes after separate collection of recoverable materials) (FS = fresh substance) (1)

Parameter per 17th BimSchV[2], Article 5 Section 1	Residual waste, MHKV Bamberg, MW, mg/Mg FS [REIMANN 1997]	AWISTA: domestic waste 1996/97 (MW, n = 91) mg/Mg FS [AWISTA, 1998]	TAUW/TUHH: residual waste, delivered to four German waste incinerating plants (WIPs) and 1 MBWPP, 1995/96; mg/Mg FS [EL DAWI et al., 1997]					residual-residential waste, Doedens, ISAH, 1997; MW; mg/Mg FS [DOEDENS, 1997]	Öko-Institut: Pollutant content in residual waste incl. lightweight packaging, yellow bag , mg/Mg FS [GEBHARDT, 1999]	Residual waste, medium-sized enterprise WIP Spittelau, converted to mg/Mg **FS**. [SCHACHER-MAYER et al., 1995]	Residual waste, medium-sized enterprise Wels WIP incinerating plant, mg/Mg FS [BRUNNER 1997]	**Modelling: rounded average; italics: average values Spittelau/Wels**
Cl	7,284,000	8,500,000						7,500,000	4,128,090	5,250,000	12,218,000	***8,734,000***
F	259,000							150,000		1,190,000	53,900	***622,000***
S	4,226,000	1,800,000						1,500,000	1,177,630	2,450,000	4,156,000	***3,303,000***
Cadmium	9,290	500	4,760	1,870	2,990	3,510	2,930	5,000	3,780	6,300	10,700	***8,500***
Thallium	< 70											**70**
Mercury	1,840	340	190	220	180	180	200	3,000	960	1,750	1,890	***1,800***
Antimony	37,900											**38,000**
Arsenic	1,600	1,390	6,100	8,890	5,710	6,130	7,070	3,000	8,000			**5,300**
Lead	592,000	56,280	30,760	38,100	26,940	30,790	31,680	450,000	192,760	420,000	398,000	***409,000***
Chromium	70,900	51,120	26,190	24,300	25,250	19,520	27,770	100,000	76,180			**47,000**
Cobalt	< 4,900											**4,900**
Copper	704,000	641,190	70,870	102,300	55,150	75,750	70,530	800,000		308,000	588,000	***448,000***
Manganese	346,000											**350,000**
Nickel	38,900	30,850	7,670	9,990	7,020	7,540	8,330	50,000	38,640			**22,000**
Vanadium	< 6,100											**6,100**
Tin	110,000											**110,000**
Hu												**9,500**

---

[2] BlmSchV is the German Federal Ambient Pollution Control Act

Table 3: Average contamination of mixed household-waste-like industrial wastes (including sorting residues and mixed building site wastes) (mg/Mg fresh substance (FS)) (2)

		Low-pollution, high calorific value industrial waste in					
Parameter (mg/Mg FS)	DSD-sorting residues (IVV)	Germany (ABANDA etc.)	Austria (ASTRA)	Modelling Group 5; (here: wood, plastics, textiles) [INFA/BZL, 2000b]	Mixed building site waste, Indiv. data BZL	hmäGA in A, [RAGOSSING et al. , 1999]	Rounded average **mixed household-waste-like industrial waste**
Chlorine	24,400,000	20,600,000	7,551,000	6,139,000	800,000 – 250,000,000	4,865,000	26,700,000
Sulphur	2,600,000	2,200,000	6,105,000		800,000 – 1,700,00	7,786,000	3,600,000
Cadmium	10,000	7,500	12,300	4,900	280 – 30,000	1,200	8,700
Thallium	90	0		140	550 – 780		100
Mercury	440	1,400	740	40	250 –350	410	700
Antimony	42,000	730,000		8,400	1,500 – 80,000	1,116,500	260,000
Arsenic	3,100	1,500		850	600 – 8,000	2,500	1,800
Lead	260,000	210,000	218,800	38,800	2,000 – 150,000	314,300	182,000
Chromium	93,000	380,000		34,000	600 – 60,000	380,400	170,000
Cobalt	9,700	440				8,700	5,100
Copper	540,000	2,900,000		10,700		1,075,100	1,200,000
Manganese	110,000	17,000		77,800		330,800	68,000
Nickel	55,000	11,000		10,900		190,200	26,000
Vanadium	17,000	0		5,100	2,000 – 6,000	16,130	7,400
Tin	79,000	39,000		17,800		58,600	45,000
VOC[1]							1,000,000
ELU[2]							45,000,000

[1] volatile organic compounds; here, data like household waste

[2] water-soluble organic matter; here, data like household waste

Tables 2 and 3 show contamination of the initial materials. It is also clear for this waste group that not just the level, but also the heterogeneous nature of the pollution (its spread) must be addressed.

Table 4 provides average data on apparently viable quality levels through reprocessing.

Table 4: Average contamination by substitute fuels calculated with model household waste and modelled domestic-waste-like industrial waste (including sorting residues and mixed building site wastes) and the transfer factors of the level of MWPP technology for substitute fuels

Parameter	Substitute fuel from domestic wastes (mg/Mg)	Substitute fuel from domestic-waste-like industrial wastes (including sorting residues and mixed building site wastes) (mg/Mg)
Chlorine	3,710,300	11,347,500
Sulphur	1,402,500	1,530,000
Cadmium	2,600	2,700
Thallium	no data	no data
Mercury	300	100
Antimony	14,300	97,500
Arsenic	900	300
Lead	102,500	45,500
Chromium	11,300	38,300
Cobalt	600	600
Copper	45,000	120,000
Manganese	52,500	10,000
Nickel	1,500	1,800
Vanadium	300	400
Tin	27,500	11,300

The above figures represent expectations under optimistic assumptions (high technical cost). The comparison of tables 2, 3 and 4 shows, that for individual elements there is a substantial reduction. For other elements, such as chlorine, the reduction is more marginal. In particular, the separation of ferrous and non-ferrous metals when reprocessing substitute fuel should be deemed a substantial "stage of removal".

The above table shows arithmetical mean values. The input-dependent range of the substitute fuel pollution, which can vary by as much as a factor of 10, must also be addressed.

3.3 Production-specific industrial wastes

There are a number of companies in Europe which specifically collect and reprocess suitable production-specific industrial wastes. Table 5 below gives data from monitoring one of these. It also indicates the quality levels which seem attainable for the moment.

Table 5: Average and maximum contamination levels of specifically collected and processed substitute fuels from production-specific industrial wastes for reprocessing in cement works and the limestone industry in mg/kg **DS** (given here in terms of dry substance; we would have to know the moisture values to convert to FS. The data in this table should be multiplied by 0.85 to make them comparable with the above data (the average humidity as estimated by us is 15%).)

Parameter	Substitute fuel from production-specific industrial waste (mg/Mg DS) (3)		Substitute fuel from production-specific industrial waste (mg/Mg DS) (4)	
	Mean	Max.	Mean	Max.
Hu (MJ/kg)	20 – 24		25 – 31	
Chlorine (%)		< 1.0		< 1.0
Sulphur (%)		< 0.3		< 0.5
Cadmium	< 60	< 10,000	< 40	< 12,000
Thallium	< 40	< 2,000	< 30	< 2,000
Mercury	< 10	< 1,000	< 10	< 1,000
Antimony	< 490	< 60,000	< 570	< 90,000
Arsenic	< 70	< 10,000	< 80	< 10,000
Lead	< 1,310	< 100,000	< 530	< 100,000
Chromium	720	< 100,000	< 360	< 100,000
Cobalt	< 70	< 10,000	< 60	< 10,000
Copper	4,460	< 400,000	1,210	< 150,000
Manganese	< 1,091	< 100,000	< 570	< 100,000
Nickel	< 340	< 100,000	< 180	< 100,000
Vanadium	< 200	< 20,000	< 110	< 20,000
Tin	< 460	< 75,000	< 420	< 50,000

What is interesting about the above set of data is that it was obtained on the basis of several hundred individual analyses, so the result can certainly be regarded as robust. Table 5 thus documents that fuels which can be produced out of collected industrial wastes can cause less pollution than substitute fuels obtained either from residential wastes (see above) or from the separate collection of packaging wastes (see below).

A critical point to note is that low values may also be a result of mixing material of both high and low contamination levels.

3.4 Packaging wastes (*Grüner Punkt* or "Green Dot")

Table 6 below shows mean contamination levels of separately collected and reprocessed fractions from DSD (Dual System, Green Dot) waste collection in Germany.

