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Definition of waste recovery and disposal operations

Part A

Recovery and disposal operations

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Executive Summary

Council Directive 75/442/EEC of 15 July 1975 on waste (the Waste Framework Directive -WFD) defines recovery and disposal operations. Articles 1(e) and 1(f) differentiate between recovery and disposal and Annexes II A and II B list recovery and disposal operations.

In recent years, waste recovery and disposal operations have undergone far-reaching changes and new processes have been developed which cannot be easily characterised using one of the entries of Annex II of the WFD. Additionally, the wording of several entries does not enable an unambiguous characterisation of the operations and some entries give rise to diverging interpretation because of a lack of clarity. There is also uncertainty at what stage recovery may be considered as completed.

The study aims at developing a basis for a possible review of the lists of recovery and disposal operations. Energy recovery and thermal treatment operations were excluded from the in-depth discussion of operations.

Part A: definitions of recovery and disposal operations

Part A of the study gives an overview about recovery and disposal operations as they occur in practice, analyses waste treatment operations in detail and identifies criteria, which could help differentiating between the competing entries. The main findings of this study on the definitions of recovery and disposal operations are:

- ➤ The definitions of recovery and disposal are asked to play competing roles in EU legislation but cannot do so effectively. In particular, defining recovery to determine whether waste circulates freely in the internal market is not the same as defining recovery in order to set mandatory targets. In the first case a process recovering a sufficient part of the waste may be considered as recovery whereas in the second case one would seek to count only the waste effectively recovered to check compliance with the target. A number of other provisions of EU environmental legislation become relevant depending on whether a process is or is not a recovery operation. This adds to the complexity of the roles played by these definitions.
- ➤ The jurisprudence of the European Court of Justice has confirmed substitution of natural resources is the basic criterion for determining whether a process is a recovery operation or not. However, this criterion alone does not necessarily reflect the complexity of waste management operations which may have both a disposal component and a recovery component. In addition other environmental issues may also need to be taken into account to define a waste management operation as recovery (e.g. soil and groundwater protection).
- ➤ In a limited number of cases, assignment of an operation to one of the entries in Annex II is not possible. This includes the regeneration of catalysts and using a mixture of mineral waste and combustible waste in cement kilns.
- A limited number of the entries of the lists are obsolete: "R 7 Recovery of components used for pollution abatement", "R 8 Recovery of components from catalysts" and "D11 Incineration at sea".



Possible options to improve the definitions include:

- a) Efficiency ratios could clarify the border between recovery and disposal. This has limitations as the appropriate threshold for efficiencies will vary depending on the process considered. Efficiencies could vary from 2% to well over 50% depending of the waste and process considered, for example mixed municipal wastes, industrial sludges or photochemical wastes. Nevertheless, such an approach could solve specific cases.
- b) The specific cases of operations where recovery takes place in subsequent operations (intermediate operations) but which are part of a recovery chain but which do not directly substitute natural resources would need clarification, for example treatment of shredder light fraction or soil cleaning. This could be done in two ways:
 - Development of a new Annex IIC.
 - > Developing entries in the existing Annex IIB for operations where recovery takes place in subsequent operations (intermediate operations).

Additionally, one would need to take into account that a process would be defined as recovery depending on what happens to the waste in subsequent waste treatment operations.

All options would necessitate a change of the WFD and of its Annexes. These options should be further nuanced to take into account:

- The function of the definition in the legislation, e.g. permit procedures for installation, calculation of recovery rates, shipment authorisations.
- Environmental impacts. Minimum mass thresholds are crucial when recovery and final disposal are done in parallel but this mass criterion should be improved by taking specific characteristics of the substituted material into account. This might be done based on the ecological burdens which would occur if the material would be produced from primary raw materials.
- The quality of the recovered material. Waste fractions which are counted as recovered should fulfil recognized European quality requirements, e.g. in the form of CEN Standards. Otherwise the quality of the fractions may be deliberately altered, e.g. by reducing the sorting of certain fractions to increase the apparent recovery rate.
- The need to clarify whether certain processes lead to recycling or another type of recovery. For example plastics may be subjected to a wide range of recovery processes. In some cases the output will be plastics, in other cases it may be base chemicals, combustible gases or mixtures of substances that can be used as a fuel. Plastics can also be used as carriers of chemical energy, for example when they are used as reducing agents in blast furnaces.



In addition it is proposed to decrease the focus of the definitions on the nature of the waste in favour of a double focus on:

- ➤ The way the waste is used in the recovery operation, e.g. as final product or as raw material from which final products are produced.
- The characteristics of the waste that are actually used in the recovery operations (specific material attributes like the electrical conductivity of copper or unspecific attributes like the volume of a material).

Part B: Completion of recovery

The objective of part B of the study is to identify for selected waste recovery chains at what point waste-specific environmental risk potentials are neutralised from a technical-scientific aspect.