The separation into foils, bottles, mixed fraction and sorting residues was chosen in line with the sorting of separately collected, so-called lightweight packaging fraction (yellow bag) customary in Germany. The mixed fraction is intended for feedstock recycling and the sorting residue is being considered for energy recycling or thermal utilization. **In quantitative terms, the sorting residues and mixed fraction comprise approximately three-quarters of the separately collected packaging material.**

Table 6: Average contamination of separately collected and sorted packaging wastes in mg/Mg **DS** (given here in terms of dry substance. We would have to know the moisture values to convert to FS. The data in this table should be multiplied by 0.80 to make them comparable with the above data (the average humidity as estimated by us is 20%).) (5)

Parameter	Foils	Bottles	Mixed fraction	Sorting residues
Hu (MJ/kg)	33	37	31	16
Chlorine (%)	0.85	0.67	1.71	1.41
Sulphur (%)	0.06	0.03	0.07	0.20
Cadmium	2,580	1,300	72,600	20,600
Thallium	290	160	280	70
Mercury	480	150	1,290	380
Antimony	4,510	12,800	21,100	9,480
Arsenic	810	460	1,320	3,890
Lead	43,300	14,400	389,000	495,000
Chromium	27,100	7,050	48,300	453,000
Cobalt	1,660	1,860	14,700	11,400
Copper	134,000	63,500	218,000	767,000
Manganese	10,300	3,260	16,800	99,300
Nickel	3,780	1,720	10,200	17,400
Vanadium	3,790	3,370	5,240	9,090
Tin	352,000	204,000	548,000	1,005,000

The interesting feature of this table is the relatively high contamination levels of the "Green Dot" fractions (after sorting). It certainly cannot be said that there are lower contamination levels here (for the DSD mixed fraction) compared with substitute fuels from residential or industrial waste.

3.5 Conclusion regarding waste qualities

A distinction should be made between the quality of waste as it occurs and the quality of waste whose contamination was reduced by reprocessing prior to recovery. In the latter instance, supervisory authorities face the difficulty of differentiating between extraction of hazardous substances, which is desirable from the waste management standpoint, and intermingling which is undesirable.

The above data also show a statistically uneven distribution of contamination, meaning that the average contamination of any waste type must be distinguished from the peak values. Generally speaking, the corpus of data we have analysed shows the distribution illustrated in the following figure.

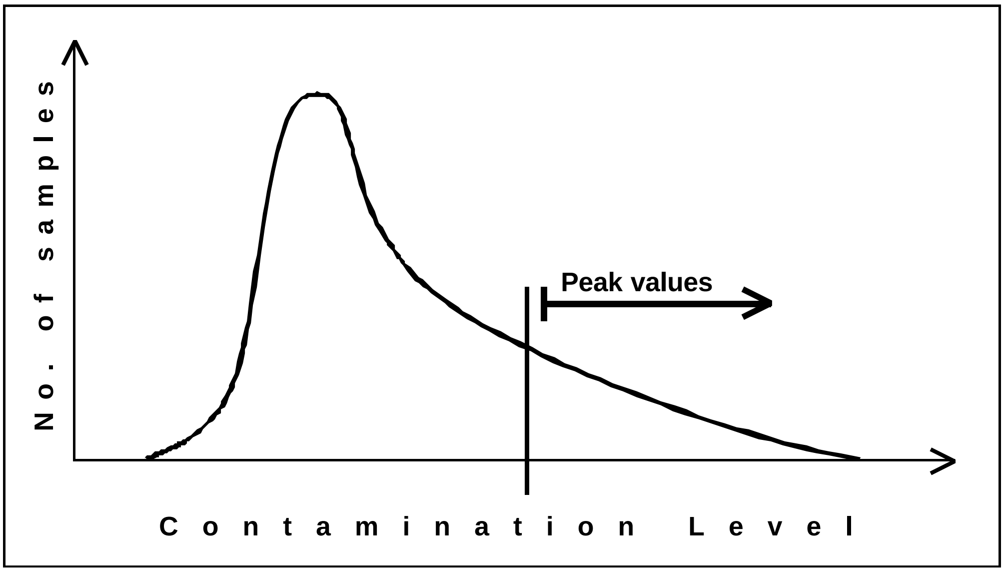

Fig. 1: Diagram of the distribution of waste qualities - empirical values

The disagreement over the evaluation of wastes intended for production of substitute fuels (and the controversy about deriving substitute fuels from waste in the first place) centres around the consideration of peak values. Opinions range from "do not include them in the assessment" to "include them only proportionately" to "include them completely". In our view both the generally higher pollution levels of substitute fuels (compared with standard fuels) and the relatively frequent peak values should be included in the overall assessment.

The above data also show that substitute fuels of varying quality can be obtained from the types of waste dealt with here:

- substitute fuels from hazardous wastes (in particular toxic wastes and wastes requiring monitoring) normally have very high pollution levels,

- substitute fuels derived from separately collected packaging wastes and from sorting residues, as well as reprocessed residential wastes (MWPP), have a medium pollutant impact by comparison, and
- substitute fuels derived from separately collected, production-specific industrial wastes can have very low pollution levels, depending on their source and quality control measures.

This suggests that it is advisable to bear in mind where the wastes in question came from. Generally speaking, in view of the high pollution levels involved, hazardous wastes should not be used for producing substitute fuels unless it can be proven that individual wastes (areas of origin) have a certifiably low pollutant impact. Other types of waste require quality standards for the substitute fuel produced (see below), which need to be linked to the environmental performance of the recovery plant, which burns the waste.

4 Disposal methods

The wastes treated in the manner outlined above can be disposed of in either disposal plants or recovery plants. These two types of facilities are dealt with separately below.

4.1 Thermal disposal of wastes

Two types of facility can be distinguished where waste disposal is concerned:
- incinerating plants for hazardous waste, and
- conventional waste incinerating plants (WIPs).

Disposal plant operators often criticize the distinction made between disposal and recovery facilities since modern disposal plants, for instance, regularly also release liberated energy in the form of electricity, steam or heat. Some disposal plants are just as efficient as energy recovery plants, or even more so (energy efficiency up to: 50-70%).

Nonetheless, this study retains the conceptual distinction since the main goal of waste disposal is to destroy or eliminate the wastes' pollutant potential, not to conserve resources.

4.1.1 Thermal disposal in incinerating plants for hazardous waste

The incineration technology at such facilities is specifically designed to deal with particularly highly polluted wastes. In addition, such plants can also process liquid and pasty wastes and barrelled goods. They are also operated at higher temperatures than standard Waste Incineration Plants so as to guarantee the mineralization of batches of persistent chemicals, for example from the chemical industry.

In terms of emission control, plants disposing of hazardous waste tend to have somewhat more elaborate waste gas scrubbing facilities than standard Waste Incineration Plants. The following table affords an overview of the pure gas values achieved in German incineration plants for hazardous waste.

Table 7: Emission concentrations at two German incinerating plants for hazardous waste (6)

Atmospheric emissions (normal operation) in mg/m³ (standard state)					
	Plant A	Plant B		Plant A	Plant B
Arsenic	<0.0001	< 0.003 – 0.006	CO_2	177.000	
Beryllium	<0.0001		CO	13	7 – 19
Lead	<0.0006	< 0.003 – 0.02	CH_4	<0.4	
Cadmium	<0.0001	0.0003 – 0.0008	NMVOC	<0.05	
$\text{Chromium}_{\text{total}}$	<0.0011	< 0.0002	PCB	0.000003	
Chromium-VI	<0.00008		PCDD/F	0.000000011	0.0000000004 – 0.0000000044
Nickel	<0.0011	< 0.0002	PCP	<0.000001	
Mercury	0.0005	0.0003 – 0.009	NOx	72	100 – 140
Thallium	<0.0003	< 0.0002	NH_3	<0.5	
TOC	0.5	0.5 – 2	HCl	0.5	< 0.5
Benzene	<0.09		SO_2	0.07	0.5 – 3
			HF	<0.01	< 0.1

Incineration plants for hazardous waste achieve a high level of mineralization where organic pollutants are concerned.

For indestructible anorganic pollutants, the plant's internal material balance must be studied. So-called transfer factors can be calculated for facilities and disposal paths from these balances. Transfer factors describe the degree to which the pollutants introduced through the waste are transferred to waste water/surface water or exhaust air/atmosphere, for example. The higher the transfer factors into waste gas/pure gas, the higher the pollution rating associated with the technology in question. Table 8 below draws up such a balance, indicating the resulting transfer factors for incineration plants for hazardous waste (mean values of two plants).

Table 8: Transfer factors for hazardous waste incineration plants; a transfer factor for pure gas of, say, 1 means that 100% of the input is emitted into the atmosphere; a transfer factor of 0.1 means 10% is emitted, and a transfer factor of 0.01 means 1% is emitted (Σ = 1; a = authors' own estimate)) (7, 8)

Parameter	Transfer factors for pure gas	Transfer factors for smelting granulate, flue gas scrubbing residues and filter cakes
Chlorine	0.0001	0.99988
Sulphur	0.00002	0.99998
Cadmium	0.00005	0.99995
Thallium	0.0000008	0.9999992
Mercury	0.002	0.998
Antimony	0.00000006	0.99999994
Arsenic	0.0000004	0.9999996
Lead	0.00002	0.99998
Chromium	0.00000002	0.99999998
Cobalt	0.0000003	0.9999997
Copper	0.00000002	0.99999998
Manganese	0.000000003	0.999999997
Nickel	0.00000002	0.99999998
Vanadium	0.00000002	0.99999998
Tin	0.00000003	0.99999997
VOC	<0.*0001*[a]	<0.*0001*[a]
ELU*	<0.*0001*[a]	<0.*0001*[a]

* water-soluble organic matter

On the one hand, we can see that the emissions into pure gas are relatively quite low. On the other hand, it is clear that the toxicologically and ecotoxicologically relevant heavy metals are transferred to the residues (dusts, flue gas scrubbing residues) and sludges. To the extent that these material flows are directed into environmental sinks, as in the case of the plants referred to above, this should be considered a further key contribution to the removal of pollutants in commercial and industrial waste management. In the technical literature 'environmental sink' is understood to mean so-called storage areas where pollutants can be kept permanently separate from the environment. Such a storage area might be an underground repository in a salt mine and, with some exceptions, also a dump above ground level but fitted with appropriate safety features (geological barriers, sealing, leachate collection, watertight surface sealing and so forth).

4.1.2 Thermal disposal in conventional waste incineration plants (WIPs)

Waste incineration plants today are normally facilities which burn a mixture of wastes as is. In the case of conventional waste incineration plants (WIPs), domestic waste is sent directly to burning as it is. This is also possible for domestic waste-like industrial wastes and production-specific industrial wastes.

Many EU Member States have strict threshold values for such facilities to guarantee emission control. The following table shows operating values for WIPs from Germany and Austria. However, in some Member States this high standard of waste incineration has not yet been achieved.

Table 9: Operating values of central European WIPs (9) (10)

			Daily/hourly mean values			Mean values				WIP Borsigstraße (HH)			Mean values	
Parameter	Unit	Threshold value 17th BimSchV 1999	WIP Ingolstadt (SCR) (11) 1992/93	WIP Zirndorf (SNCR) (12) 1992/93	WIP Bonn (SNCR) (13) 1993	WIP Stuttgart (14) no year	WIP Ulm (14) no year	WIP Mannheim (14) no year	WIP Bielefeld (15) 1996	Measured values (16) 1995	∅ Line 1 + 2 1996	Annual mean value planning permission	WIP Spittelau (A) (10) 1998	WIP Wels (WAV) (A) (10) 1997
Dust	Mg/Nm^3	10	< 1	< 0.3	0.02	0.4	1.4 - 2.8	1	0.23	0.3	0.2	3	0.30	0.082
SO$_2$	Mg/Nm^3	50	< 1	< 1	< 5	8	0.1 - 0.5	5	0.68	4.0	5.6	30	3.70	< 1.0
HCl	Mg/Nm^3	10	< 1	< 1	< 0.2	5	0.3 - 1.6	0.1	0.01	0.7	0.03	10	0.40	< 0.05
HF	Mg/Nm^3	1	< 0.02	0.9	unknown				0.01	0.1	0.1	1	0.07	< 0.05
Nox	Mg/Nm^3	200	40	no data	180	46	65 - 67	60	41.1	93.0	92.7	100	16.0	52
CO	Mg/Nm^3	50		11	11				2.4	5.0	2.7	50	34.00	11
Total-C	Mg/Nm^3	10		< 2	< 2	1	< 0.5	2	0.02	0.1	0.1	10	0.20[b]	< 1.0[b]
Cd + Tl	µg/Nm^3	50	< 2	< 1	< 1	0.3	1.8 - 2.5	10	0.1	0.1	0.003	2	< 2[c]	0.4[c]
Hg	µg/Nm^3	50[a] 30	< 20	< 20	20	9.3	< 1	12	0.01	0.3	unknown	20	6	0.07
Σ Sb ... Sn	µg/Nm^3	500	< 100	< 20	< 1	40	< 10 - 30	50		20	3	38	< 13[d]	2.4
PCDD/F I-TE	Pg/Nm^3	100	21	6	4	< 50	< 50	< 50	10	21	24	50	33	< 50

a) Half-hourly mean value b) C$_{org.}$ c) Cd only d) Σ As, Pb, Cr, Co, Ni

Organic pollutants are over 95% mineralized. The following table shows the relevant material flows for important anorganic pollutants.

Table 10: Transfer factors (TF, mean values) for 23 WIPs in Germany, Switzerland, the Netherlands and Austria; * = flue gas scrubbing residues (data from 1, 2, 17 amongst others).

Parameter	TF air: pure gas	TF ferrous/non-ferrous metals	TF dust/RGR*/sludge/ashes/slag (total TF pure gas + TF ferrous/non-ferrous metals supplemented to 1)
Chlorine	0.0008		0.9992
Sulphur	0.001		0.999
Cadmium	0.0005	0.050	0.9495
Thallium	0.00065		0.99935
Mercury	0.05		0.95
Antimony	0.00004		0.99996
Arsenic	0.00001		0.99999
Lead	0.00005	0.100	0.89995
Chromium	0.00005	0.100	0.89995
Cobalt	0.00005		0.99995
Copper	0.00005	0.100	0.89995
Manganese	0.00005		0.99995
Nickel	0.00005	0.100	0.89995
Vanadium	0.00005		0.99995
Tin	0.00005		0.99995

So with WIPs too, the low transfers of pollutants to pure gas are evident. Provided that the dusts, sludges and other combustion residues are disposed of in environmental sinks, as with the WIPs described above (for dusts and residues from flue-gas scrubbing), this can be considered a major positive environmental effect. A negative factor is that in Germany (unlike in Austria, for example), many WIP operators recycle the WIP ashes/slag in the construction industry (for instance, in road construction). This cannot be described as striving for their transfer to adequately equipped environmental sinks.

4.1.3 Conclusion regarding disposal

Facilities for the thermal disposal of wastes are very efficient at maintaining a very high quality of air.

They also make an important contribution to removing the pollutant load from the environment provided that the ashes and residues are managed appropriately.

On the basis of the given environmental protection performance by the plants described above, no general quality requirements for waste input are required for disposal. It is up to the relevant authorities to check whether a type of waste is suitable for a specific disposal plant on a case-by-case basis.

4.2 Waste recovery

Material, energy and feedstock recycling are dealt with separately below.

4.2.1 Material recycling

Material recycling is generally not associated with any important emission problem. In certain cases dust, fine particles and/or organic pollutants can escape during reprocessing; for instance, CFCs can be emitted when bulk waste is crushed.

One central issue is the circulatory management of pollutants. Table 6 above shows for packaging plastics that the material recycling of foils and bottles would not pose a major problem since the pollution level of the materials in question is low. The mixed fraction, which hardly differs from sorting residues or domestic waste itself, is much more polluted.

The problem posed by the circulatory management of the pollutants in connection with material recycling can be clearly highlighted by analysing the waste-recycling efforts of the PVC industry. As is well known, PVC is highly contaminated with plasticizers and/or heavy metals like lead, cadmium and tin, depending on the PVC application in question. As a result, from the environmental point of view, these recycling efforts should not be undertaken. One reason for this is that circulatory management causes increasing distribution (spreading) in the environment of those highly contaminated materials which can still be clearly identified. The next figure illustrates this effect schematically.