The work was based on practical descriptions of recovery chains. Research into quantity flows, the structure of existing recovery chains and the status of individual treatment technologies and material compositions was carried out. In addition, it was necessary to develop a methodology to analyse the waste-specific characteristics in the course of the recovery chains.

The main findings of this study on the point at which the waste specific environmental risks are neutralised are:

- ➤ A qualitative methodology has enabled the assessment of the general and relative evolution of risk properties for the considered wastes along the recovery chain. This was also valid for those cases where limited information about environmental aspects of the waste was available.
- The wastes were compared using as references the original product from which the waste is derived from, primary materials that are functional equivalents to the output of the recovery chain or input specifications of recovery installations. This did not allow concluding that the waste specific environmental risks are neutralised before the last stage of the recovery chain. A notable exception was those cases where only the shape or the size of the material is changed by the last treatment step. Comparison with primary raw materials was particularly problematic in those cases where the primary raw material has a wide range of possible compositions (e.g. iron ore, zinc concentrates) and no sensible description of average compositions can be elaborated¹.

¹ Especially not with regard to hazardous substances, which are of relevance for the assessment of waste specific risk potentials. In addition it has to be taken into consideration that the composition of marketed ores changes with the time and the market situation.

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Product standards or specifications that are recognised across the EU and cover all relevant environmental aspects in a practical way do not exist for the investigated cases. For example: the European steel scrap specification does not cover PCB or a maximum chlorine content or certain heavy metals in a sufficiently practical way; the Dutch Building Materials Decree covers the most relevant environmental aspects but has its national limitation.

The development of and compliance with standards or specifications that adequately address the issues of specific waste streams would be necessary to determine at which stage recovery may be considered as completed.



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1 Background and objectives of the study

Council Directive of 15 July 1975 on waste $(75/442/EEC)^2$ defines recovery and disposal operations. While Articles 1 e and 1 f differentiate between recovery and disposal, Annexes II A and II B respectively list recovery and disposal operations.

In the recitals of Council Directive 75/442/EEC it is pointed out that this directive also aims at the harmonisation of legislation in the Member States. The possibility of a clear characterisation of waste recovery and disposal processes, as they occur in practice, is therefore important not the least to avoid unequal conditions of competition inside as well as between the European Member States. Directive 75/442/EEC also aims at building a basis for the requirements concerning waste transportation³ and the proximity principle.

A unique characterisation of operations to entries in Annex II A and Annex II B has also relevance in view of achieving the recycling and recovery targets of product-specific waste legislation such as, for example, the Packaging Directive, ELV Directive and the WEEE Directive.

In recent years, waste recovery and disposal operations have undergone far-reaching changes and new processes have been developed which cannot be easily characterised using one of the entries of Annex II of the Waste Framework Directive (WFD).

Additionally, the wording of several entries does not enable an unambiguous characterisation of the operations and some entries give rise to diverging interpretation because of a lack of clarity.

Additionally, there is uncertainty about the question after which stage recovery may be considered as completed.

The study aims at developing a basis for a possible review of the lists of recovery and disposal options in Annex II A and Annex II B of Directive 75/442/EEC.

Energy recovery and thermal treatment operations within the meaning of Entries R1 and D10 of the Waste Framework Directive were excluded from the in-depth discussion of operations according to the technical annex of the contract.

The subject of Part A of the study is the characterisation of waste treatment operations. Chapter 2 of Part A of the study gives an overview about disposal and recovery operations as they occur in practice. Chapter 3 analyses waste treatment operations in more detail and identifies operations (other than R1 and D10 operations) for which

³ E.g. relevance for Waste Shipment Regulation, Council Decision C (2001)107 (Revision of Decision C (92)39/FINAL on the control of transboundary movements of wastes destined for recovery operations, and the Basel Convention).

² Amended by Council Directive 91/156/EEC of 18 March 1991, Council Directive 91/692/EEC of 23 December 1991, Commission Decision 96/350/EC of 24 May 1996.

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there is ambiguity in their classification in a disposal or recovery entry of Annex II of the Waste Framework Directive. Criteria, which could help differentiating between the competing entries, were identified.

Subject of Part B of the study is a methodology to analyse how the waste-specific, inherent, potential environmental risks change along recovery chains. Comparison with different references is chosen to identify at which stage of the recovery chain the waste-related environmental issues are neutralised.

Part C of the study lists the institutions that have contributed to this study with discussion and data. Furthermore, the input from Stakeholders, received after a Commission workshop held on the definitions of waste recovery and disposal operation in Brussels in July 2003, is presented.



2 Waste treatment operations in Europe

In order to generate an overview about waste treatment operations as they are performed in Europe information from literature and other sources like the internet were evaluated. In addition discussions with experts from different sectors of waste management were performed.

The relevance of waste treatment operations induced by mass streams of wastes is subject of Section 2.1 and 2.2. While available information sources are fragmentary, Section 2.3 analyses selected waste streams and connected operations in more detail. Information about waste treatment operations and facilities are evaluated in Section 2.4.