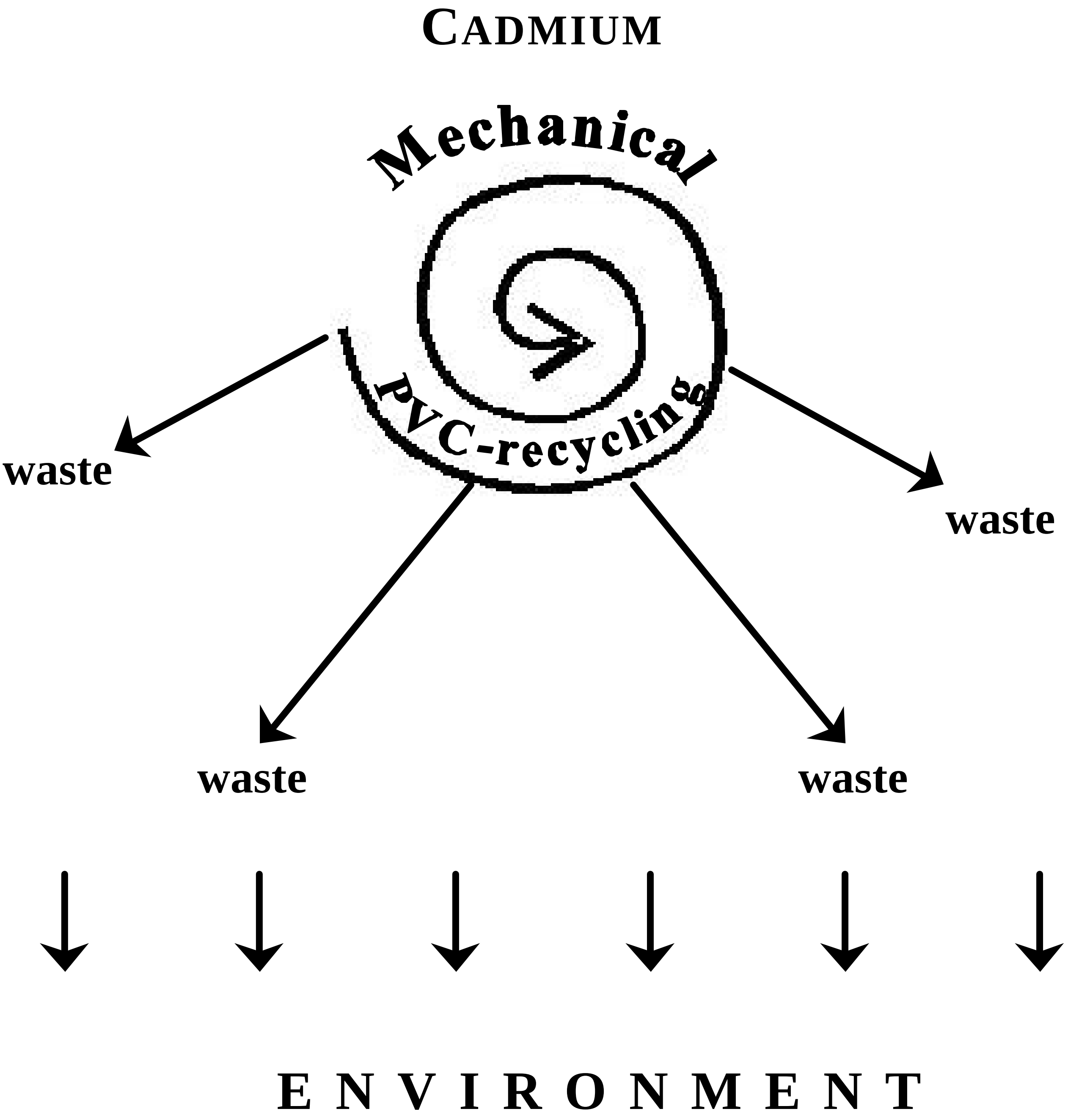

Fig. 2: Diagram of the distribution risk with multiple material recycling of contaminated plastic products, based on the example of PVC

4.2.2 Energy recovery

The industrial facilities and power plants essentially used in Europe for thermal waste recovery were originally not equipped to reclaim fuel from waste. As a result, in practice two problems always arise:

- How can the substitute fuel be optimally fed to the combustion area?
- What impact do the high levels of pollution have on the process?

Technical solutions are being sought which should include the reprocessing of wastes in special facilities (pollutant removal, blending).

4.2.2.1 Energy recovery in cement works

Table 11 shows the current BAT standard and level of technology, Table 12 the actual fluctuation in the emission standard of cement works in Europe.

Table 11: BAT standard for cement works according to EIPPCB (18); reference oxygen content: for cement works = 10 Vol % O_2, for blast furnaces 3 Vol % O_2

Plant	Cement works BAT[3] (1)	Cement works level of technology, individual plants in Austria and Germany
Energy consumption in MJ/Mg		
Product	3,000	2,500
Dust	20 - 30 mg/m³	10 mg/m³
Particulate matter	-	-
Nox (as NO_2)	200 – 500 mg/m³	100 mg/m³
SOx (as SO_2)	200 - 400 mg/m³	50 mg/m³

---

[3] BAT = Best Available Techniques according to the IPPC Directive

Table 12: Range of the environmental protection standard in Europe at selected plants according to EIPPCB (18); reference oxygen content: for cement works = 10 Vol % O_2

Plant	Actual cement works in EU
Energy consumption in MJ/Mg of product	< 3,000 - 5,000
Dust	5 – 200 mg/m³
Particulate matter	no data
NOx (as NO_2)	< 200 - 3,000 mg/m³
SOx (as SO_2)	<10 – 3,500 mg/m³
CO	500 – 2,000 mg/m³
CO_2	400,000 - 520,000 mg/m³
TOC	5 – 500 mg/m³
HCl	< 1 - 25 mg/m³
HF	< 0.4 - 5 mg/m³
PCDD/F (ITE)	< 0.1 - 0.5 ng/m³
Hg, Cd, Tl	0.01 - 0.3 mg/m³ (mainly Hg)
As, Co, Ni, Se, Te	0.001 - 0.1 mg/m³
Sb, Pb, Cr, Co, Mn, V, Sn, Zn	0.005 - 0.3 mg/m³

The above data also show that cement works' emission control standard is well below that applied to thermal disposal plants. They also show wide ranges of pollution control – a problem which might contribute to distortions and to the diversion of waste streams towards the most polluting installations.

Organic waste materials are largely mineralized in the cement process (> 98% for use in the primary firing).

Where waste co-incineration is concerned, mercury poses a major problem with respect to atmospheric emissions. Depending on how the cement works is equipped, from 20% to more than 90% of the mercury contained in the waste is emitted into the air.

Table 13 shows the proportion of heavy metals transferred to pure gas or the product in question for dry and wet processes.

Table 13: Comparative presentation of various transfer factors from different sources

Elements	VDZ[4] (D) ① pure gas	VDZ (D) ② pure gas	Gallenk./ Braungart (D) ③ Pure gas	BZL (D) ④ pure gas	GCI (USA) ⑤ pure gas	Graf (CH) ⑥ pure gas	PRIZMA study (A) ⑦ pure gas	Gierzatowicz (P) ⑧	Mean value Pure gas	Mean value product
Process	Dry	dry	dry	dry	wet/dry	dry	dry	wet	All	**all**
Mercury	0.4	0.3	0.93	0.75		0.16	0.40		0.49	0.51
Antimony	0.0003	0.000005	0.0002	0.0003	0.0016	0.0001			0.00042	0.9996
Arsenic	0.0002	0.000005	0.0002	0.0001	0.0006	0.0001			0.00020	0.9998
Lead	0.0005	0.00002	0.0002	0.0036	0.0064	0.0001	0.0004	0.07	0.01015	0.9898
Cadmium	0.0017	0.00003	0.0005	0.0028	0.0044	0.0002	0.0002	0.14	0.01873	0.9813
Chromium	0.00012	0.000005	0.00004	0.0001	0.0005	0.000023		0.0005	0.00018	0.9998
Cobalt	0.0002	0.000005	0.0003	0.0002		0.00001			0.00014	0.9999
Copper	0.00009	0.000005	0.0002	0.0001		0.00001		0.002	0.00040	0.9996
Manganese	0.0002	0.000005		0.0001					0.00010	0.9999
Nickel	0.0003	0.000005	0.0001	0.0002		0.00001		0.0005	0.00019	0.9998
Thallium	0.013	0.0002	0.011	0.027	0.0005	0.0008			0.00875	0.9913
Vanadium	0.0005	0.000005		0.001					0.00050	0.9995
Zinc	0.0003	0.000005	0.00007	0.0001		0.000006	0.0001	0.03	0.00437	0.9956
Tin	0.0007	0.000005	0.00003	0.001					0.00043	0.9996

① Mean values for Germany according to the Association of German Cement Works (VDZ) from (20) using $\Upsilon = F_{Pure}/F_{In}$ (F = load)

② Mean values for Germany according to the Association of German Cement Works from (20) using "binding efficiency times separation efficiency"

③ Transfer factors according to (21)

④ Mean value for cement works in North Rhine-Westphalia, calculated using $\Upsilon = F_{Pure}/F_{In}$, data basis according to Winkler (22)

⑤ Mean value from balance measurements at 34 cement kilns (23)

⑥ Theoretical Υ calculated from the Υ used in the Graf material model (24) without a coke filter (90% compound operation, 10% direct operation), see there: (A40 to L63)

⑦ Transfer factors using $\Upsilon = F_{Pure}/F_{In}$ (25, 26)

⑧ Measurements for one cement works extrapolated from the figure (27).

It is clear that the main problem in utilizing the cement process for energy recovery of waste leaving aside the issue of mercury for pure gas, lies in the transfer of heavy metals into the product.

Furthermore, significant discrepancies between the environmental efficiency of cement works causes both distortions to competition and a channelling effect whereby waste flows to the worst equipped or least energy-efficient cement works (Belgium, wet process).

---

[4] VDZ = Association of German Cement Works

4.2.2.2 Energy recovery in power plants (large combustion plants)

The following table shows emission values of modern power plants (large combustion plants).

Table 14: Evaluation of emission register for North Rhine-Westphalia (1994), here: mean values of emission concentrations (mg/m³) in waste gas from power plants

	Soft coal		Hard coal	
	Mean value for all plants	Number of plants with measured value	Mean value for all plants	Number of plants with measured value
Compound	**mg/m³**	n of 6 =	**mg/m³**	n of 15 =
Ammonia		0	0.7	6
Antimony		0	0.0009	6
Aromatic hydrocarbons		0	17	1
Arsenic	0.0004	3	0.01	13
Barium	0.02	6	0.03	14
Benzo(a)pyrene		0	0.00	1
Beryllium	0.000006	2	0.0004	4
Lead	0.0004	1	0.04	15
Boron		0	0.007	7
Soft coal dust	9	1		0
Bromium		0	0.0005	1
Cadmium	0.00001	2	0.003	13
Chlorine	15	4	27	12
Hydrogen chloride	1.8	2	19	3
Chromium	0.0003	2	0.01	14
Cobalt	0.0001	2	0.001	8
Fluorine (solid)	1.5	4	2.1	11
Fluorine (gaseous)		0	2.0	2
Fluoro-ion		0	0.4	1
Hydrogen fluoride	0.4	2	23	2
Formaldehyde		0	0.3	5
Carbon dioxide	220,000	1	210,000	2
Carbon monoxide	75	6	37	15
Carbon		0	0.004	1
Copper	0.0003	2	0.005	9
Manganese	0.06	1	0.01	7
Molybdenum		0	0.002	6
Nickel	0.0002	1	0.01	15

	Soft coal		**Hard coal**	
	Mean value for all plants	Number of plants with measured value	Mean value for all plants	Number of plants with measured value
Compound	**mg/m³**	n of 6 =	**mg/m³**	n of 15 =
Organic gases from hard coal		0	7	8
Organic compounds of hard coal		0	13	1
Organic compounds	3.7	3	27	5
PCDD/ PCDF: I-TE		0	0.000000005	1
Phosphorus		0	0.1	7
Polycyclical aromatic substances	0.004	2		0
Mercury	0.007	3	0.0001	3
Elemental mercury		0	0.04	2
Sulphur dioxide	140	6	350	15
Selenium	0.0004	3	0.0009	8
Silver		0	0.0002	1
Dust	31	6	17	15
Nitrogen dioxide	130	2	590	2
Nitrogen monoxide		0	1,000	1
Nitrogen oxides, stated	280	4	190	13
Strontium	0.02	6	0.02	13
Total $NO+NO_2$	50	5	160	14
Tellurium	0.000008	1	0.0002	1
Thallium	0.000008	1	0.0003	3
Uranium		0	0.0003	1
Vanadium		0	0.01	14
Elemental vanadium		0	0.001	1
Bismuth		0	0.0002	1
Tungsten		0	0.00004	1
Zinc	0.002	6	0.04	14
Elemental zinc	0.001	1		0

A comprehensive survey of the situation in Europe shows that some power plants currently in operation adhere to air quality standards well below the above values (28). Even for the better power plants in Europe, the SO_2 emissions range between 100 and 1,500 mg/m³ (28).

Like cement works, power plants normally have no satisfactory solution for the retention of mercury contained in waste. Here once again, the breakthrough rates are between 40% and over 90%.

For the remaining pollutants, depending on the standard applied at the facility in question, conventional power plants have relatively higher pure gas breakthrough rates than waste disposal plants due to their less effective waste gas purification. Table 15 provides a numerical example illustrating the full range applying to **modern** power plants.

Table 15: Transfer factors into pure gas and into solid waste from the incineration process at modern power plants in the Netherlands, Austria and Germany (20); * depends on the SO_2 abatement technology used and how it is operated

Parameter	Dust firing hard coal pure gas	Dust firing soft coal pure gas	Smelting oven firing pure gas	Smelting oven firing pure gas	Dust firing and grate firing hard coal / waste pure gas	Calculated mean value pure gas	Calculated mean value dust/RGR / ash
Chlorine	0.005	0.002			0.0021	0.003	0.997
Fluorine	0.004	0.0001			0.0022	0.002	0.998
Sulphur						0.10 – 0.01*	0.90 – 0.99
Cadmium	0.003	0.0002	0.00001	0.000004	0.0036	0.0014	0.9986
Thallium	0.004	0.02	0.000004	0.000003		0.006	0.994
Mercury	0.83	0.62		0.5	0.2	0.54	0.46
Antimony	0.003	0.005			0.0028	0.004	0.996
Arsenic	0.04	0.002	0.000001	0.000003	0.002	0.009	0.991
Lead	0.0003	0.003	0.0000002	0.000004	0.00022	0.0007	0.9993
Chromium	0.0001	0.0002	0.0000004	0.000001	0.0006	0.0002	0.9998
Cobalt	0.0003	0.0007			0.0011	0.0007	0.9993
Copper	0.0005	0.004			0.00057	0.002	0.998
Manganese	0.0001	0.0008				0.0005	0.9996
Nickel	0.0004	0.02	0.0000002	0.000001	0.0016	0.004	0.996
Vanadium	0.001	0.0002	0.0000002	0.000001	0.00054	0.0003	0.9997
Tin	0.0006	0.003			0.0079	0.004	0.996

According to this presentation, also where thermal waste recycling takes place at power plants, by far the major share of the pollutants (leaving aside Hg) is transferred to dusts, gypsum, residues from flue-gas scrubbing and ash/slag/granulate, regardless of the technology used at the power plant in question (fluidized-bed, dust firing, smelting oven firing, grate firing). Since traditionally power plants have emitted very extensive amounts of these materials openly into the environment rather than channelling them into environmental sinks (in some cases via intermediate stages such as their utilization as construction material or as aggregate in producing construction materials), the result is an environmental risk for waste co-incineration if the wastes used (see above) are quite heavily contaminated with heavy metals. Additionaly, a high proportion of the dusts arising from flue-gas scrubbing in power plants are used as anorganic aggregate in cement production.

Consequently, one overall result of waste recycling in power plants is more air pollution (Hg, chlorine, in some cases other heavy metals); another is input into the environment via the recycling of mineral wastes from incineration (gypsum, dusts, ash).

The following example, referring to an Austrian facility, shows that industrial power plants for waste recycling can also be operated at a much higher standard.

Table 16: Transfer factors for a state-of-the-art industrial fluidized bed (17)

Parameter	**Pure gas**	**Effluent**	**Filter residues**	**Ash**	**Gypsum**
Chlorine	0.0023	0.54	0.005	0.45	0
Sulphur	0.0065	0.08	0.06	0.45	0.40
Cadmium	0.0005	0.0045	0.005	0.99	0
Mercury	0.013	0.001	0.96	0.03	0
Lead	0.0001	0.001	0.005	0.99	0.0039
Zinc	0.0003	0.001	0.0037	0.99	0.005

4.2.2.3 Energy recovery in heating plants

Energy recycling in heating (power) plants is especially widespread in Scandinavia. The facilities involved are normally smaller than power plants run by the electricity industry. Their emission levels are not up to the standard of disposal plants since they are often fitted only with equipment for waste gas dust-purification.

But there are also some heating plants already in operation (or at the planning stage) in Scandinavia that are specially designed to recover waste and which reach a standard comparable to that attained by waste disposal plants. The following table shows transfer factors for such a plant in operation in Ranheim, Norway (near Trondheim) (29).

Table 17: Transfer factors of a heating plant in Norway (29)

	Transfer factor	
	Pure gas	Dust, ash, flue-gas scrubbing
Chlorine	0.003	0.997
Fluorine	-	
Sulphur	0.01	0.99
Cadmium	0.*000*06	0.*999*94
Thallium	-	
Mercury	0.02 – 0.05	0.98 – 0.95
Antimony	0.*000*03	0.*999*97
Arsenic	0.*000*3	0.*999*7
Lead	0.*000*05	0.*999*95
Chromium	0.*000*05	0.*999*95
Cobalt	0.*000*5	0.*999*5
Copper	0.*000*03	0.*999*97
Manganese	0.*000*04	0.*999*96
Nickel	0.*000*3	0.*999*7
Vanadium	0.*000*06	0.*999*94
Tin	0.*000*05	0.*999*95

The above data for best performing plants show that energy recovery does not necessarily go hand in hand with high emissions. Such values however are not achieved by the average or the lower end of installations.

4.2.2.4 Energy recovery at other plants

The limestone industry is particularly worth noting at this juncture, as it can be a major regional consumer of fuel.

In terms of emissions, the material flows generated by the limestone industry are comparable to those associated with the power generation and cement industries.

Asphalt mixing plants can be another market for energy waste recycling. They normally operate on the basis of relatively low waste gas purification standards.

4.2.3 Feedstock recycling

Feedstock recycling or chemical recycling can be defined as a method of reprocessing waste by changing the chemical structure of the processed material, other than by burning or organic recycling. It covers such processes as thermal cracking, pyrolysis, gasification and blast furnace processes (use of plastics as reduction agent).
Feedstock recycling is a concept that has become much more important in the context of recycling packaging wastes (the Green Dot), especially in the light of the German debate on the issues associated with the Dual System (Green Dot).