2.1 Waste amount – general view

EEA states that about 2,225 million tonnes occur yearly within the European OECD Member States [EEA 1998]. This amount does not yet include wastes from the agricultural sector and mining for 40% of the integrated country data. EEA estimates that approximately 4,000 million tonnes of solid wastes occur every year in Europe. The agricultural sector has been indicated to produce the biggest amount of waste [European Commission 1999].

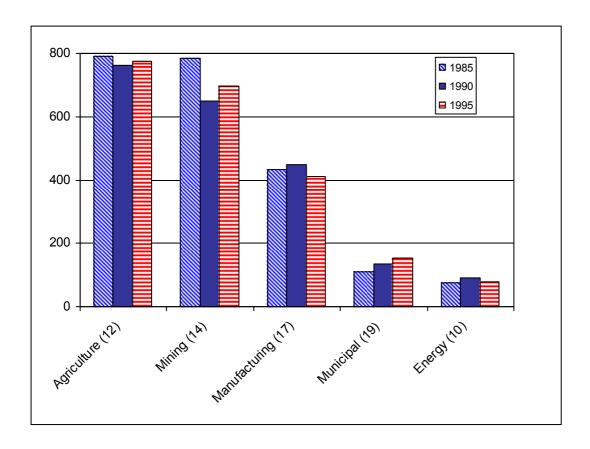
A recent publication stated that more than 3,000 million tonnes of waste arise in Europe annually [EEA 2003].

EEA generated an overview of the sector-specific waste generation for EEA countries⁴, which includes a waste amount of 1,300 million tonnes per year. Figure 1 shows the annual waste production for OECD Europe⁵.

⁴ Based on Eurostat Data and the ETCW enquiry on specific waste streams, taken from [EEA 2001a]

⁵ Excluding radioactive waste





[EEA, 1998]⁶

Figure 1: Waste generation by sector in EEA countries

It can be estimated that roughly half of the waste for which a sector-specific breakdown is available is mineral waste.

⁶ "Figures in brackets indicate the number of countries for which data was available. For many countries/sectors, data does not stem from the reported year"



2.2 Total waste generation by waste type

Data from the EEA concerning the different waste types in Europe are presented in Table 1.

Table 1: Total generation of waste by selected waste types in EEA countries in different years

Waste type	in 1,000 tonnes
Construction/Demolition waste	337,981 ⁷
Paper/Cardboard	63,704 ⁸
Residues from coal-fired power plants	51,497 ⁹
Packaging waste	47,593 ¹⁰
Sewage sludge	8,156 ¹¹

These data represent about 22 % of the above-indicated total waste generation of 2,225 million tonnes from the European OECD Member States.

Data in the EEA document on Europe's Environment indicate that 203 million tonnes of municipal solid wastes occurred in 1995 within the European OECD Member States [EEA 1998]. In 1995, approximately 107 million tonnes of biodegradable municipal waste were generated in the EU and Norway [EEA 2003].

In the publication in 2003, it was indicated that 306 million tonnes of municipal waste are estimated to be collected each year [EEA 2003].

740 million tonnes of waste are generated by the manufacturing industry [EEA 2003].

Hazardous waste makes up less than 1 % of all waste generated in Europe [EEA 2003].

⁷ European Environment Agency (2002): Review of selected waste streams, Annex II Construction and demolition waste for the countries A, S (1999),,DK, Fin, I, L, (1997), G, GR, NL (1996), IR (1998), SW, NO (1993), UK (1990)

¹⁸ EEA (2002): Construction and demolition waste for the countries AT, ES (1999), DK, FI, IT, LU, (1997), DE, GR, NL (1996), IE (1998), SE, NO (1993), F (1992), UK (1990), p.32

⁸ http://waste.eionet.eu.int/wastebase/quantities, waste type: paper and cardboard, year: 1996, for the countries A, B, DK, Fin, F, G, GR, IR, I, NL, P, S, Sw, UK, No

⁹ European Environment Agency (2002): Review of selected waste streams, Annex II Construction and demolition waste for A, GR, NL (1999),B (1995), F (1996), G (1993), IR (1998), I, UK (1997), P (1998), Sw (1994),

http://waste.eionet.eu.int/wastebase/quantities, waste type: packaging waste, year: 1997, for the countries A, B, DK, Fin, F, G, GR, IR,I, NL, P, S, Sw, UK, No

¹¹ European Environment Agency (2002): Review of selected waste streams, Annex I, Sewage sludge, for the countries A, B, DK, Fin, F, G, GR, IR, L, NL, P, S, UK (2000), S (1995)



2.3 Selected waste streams

Additional information about waste treatment operations was elaborated by analysing the fate of specific waste streams. The main criterion for the selection of waste streams in this section was mass relevance. In addition recent discussions about priority waste streams and waste orientated European Directives were evaluated.