4.2.3.1 Feedstock recycling in blast furnaces

Blast furnaces are used to obtain iron from iron ore. Coke and other fuels and reducing agents are used to reduce iron at high temperatures in a shaft-shaped furnace. The iron is then drawn off as a liquid at the bottom of the furnace.

Blast furnaces are not widely used these days for thermal waste recovery, especially for hazardous wastes (feed stock recycling). In Germany 150,000 Mg/yr of Dual System mixed plastics are used in blast furnaces. In all, Europe has four blast furnaces in use for incinerating waste.

The following table summarizes the range of standards and the recommended BAT standard as well as the latest technology available in Europe.

Table 18: Range of blast furnace standards in Europe (18); LS = liquid steel

Plant	Actual blast furnaces in EU
Energy consumption in MJ/Mg of product	4,400 - 5,000
Dust	10 – 50 g/Mg liquid steel
Particulate matter	no data
Nox (as NO_2)	30 – 120 g/Mg liquid steel
SOx (as SO_2)	20 – 230 g/Mg liquid steel
CO	770 - 1,750 g/Mg LS
CO_2	280 - 500 g/Mg LS
TOC	no data available
HCl	no data available
HF	no data available
PCDD/F (ITE)	< 0.001 - 0.004 µg ITE/Mg LS (?)
Hg, Cd, Tl	no data available
As, Co, Ni, Se, Te	Ni: < 0.01 - 0.02 g/Mg LS
	Mn: < 0.01 - 0.13 mg/Mg LS
Sb, Pb, Cr, Co, Mn, V, Sn, Zn	Pb: < 0.01 - 0.12 mg/Mg LS

Here, too, the emission control standard is clearly inferior to the values for disposal plants by several orders of magnitude (factor 100 and more).

The following table shows the transfer factors into pure gas for one of the two blast furnaces at Bremen steelworks, which is used intensively for waste co-incineration.

Table 19: Pure gas transfer factors for a blast furnace at Bremen steelworks (30)

Name	Pure gas transfer factor for the Bremen blast furnace
Chlorine (as HCl)	0.05
Sulphur (as SO_2)	0.023
Mercury	1
Arsenic	0.01
Lead	0.01
Cadmium	0.01
Chromium	0. 0009
Nickel	0. 0009

As it turns out, compared to the other recycling possibilities studied here, the blast furnace has the highest breakthrough rates for pollutants and it is less favourable than disposal plants by several orders of magnitude.

Where the blast furnace is concerned, it is also significant that heavy metals (leaving mercury aside) are conveyed to other areas of the environment via the solid output flows. For example, in Bremen the blast furnace gas dusts are separated by a water jet and stored in **open** earth basins. Moreover, the residues from the production are often "reprocessed" in the plant's own sintering plant, causing further emissions, since such plants normally only subject their waste gases to dust filtration.

Lastly, the scrubbing of the blast furnace gas often results in emissions into water.

Overall, the above figures show that recycling entails two basic environmental problems:

- the emissions into the atmosphere by the blast furnace itself, and
- the transfer of emissions to other facilities of the "iron and steel complex" and into water.

4.2.3.2 Chemical feedstock recycling

A special form of feedstock recycling involves the use of wastes in conversion processes where the organic waste components are chemically "broken open" and can be supplied to the chemical industry for synthesis purposes as chemical feedstocks.

In the case of the "Black Pump" secondary raw material recycling centre (SVZ) a gas and methanol are produced (in a 50:50 ratio) from the recycled wastes (domestic refuse, mixed plastics, hazardous wastes). The gas is converted into electricity in a steam and gas turbine power station and the methanol is sold as a synthesis stock.

Until a few years ago, a similar project was carried out in the form of a hydrogenation process (in Bottrop, Germany) producing a crude oil that was supplied to refineries. That procedure has since been discontinued.

The emission control requirements of these plants are also outside the scope of those imposed on waste disposal plants. In Germany, for example, the requirements for such plants are established on the basis of the Clean Air Technical Directive "*TA Luft*", the threshold value requirements of which lie well below those applicable to waste disposal plants. As a result, here again there is a discrepancy in the levels of environmental protection provided.

4.2.4 Conclusion regarding recovery

The analysis of recycling shows a considerable regulatory discrepancy between disposal and recovery, resulting in significantly higher emissions and/or a shifting of the problem to products whose contamination of the environment cannot be controlled.

Discrepancies between the environmental performance of recovery installations lead in turn to distortions of competition and a channelling effect as flows of waste go to the worst-equipped plants (ecodumping). This is clear from today's national project lists for waste recycling in industrial facilities. As a rule it is not the new, efficient plants but older, uneconomical ones threatened with closure that seek to ensure their survival by recovering waste.

So there is an urgent need to find solutions that help to reduce the spread of ecodumping in the recycling field whilst at the same time providing the necessary investment security to developing markets (especially in the area of energy recycling).

Two domains should be dealt with separately in this regard:

- the quality and pollutant impact of the wastes being recoverd, and
- the quality and pollutant management (material flow) of disposal plants, and especially of recovery plants.

5 Solving the problem

Not only is waste avoidance the top priority, it also prevents damage to the environment.

But material recycling, which has proven superior to energy (including feedstock) recycling processes in all ecobalances and life-cycle analyses to date, should only be pursued further where the materials to be recycled are non-polluting. In these cases, material recycling should be carried out as a second priority.

For wastes which are unavoidable and cannot be materially recycled, the issue of energy disposal arises. In this regard, at European level we are currently faced with the paradoxical situation that recycling plants, which are widely regarded by the public as being a preferable option, are actually worse polluters than the well-equipped disposal plants in most of the EU Member States. This leads to ecodumping and means that the third priority of the waste hierarchy, (energy) recovery cannot unreservedly be spoken of in favourable terms.

In our view, this unsatisfactory situation can be solved by adopting the raft of measures outlined below.

5.1 The dual nature of recycling and disposal

Waste disposal results in a deliberate elimination of pollutants from the biosphere and their disappearance into environmental sinks. Indeed, this is essentially the task of waste disposal. Pollutants which otherwise would go in a cycle and consequently be distributed in the relevant environmental media are eliminated from the cycles by waste disposal and permanently removed (concentrated in sinks). Figure 3 shows this connection as a simplified diagram.

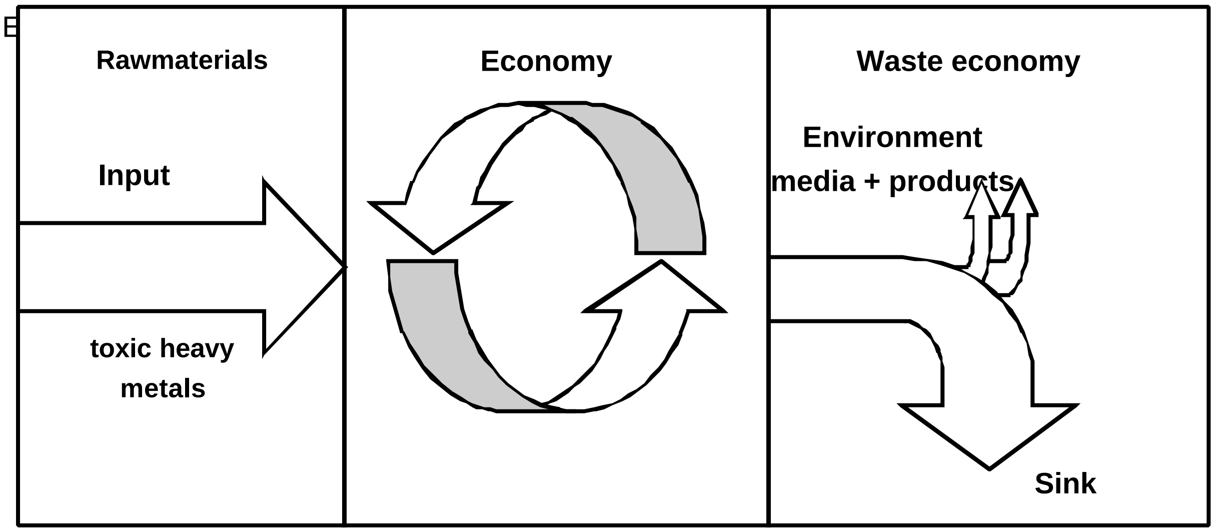

Fig. 3: Schematic representation of the pollutant flows in waste disposal

The main difference is that recovery only directs pollutants to sinks to a secondary degree, distributing them more to environmental media (and into products). Figure 4 shows this connection as a simplified diagram.