2.3.1 Construction and demolition waste

The treatment of different fractions from construction and demolition waste is illustrated in Figure 2. Recycling includes crushing of bricks and concrete for use as filling in new building materials or simply as filling under new constructions to replace the use of gravel [EEA 2002].

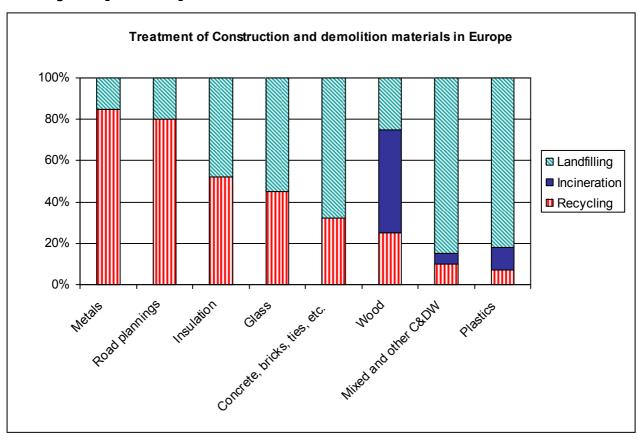


Figure 2: Treatment of construction and demolition waste in Europe in percent



2.3.2 Ferrous scrap (including metal packaging)

65 – 80 million tonnes of ferrous scrap were consumed in 2000 by around 210 electric arc furnaces and 90 oxygen converters in Europe [WVS/VdEh 2000]. Pretreatment is mainly carried out using shredder or shears.

2.3.3 Paper/cardboard

32.5 million tonnes of waste paper and cardboard were incinerated or landfilled in EEA Member States in 1996 [ETC WMF 2003]. [CEPI 2000] reports an amount of around 40 million tonnes of waste paper recycled in the paper industry in 2001.

2.3.4 Waste from coal-fired power plants

Ashes from coal-fired power plants are widely used for construction purposes (18.1 million tonnes of fly ash and 2.4 million tonnes of bottom ash in EU 15 in 2001 [ECOBA 2003]). In addition 7.1 million tonnes of gypsum from flue gas cleaning are used in the production of gypsum products [EEA 2002] [ECOBA 2003].

2.3.5 Paper/cardboard packaging

13.3 million tonnes of paper/cardboard packaging have been recycled (mainly as secondary raw material in the paper industry) in the EU in 1997. 1.7 million tonnes have been used in energy recovery operations [ARGUS 2001].

2.3.6 Glass packaging

7.5 million tonnes of glass packaging have been recycled mainly in the glass industry in 1997 [ARGUS 2001]. EEA reports an amount of 7.4 million tonnes of recycled and 5.9 million tonnes landfilled glass from packaging in EEA Member States.

2.3.7 Plastic packaging

1.5 million tonnes of plastic packaging have been recycled in 1997 in the EU and 1.3 million tonnes were used in energy recovery operations [ARGUS 2001]. 337,000 tonnes have been used in feedstock recovery in blast furnaces¹². 1.1 million tonnes plastic packaging waste was used in mechanical or chemical recovery [ARGUS 2001].

Because of restrictions in view of available plastic wastes it can be expected that not more than 4 of the \sim 70 blast furnaces in Europe [WVS/VdEh (2000)] may be operated with plastic wastes in the future.



2.3.8 Sewage sludge

Recycling of sewage sludge has been indicated by most Member States as the preferred treatment. Despite this, large amount of sewage sludge are still either incinerated or landfilled [EEA 2002]¹³.

2.3.9 End-of-life vehicles (ELV)

In the recital clauses of Directive 2000/53/EC (ELV Directive) 8-9 million tonnes of wastes from ELV are mentioned. EEA reports an amount of 8-10 million tonnes per year for reporting EEA Member States [ETC WMF 2003a]. The *projected* number of ELV is described as 13 million for 2000^{14} . According to the ELV Directive, depollution and dismantling steps are mandatory for all ELV. Crushing of depolluted body shells is a crucial pre-requisite for further treatment in order to separate ferrous, nonferrous metallic and non-metallic components. For the vast majority of body shells these are currently, and will be in the future, shredded.

The exact number of companies dismantling ELV in Europe is not known [EFR-ESG 2002].

2.3.10 Waste electrical and electronic equipment

Around 6 million tonnes of waste electrical and electronic equipment (WEEE) were generated in 1998. The volume of WEEE is expected to increase by at least 3-5% per year. Up to now, more than 90% of WEEE is landfilled, incinerated or recovered without any pre-treatment [European Commission 2000]. According to the requirements of the WEEE Directive, the depollution and dismantling steps are mandatory [WEEE Directive Annex II].

No information is available about the number of facilities where electric and electronic waste is treated.

2.3.11 Batteries

Around 66 million units of automotive batteries are estimated to have been sold in 2000 in Western Europe (including the original equipment and aftersales market) [Eurobat 2000]. It can be assumed that approximately half of the total battery market is made up from automotive batteries [DTI 2002]. Therefore, roughly 120 million batteries of all types (automotive, industrial and consumer batteries) can be estimated for Western Europe.

¹³ It has to be taken into consideration that these figures are based on dry matter. There may be other results if the figures were to be based on original matter.

¹⁴ http://waste.eionet.eu.int/wastebase/quantities, waste type: End-of-life vehicles, year: 2000. Data for AT, BE, DK, FI, FR, DE, GR, EI, IT, LU, NL, PO, ESP, SE and UK.



Transferring the projections from the UK [DTI 2002] to a EU level would mean that battery sales are almost equal to the amount of wastes yielded [DTI 2002]. In tonnes, this would mean that approximately three million tonnes of battery waste arose 2000 in Western Europe. This gives only a very rough idea of the actual amounts of battery waste produced in Europe but will be used until more specific data is available. ¹⁵

More than 20 plants in Europe accept spent batteries to recover components, including lead, cadmium, steel and plastics. They are located in countries throughout Europe, some are specialised battery recycling units and others accept batteries as one component of their feedstock [DTI 2002]. Detailed data about the recovery and disposal rates within the EU Member States could not be made available.¹⁶

2.3.12 Waste oil

For a total of 1.5 million tonnes of waste oils per year the following treatment paths are reported [CONCAWE 1996]:

- direct burning 32%

- re-processing to industrial fuel 25%

- re-refining to base oils 32%

- reclaiming of specific industrial oils 11%

According to the same source direct burning is mainly done in cement kilns (\sim 80%). 10% are used for space heating and another 10% are used in dedicated waste incinerators [CONCAWE 1996].

EEA published a total amount of waste oil of 2.5 million tonnes¹⁷. 0.5 million tonnes were regenerated, 1.5 million tonnes incinerated [EEA 2002]¹⁸. Differences in the amount may result, inter alia, from different inclusion of contained water phase.

2.3.13 Hospital waste

Clinical waste is made up from waste comparable with municipal waste (75-90%) and hospital specific 'hazardous' waste. In several countries, it is not separated from

¹⁵ Eurobat for example is currently investigating the battery wastes on an European level.

¹⁶ ICON [2001] states that "Member States already have organised collection schemes to increase collection rates, with obligations for retailers and producers to accept batteries returned to them. Stated collection targets for batteries range from 100% in France and 99.9% in Denmark, to 75% in Portugal. (Bied-Charreton, 1997). Some Member States, including the UK, have not set up any formal system as a high (estimated at >90%) recycling rate is already achieved by existing routes using scrap dealers. However, this relies purely on the scrap value of lead providing an economic incentive. Thus, at times of low value, there is less incentive for collection ".

¹⁷ It has to pointed out that the collection of waste oils in DK, IS and SE has been indicated, but no data for the total amount generated have been published. These amounts do not appear to be a part of the total waste generated.

¹⁸ It was not indicated by the EEA which countries have been integrated into the conclusions.



municipal waste and this might be the reason that no coherent data for this waste stream seems to be available [EEA 2003]. One source stated that around 1.3 million tonnes of clinical wastes are incinerated each year in the European Union [European Commission 1998].

2.3.14 Waste containing PCB

PCBs have been used in electrical equipment or as pesticide extenders, flame-retardants, sealants, paints, etc. Even though PCBs have been banned since 1985 they are still released from landfilling, waste incineration, sewage sludge, combustion of waste oils etc [European Commission 2001]. No comprehensive data on PCB-containing equipment and/or PCB-containing waste could be made available.

2.3.15 Waste tyres

For approximately 2 million tonnes of waste tyres arising in Europe in 2001¹⁹, the European Association of the Rubber Industry (BLIC) reports the following treatment paths:

-	material recycling	29%
-	landfill	24%
-	energy recovery	16%
-	re-treading	13%
-	export	12%
-	re-use	5%

The European Tyre Recycling Association (ETRA) estimates that approximately 2.5 million tonnes of waste tyres arose in the EU in 2000²⁰. Concerning estimated recycling paths following was indicated:

landfilling	37%
material recycling	20%
energetic recovery	21%
re-treading	11%
re-use	11%
[ELIMID 2001]	

[EUWID, 2001]

-

¹⁹ Data from BLIC, including the following Member States: BE, DK, FI, FR, DE (only capacities), IT, NL, PO, ESP, SE, UK as well as the Accession Countries Hungary and Poland.

²⁰ Data from the following member States: AU, BE, DK, FI, FR, DE, IE, IT, LX, NL, PO, ESP, SE, UK



2.4 Waste treatment installations

Presently there is no database available which comprises all waste treatment operations in the European Union and which gives indications on operation relevance. The most comprehensive database about waste treatment operations is presently the database of the European Environmental Agency (EEA).

In its report about waste management facilities for hazardous waste in Europe, the EEA lists ca. 1,900 facilities and 280 landfills²¹ (see Table 2).