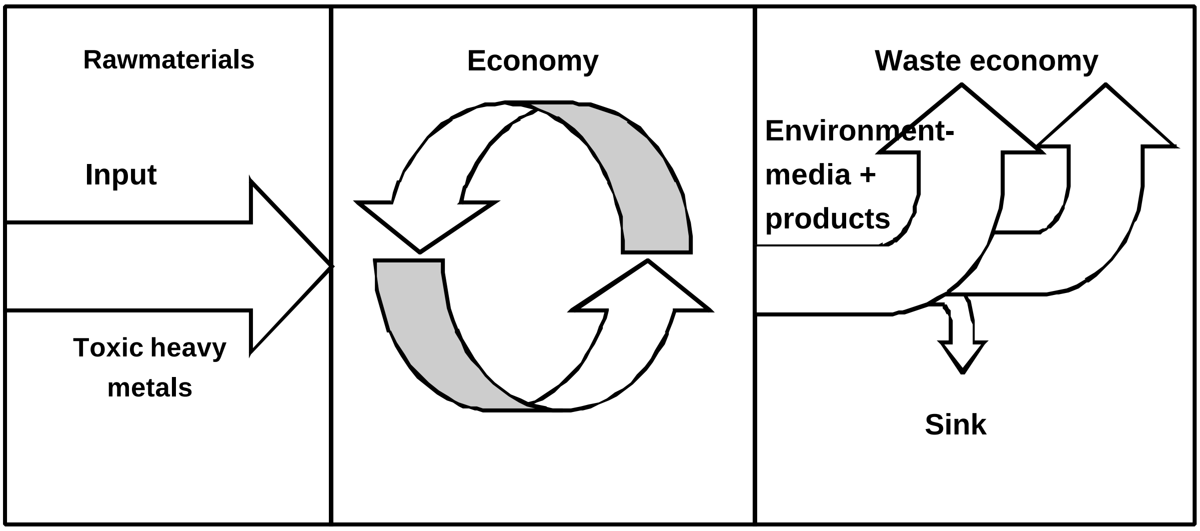

Fig. 4: Diagram of the pollutant flows in waste recycling

Consequently, for the waste management industry, recovery and disposal are two mutually complementary and dependent areas of responsibility. Only when disposal removes the pollutants contained in waste from cycles to the ecologically necessary degree can recycling realize its full ecological benefit for the remaining types/amounts of waste.

The derivation and establishment of clear scientific and technical rules is crucial here for directing material flows on the basis of their contamination (material flow management). These rules should ensure a relative maximum level of pollutant removal and the optimal management of sinks as well as the highest possible quality of recycling.

The main mistake of previous "recovery" practice has been to unravel this duality, mainly for economic reasons. "Recycling" quantities are maximized for economic reasons without any guarantees being given that the processes involved are also appropriate for the wastes in question.

Existing European waste law, through very abstract rules and regulations (and interpretations), has created a barely comprehensible interface between disposal (removing the pollutant load from cycles) and recovery (closing cycles). As a result, increasingly contaminated wastes have been input into ecologically dubious "recovery" processes.

However, the complementary duality of disposal and recovery also contains the key to solving the problem:

Contaminated wastes should be directed to disposal. The quality requirement with respect to disposal is that it mineralises and/or eliminates pollutants by depositing them in secure environmental sinks along preset lines. Contaminated wastes are defined as "hazardous wastes" with a high content of organic pollutants and/or which are highly contaminated by heavy metals, but also domestic waste and domestic-waste-like industrial waste.

Wastes containing few or no pollutants should be directed to recovery. But here too requirements have to be imposed, especially by setting uniform emission threshold values and guaranteeing the resource-related efficiency of the techniques and processes used.

Contaminated wastes can only be **reprocessed** to produce a "usable waste" by removing the pollutant from the original waste. This would create a concentrated contaminated fraction (for disposal) and a less-contaminated fraction (for recovery). This respects the dual nature of recovery and disposal. Mixing contaminated with uncontaminated wastes, on the other hand, is not a suitable reprocessing strategy, because pollutant concentrations are diluted but the pollution is not actually eliminated.

In our view, future suggestions for solving the problem at the point where recovery and disposal meet should be assessed by virtue of the extent to which they actually guarantee in practice the necessary duality of disposal and recovery with respect to considerations to do with pollutants.

5.2 The EU Incineration Directive - a partial solution

The EU Incineration Directive adopted in the meantime is a step in this direction but has a number of shortcomings, meaning that more far-reaching harmonisation is required. Moreover, the directive only offers a solution for some areas of the ecodumping as presented here.

For example, the threshold values of co-incineration (i.e. energy recovery) are established in accordance with the waste disposal requirements for only some of the relevant parameters.

Moreover, the EU Incineration Directive makes no mention of feedstock recycling. This is an especially serious omission, because these processes have a particularly environmentally friendly image.

Lastly, it must be pointed out that at present the directive is merely paper. In our view it will be a good few years yet before the EU Waste Incineration Directive is transposed into national regulatory systems and then implemented via the individual licensing of incineration plants. During this period, the ecodumping described above will not be curbed even by the partial solutions contained in the Incineration Directive.

5.3 Solving the problem by imposing requirements with regard to substitute fuel

Consequently, we feel that in the short run quality requirements must be established for the substitute fuel used for energy or feedstock recycling, for which we demand **binding pollutant threshold values**. In principle these threshold values should be derived with reference to the pollutant impact of current standard fuels. The use of substitute fuels must not result in higher environmental pollution (air, water, soil) or lead to increased pollution in products.

The table below shows a selection of guideline and threshold value proposals currently in force or under discussion for energy waste recovery.

Table 20: Comparison of different existing or recommended pollutant limits (referring to heating value, in mg/MJ) for use of waste to recovered fuels compared to hard coal as regular fuel; X = limits cannot presently be derived; n.d. = no data available

Parameter	Regular fuel hard coal average** [1997] Mg/MJ	guiding value LAGA [1997] mg/MJ	Guiding concentration BUWAL [undated] mg/MJ	Finnish standard quality class I upper limit mg/MJ***	Finnish standard quality class II upper limit mg/MJ***	Bundes-gütege-meinschaft Sekundärbrennstoffe, draft, Median**** mg/MJ	Bundes-gütege-meinschaft Sekundärbrennstoffe, draft, 80 Quantil**** mg/MJ
Chlorine*	0.0002	< 1		< 0.15	< 0.50		
Cadmium	0.02	0.3	0.08	< 0.05	< 0.2	0.25	0.45
Thallium	< 0.04	0.15	0.12			0.06	0.125
Mercury	0.004	0.02	0.02	< 0.005	< 0.01	0.04	0.075
Antimony		0.07	0.2			1.6	3.75
Arsenic	0.4	1.9	0.6			0.3	0.81
Lead	1.5	10	8			11.9	X
Chromium	0.7	3.7	4			7.8	15.6
Cobalt	0.2	1.2	0.8			0.4	0.75
Copper	0.6	3.7	4			21.9	X
Manganese						15.6	31
Nickel	0.7	3.5	4			5.0	10
Vanadium	1.5	n.d.	n.d.			0.6	1.56
Zinc	0.1	0.4	0.4				
Tin						1.9	4.38

* weight-%

** calculated with 7% H_2O from original data source

*** calculated with calorific value 20,000 MJ/Mg

**** high-calorific fraction from MSW, mg/kg d.s, calculated to mg/MJ with Hu 16,000 MJ/Mg

A closer analysis of the proposals shows that the greatest differences occur when evaluating the peak values (see above). As shown, however, the considerable spread in contamination is a characteristic feature of substitute fuels from wastes. As a result, both the average and higher pollution levels must be included in a substitute fuel system. The approach of the Finnish standard seems the most promising in this regard since it works with clear upper values (maximum values). However, the parameters considered in the Finnish standard are incomplete or need to be supplemented.

It is also important that the waste defintion should not be weakened if ambitious ideas for substitute fuels gain acceptance. Even substitute fuels with a contamination comparable to that of standard fuels should continue to be covered by the legal waste regime, because careful monitoring must remain guaranteed. Such careful monitoring is necessary given the origin of the fuel and is justified by the large spread of the pollution described.

5.4 Article 18 of the IPPC directive

Article 18 of the Directive concerning Integrated Pollution Prevention and Control gives the European Commission and the EU's Council of Ministers the authority to establish their own binding progressive measures geared towards harmonizing environmental protection standards within the European Community.

It enables the Commission to submit to the Council any uniform emission threshold values for plants if it considers such limit values necessary, especially on the basis of freshly available information.

In our view, depending on the requirements laid down for such waste-derived substitute fuels, further harmonization of the emission threshold values of recovery plants will be necessary (extending beyond the EU Incineration Directive) both to close the gap between best performing incineration and recovery and to reduce the differences between different recovery operations.

Furthermore, minimum requirements for energy and material efficiency should also be established, so that only modern techniques are used in thermal waste recycling. Facilities failing to meet specified minimum requirements should be deemed unsuitable for recycling.

For example, facilities using obsolete techniques to produce cement with a specific energy consumption well above that of dry processes (>3,500 MJ/Mg clinker) should not be licensed to operate as recycling plants.