Table 2: Waste management facilities in Europe (hazardous waste)

Table 2. Waste management racintles in Europe (nazardous waste)						
Country		Companies	Facilities	Landfills	Locations altogether	Date of data
Austria	(AT)	102	129	0	129	1999
Belgium	(BE)*	60	70	9	79	1999
Germany	(DE)	579	582	171	753	1999
Denmark	(DK)	62	50	13	63	1999
Spain	(ES)	217	209	10	219	1999
Finland	(FI)	77	83	9	92	2000 (1st update)
France	(GB)	99	89	14	103	2000
Greece	(GR)	13	13	0	13	2000 (1st update)
Ireland	(IE)	12	12	0	12	1999
Iceland	(IS)	1	1	0	1	1999
Italy	(IT)	458	449	39	488	1999
Liechtenstein	(LI)	3	3	0	3	1999
Luxembourg	(LU)	3	3	0	3	1999
The Netherlands	(NL)	305	99	11	110	1999
Norway	(NO)	34	37	1	38	1999
Portugal	(PT)	7	7	1	8	1999
Sweden	(SE)	131	n.d.	n.d.	n.d.	2000
All countries		2163	1836	278	2114	

^{*} Only Belgium Flanders and Wallonia; n.d.: no data available at the moment [EEA 2001b]

A further differentiation and clustering of operations cannot yet be generated by the EEA because of missing data reported by the Member States.

A first impression concerning the type of operations may be given by the analysis of R/D codes, which have been reported for the facilities. Nearly a third of the facilities were reported with more than one R/D code. Table 3 shows an overview of the number of R/D codes classified according to single R and D codes for EEA Member States²² for the year 1997.

²² In addition to the actual EU Member States Liechtenstein, Norway and Iceland are also a part of the EEA (Economic European

Area) Member States.

²¹ Based on 17 EEA Member countries which delivered data.



Table 3: Number of R/D codes classified according to single R and D codes for EEA Member States for the year 1997

Number	Entry			
201	R 4 Recycling/reclamation of metals and metal compounds			
129	R 1 Use principally as a fuel or other means to generate energy			
119	R 13 Storage of wastes pending any of the operations numbered R 1 to R 12			
107	R 3 Recycling/reclamation of organic substances which are not used as solvents			
105	R 9 Oil re-refining or other reuses of oil			
94	R 2 Solvent reclamation/regeneration			
91	R 5 Recycling/reclamation of other inorganic materials			
53	R 12 Exchange of wastes for submission to any of the operations numbered R 1 to R 11			
18	R 8 Recovery of components from catalysts			
9	R 6 Regeneration of acids or bases			
9	R 11 Use of wastes obtained from any of the operations numbered R 1 to R 10			
6	R 7 Recovery of components used for pollution abatement			
6 R 10 Land treatment resulting in benefit to agriculture or ecological improvement				

Table 4: Number of R/D codes classified according to single R and D codes for EEA Member States for the year 1997 (continued)

Number	Entry			
610 D9 Physical-chemical treatment which results in final compounds or mixtures				
discarded				
186	D 1 Deposit into or onto land			
180	D 15 Storage pending any of the operations numbered D 1 to D 14			
170	D8 Biological treatment which results in final compounds or mixtures which are discarded			
163	D 10 Incineration on land			
91	D 5 Specially engineered landfill			
52	D 14 Repackaging prior to submission to any of the operations numbered D 1 to D 13			
44	D 13 Blending or mixing prior to submission to any of the operations numbered D 1 to D			
	12			
18	D 2 Land treatment			
5	D 4 Surface impoundment			
4	D 12 Permanent storage (e.g. emplacement of containers in a mine, etc.)			
FEE 4 200	723			

[EEA 2001c]²³

The EEA database shows the importance of physical-chemical treatment operations (D9) for the disposal of hazardous wastes as well as deposit and storage operations (D1, D5, and D15). For recovery operations, the picture has lower significance. Recovery and reclamation operations for metals and organic compounds/substances (R4, R3) have the highest relevance in view of number of facilities followed by the incineration of waste (R1).

²³ For the 221 material recovery facilities for hazardous waste an assignment of R/D codes was not possible. UK (>1000 facilities) data are not included.



Information about capacity referring to R/D codes and waste type is still very scarce. Relevance of the operations aside from facility numbers can thus not be derived from the EEA database²⁴.

CEN estimates that in the year 2000 around 1.4 million tonnes of processed solid recovered fuels were **co-incinerated**²⁵. The 'European Recovered Fuel Organisation' (EFRO) expects an amount of above 5 million tonnes of co-incinerated SRF in 2005. Information about the number of installations that co-incinerate waste is rare. WT BREF estimates a number of 155 producers of solid recovered fuels [Draft WT BREF]. WRc estimates for the year 2001 a number of more than 50 plants in Europe generating around 3 million tonnes of refuse derived fuels (RDF) from more than 3.7 million tonnes of input municipal solid waste [WRc 7.2003]. Co-incineration of waste occurs inter alia in cement industry, lime kilns, power plants and brick kilns [WRc 7.2003].

For **non-hazardous wastes**, only data about landfills and dedicated waste incinerators from ETC/W partner countries and regions²⁶ are reported. 8,700 licensed landfills accepting non-hazardous waste are reported and between 3,500 and 10,000 unlicensed landfills [ETC/WMF 2003].

The number of dedicated solid waste incineration plants in Europe is reported in different sources as between 250 and 300 in the European Union²⁷ and above 750 in EEA Member States [ETC/WMF 2003] for non-hazardous waste and 239 for hazardous waste.

The draft of the BREF document on "Best Available Techniques for the Waste Treatments Industries" gives a preliminary overview of waste treatment operations within the scope of the document which covers:

 installations for the disposal or recovery of hazardous waste as defined in the list referred to in Article 1 (4) of Directive 91/689/EEC, as defined in Annexes II A and II B (operations R1, R5, R6, R8 and R9) to Directive 75/442/EEC with a capacity exceeding 10 tonnes per day

-

²⁴ The overview of waste treatment facilities in Europe from the BAT TWG Waste Treatment (First draft of the WT BREF, February 2003) is mainly based on EEA data.

²⁵ CEN/BT/TF 18 N 46

²⁶ Austria, Baden-Württemberg, Catalunya, Denmark, Ireland

²⁷ e.g. Juniper Consultancy, UK, Energy from waste plants: Data book of European Sites, Nov. 1997

²⁸ Draft Reference Document on Best Available Techniques for the Waste Treatments Industries Draft January 2004



- installations for the disposal of waste oils as defined in Council Directive 75/439/EEC of 16 June 1975 with a capacity exceeding 10 tonnes per day
- installations for the disposal of non-hazardous waste as defined in Annex II A to Directive 75/442/EEC under headings D8 and D9, with a capacity exceeding 50 tonnes per day.

It has to be taken into account that this overview does not comprise all waste treatment operation of the respective area. It is nevertheless one of the most comprehensive databases about the number of such operations.

Table 5: Overview about waste treatment operations which are in the scope of the WT BREF

Waste treatment operation	Number of known installations		Known capacity (kt/yr)	
Waste treatment operation	Hazardous	Non-hazardous	Hazardous	Non-hazardous
Waste transfer installations	249			
Installations for the biological	176	247		
treatment of waste	610			
Installations for the physico- chemical treatment of waste	618			
Installations for re-refining waste oil	35	3	1500	
Waste solvent installations	106			
	Number of kn	own installations	Known ca	pacity (kt/yr)
Treatment of waste catalyst		20		
Treatment of other inorganic materi-	126			
als (excluding metals and metal com-				
pounds)				
Recovery of components used for	20			
pollution abatement				
Installations for the regeneration of	13			
waste acids or bases TOTAL				
Installations for the preparation of waste to be used as fuel TOTAL	140		129	



2.5 Waste shipment

In 1999 the cross-border shipment of around 7 million tonnes of waste has been reported. Because of the rules of the Waste Shipment Regulation, the characterisation of waste treatment operations as recovery or disposal has relevance for the shipment of wastes. The cross-border movement involving the EU "accounts for 70% of all reported movements. Nearly 50% of all reported movements are between EU countries" (see Figure 3) [Wielenga 2002].²⁹

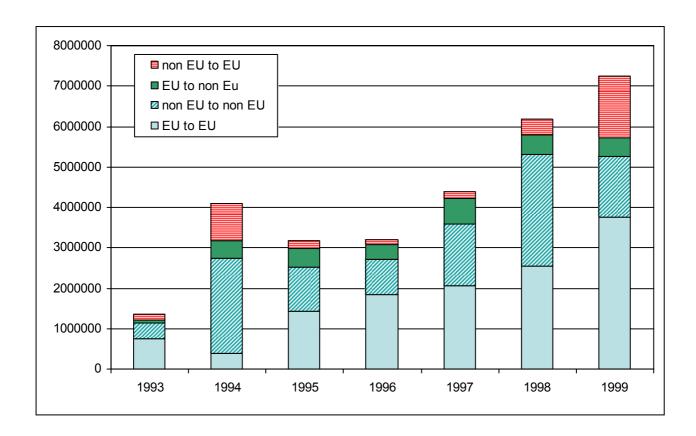


Figure 3: Movements involving EU and non-EU countries

The increase in the number of movements is mainly based on an increase for recovery operations, while the number of movements for disposal operations is quite stable (see Figure 4).

-

²⁹ The part of the report to which the following figures and statements refer only takes into consideration those movements for which the information on treatment was specified. It therefore provides insight into the relative importance of the different operations and for trends over time but gives an underestimation of the total amounts treated.