In addition, requirements will have to be imposed on the use of any resulting residues and products (material flow, management of sinks).

Article 18 of the IPPC Directive constitutes a legal basis to the harmonization of emission values for existing and new plants and facilities.

6 Overall conclusion

We recommend that the European debate focus more on the actual quality levels and contamination levels of wastes. The legal efforts made so far to organize the respective markets have not succeeded in preventing ecodumping.

We recommend that defined upper limits of pollutant contamination (especially with respect to chlorine and toxic heavy metals) be laid down for the material, energy and feedstock recycling of wastes, in accordance with Europe's objectives. The recently adopted Finnish standard (for substitute fuels) can serve as a good working basis for Europe.

For wastes that generally cannot comply with such upper limits owing to their high pollutant impact (or the resulting pollutant spread), we recommend that strict waste code recommendations for disposal be drawn up.

In particular, we recommend that emission protection requirements be harmonized with thermal waste disposal by applying Article 18 of the IPPC Directive to energy and feedstock recycling. This should help to consistently pursue the process of harmonizing environmental standards in the Community initiated by the EU Incineration Directive.

7 References

(1) Stoffflussanalyse bei abfallrechtlichen Beurteilungsfragen. Ministerium für Umwelt und Naturschutz, Landwirtschaft und Verbraucherschutz des Landes Nordrhein-Westfalen. Düsseldorf, Oktober 2000

(2) DPU GmbH und BZL GmbH: Studie zu den abfallwirtschaftlichen und ökologischen Auswirkungen der im Arbeitsentwurf einer Allgemeinen Verwaltungsvorschrift (AbfallVwV) vertretenen Rechtspositionen. Studie im Auftrag des baden-württembergischen Ministeriums für Umwelt und Verkehr, September 2000
Studie: http://www.uvm.baden-wuerttemberg.de/uvm/abt2/abfallvwv/DPU_BZL-16.08.2000.pdf
Kurzfassung: http://www.uvm.baden-wuerttemberg.de/uvm/abt2/abfallvwv/DPU_BZL_kurzfass.pdf

(3) BPG 2 (Trienekens); Glorius, T.: Erfahrung mit der Produktion und Einsatz qualitätsgesicherter Sekundärbrennstoffen, Aktivitäten der Bundesgütegemeinschaft Sekundärbrennstoffe. VDI – Bildungswerk: Ersatzbrennstoffe für Industrieanlagen, Düsseldorf März 2000

(4) BPG 3 (Trienekens); Glorius, T.: Erfahrung mit der Produktion und Einsatz qualitätsgesicherter Sekundärbrennstoffen, Aktivitäten der Bundesgütegemeinschaft Sekundärbrennstoffe. VDI – Bildungswerk: Ersatzbrennstoffe für Industrieanlagen, Düsseldorf März 2000

(5) Heyde M., Kremer M.: Recycling and Recovery of Plastics from Packagings in Domestic Waste. LCA Documents, ecomed, Vol 4 1999

(6) Sonderabfallverbrennungsanlage der AVG (Hamburg) und der HIM (Biebesheim/Hessen)

(7) Mitteilung der AVG vom 23. 05. 2000

(8) Stoffflussanalyse bei abfallrechtlichen Beurteilungsfragen. Ministerium für Umwelt und Naturschutz, Landwirtschaft und Verbraucherschutz des Landes Nordrhein-Westfalen. Düsseldorf, Oktober 2000, hier: Anhang II.01

(9) BZL GmbH, Oyten, Dr.-Ing. A. Nottrodt GmbH, Hamburg, THERMOCHEM GmbH, Aachen: Arbeitshilfe Kreislaufwirtschaft, erstellt im Auftrag des Landesumweltamtes NRW, November 1998

(10) ARGE BZL GmbH, Oyten (D) / ZI Dipl.-Ing. K. Scheidl, Eisenstadt (A): Durchführung einer Evaluierung für die Errichtung einer Abfallbehandlungsanlage für die im Raum Linz anfallenden Abfälle – Verfahrensauswahl, im Auftrag vom Amt für Natur- und Umweltschutz, Magistrat der Landeshauptstadt Linz, 1998/99

(11) Krätzig et al., 1993, 1992; zit. in: SRU: Umweltgutachten 1998; Februar 1998, hier Tab. 3.1.5-5

(12) Gottschalk, 1993, 1992; zit. in: SRU, s.o., hier Tab. 3.1.5-5

(13) Pranghofer, 1993; zit. in: SRU, s.o., hier Tab. 3.1.5-5

(14) Lahl U., Zeschmar-Lahl B., Weiler C.: Gewerbeabfälle in Baden-Württemberg – Wege und Verbleib. Studie im Auftrag von Bündnis 90/DIE GRÜNEN im Landtag von Baden-

Württemberg, November 1997

(15) Bericht des Immissionsschutzbeauftragten der MVA Bielefeld-Herford, Januar 1996

(16) Kaulbarsch R.: Betriebserfahrungen mit der neuen MVA Borsigstraße in Hamburg. Abfallwirtschaftsjournal 5, 35 - 39, 1997

(17) GUA, AWS, IFIP: Bewertung abfallwirtschaftlicher Maßnahmen mit dem Ziel der nachsorgefreien Deponie, Wien, Sep. 2000

(18) IPPC: Council Directive 96/61/EC concerning Integrated Pollution Prevention and Control (96/61/EG) (= IVU-Richtlinie); EIPPCB: „European IPPC-Bureau“ (EIPPCB), angesiedelt beim „Institute for Prospective Technological Studies“ (IPTS) der Europäischen Kommission in Sevilla (Spanien)

(19) EIPPCB: IPPC, Best Available Techniques Reference Document in the Cement and Lime Manufacturing Industries. February 2000; Download über http://eippcb.jrc.es

(20) BZL GmbH, Oyten/DPU GmbH, Essen: Beurteilung der Umweltverträglichkeit von thermischen Entsorgungsmaßnahmen. Studie im Auftrag des MURL NRW, 1999; und darauf aufbauend: Ministerium für Umwelt, und Naturschutz, Landwirtschaft und Verbraucherschutz des Landes Nordrhein-Westfalen: Arbeitshilfe "Stoffflussanalyse bei abfallrechtlichen Beurteilungsfragen"

(21) Gallenkemper, B., Braungart, M. et al.: Untersuchung zur Umwelt- und Gesundheitsverträglichkeit von Substitut-Brennstoffen. Rethmann Entsorgung, Dieselstr. 3, 44805 Bochum, 1999

(22) Winkler, Landesumweltamt NRW, diverse Publikationen u.a. Winkler H.-D.: Praxis der energetischen Verwertung von Abfällen in Nordrhein-Westfalen. In: Bayerisches Landesamt für Umweltschutz (Hrsg.): Zementwerke – NOx-Minderung – Abfallverwertung. Fachtagung am 2.7.1998 in Wackersdorf, Dokumentation, S. 65–98, 1998

(23) Goosman, D., Constans, D., Woodford, J. et. al.: Metal Equilibration and Process Capture Efficiencies in Cement Kilns. AWMA International Specialty Conference on Waste Combustion in Boilers an Industrial Furnaces March, 1993

(24) Modell Dr. Graf AG, Gerlafingen (CH)/BUWAL (CH): Beschreibung zum Stoffflussmodell des Zementwerks DR. GRAF AG (BESCHREI.DOC), und Stoffmodell in EXCEL (STOFLMOD.XLS), 20.1.2000

(25) Fehringer R., Rechberger H., Brunner H.P.: Positivlisten für Reststoffe in der Zementindustrie: Methoden und Ansätze (PRIZMA). Endbericht, im Auftrag der Vereinigung der österreichischen Zementindustrie. Wien, im Dezember 1999

(26) Fehriger et al. 1997: zitiert in: GUA, AWS, IFIP: Bewertung abfallwirtschaftlicher Maßnahmen mit dem Ziel der nachsorgefreien Deponie, Wien, Sep. 2000

(27) Gierzatowicz R.: The environmental influence of heavy metals introduced to the clinkering prozess with waste. In Pawlowski L. (Hrsg.): Thermal solid waste utilisation in regular and industrial facilities. Environmental Science Research, 58; Kluwer Academic Plenum Publisher (2000).

(28) Barret M.: The worst and the best – Atmospheric Emissions from Large Point Sources in Europe. Air Pollution and Climate Series. Acid Rain, Göteborg 2000

(29) BZL GmbH: Emissionsprognose für den Einsatz von Sekundärbrennstoffen im geplanten Heizwerk Mindener Industriehafen, im Auftrag der ENERGOS ASA (NL). Oyten, 13. März 2000

(30) IFEU-Institut Heidelberg, persönliche Mitteilung (errechnet auf der Basis einer Untersuchung des Öko-Instituts Freiburg, Stahlwerke Bremen 1993)