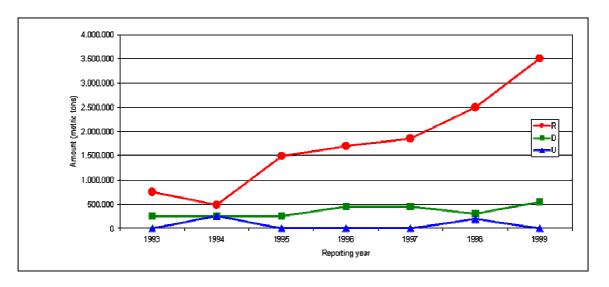


Figure 4: Movements inside EU per type of waste management operation [Wielenga 2002] r = R-operations, d = D-operations, u = unassigned

The cross-border movements are dominated by wastes containing metal (Y31, 22, 17 and 23) and oil/water mixtures (Y09) (see Table 6).

Table 6: Most important waste streams involved in cross-border movement

Code	Description	Amount reported (metric tonnes)	Number of movements
Y31	Lead, lead compounds	3,617,000	1,550
Y18	Residues from industrial waste disposal	2,645,000	764
Y22	Copper compounds	2,415,000	1,092
Y23	Zinc compounds	2,236,000	908
Y17	Wastes from surface treatment of metals and plastic	2,233,000	1,380
Y09	Oil/water mixtures	1,092,000	645
Y06	Wastes from manufacture, formulation and use of organic solvents	863,000	1,331
Y12	Wastes from manufacture, formulation and use of paints	827,000	1,005
Y34	Acids	792,000	1054
Y42	Organic non-halogenated solvents	551,000	1079

[Wielenga 2002]

Table 6 gives an overview of the waste management operations of those wastes in the country of destination. Metal recycling and incineration hold prominent positions in the list of operations. Physical-chemical treatment is listed mainly as a final disposal operation.



Table 7: Wastes mostly involved in cross-border movements and its treatment

Waste	Recovery ³⁰		Final disposal		
	Amount Operation		Amount	Operation	
Lead, lead compounds	75%	25% incinerat		50% physical-chemical treatment 25% incineration 25% engineered landfill	
Copper compounds	95%	50% recycling of inorganic material 40% metal recycling	3%	60% incineration 33% engineered landfill	
Wastes from surface treat- ment of metals and plastic	95%	60% metal recycling	5%	60% physical- chemical treatment 20% permanent storage	
Residues from industrial waste disposal	75%	45% metal recycling 20% recycling of inorganic material 10% use as fuel	25%	55% incineration 25% physical- chemical treatment	
Zinc compounds	90%	95% metal recycling	5%	50% permanent storage	
Wastes from manufacture, formulation and use of organic solvents	80%	50% use as fuel 25% solvent reclamation	20%	90% incineration	
Oil/water mixtures	55%	40% recycling of organic material 30% use as fuel	40%	40% incineration 25% physical- chemical treatment 20% biological treatment	
Wastes from manufacture, formulation and use of paints	55%	50% use as fuel 20% accumulation ³¹ 15% metal recycling	35%	55% incineration 35% physical- chemical treatment	
Acids	80%	55% regeneration of acids 20% 70% physical- chemic 20% metal recycling 10% deep injection 20% recycling of inorganic materials 10% incineration			
Organic non-halogenated solvents	70%	70% 45% use as fuel 30% 65% incit 20% solvent reclamation 20% metal recycling		65% incineration	

[Wielenga 2002].

Table 7 lists the R and D entries according to their relative importance. It shows that the three entries R4, R5 and R3 make up more than 55% of the total amount of shipped waste.

³⁰ The total percentage of recovery and disposal may not add up to 100%. For some movements these operations had not been specified.

³¹ For paint waste it should be noted that 'accumulation' is often used for operations that prepare waste for use as a fuel e.g. by mixing it with sawdust. The mixture is subsequently used as a fuel in another installation. It is therefore likely that approximately 70% of all recovery would ultimately be use as a fuel.



Table 8: Recovery and final disposal operations receiving the largest amounts of waste

Code	Description	Relative importance (%)	Most important waste streams
R4	Recycling/ reclama- tion of metals and metal compounds	31	Lead and lead compounds (Y31), zinc compounds (Y23), wastes from surface treatment of metals (Y17) and residues from industrial waste treatment operations (Y18).
R5	Recycling/ reclama- tion of other inor- ganic materials	14	Copper compounds ³² (Y22), residues from industrial waste treatment operations (Y18), residues from incineration (Y47), soil, glass and aluminium residues (no Y code specified)
R3	Recycling/ reclama- tion of organic sub- stances which are not used as solvents	11	Treated wood (partly no Y code, partly Y5), waste paper and paper sludge
R1	Use as a fuel (other than in direct incin- eration) or other means to generate energy	8	Treated wood (Y5 or not classified by Y code), household waste (Y46), organic solvents (Y6), wastes from the manufacture, formulation and use of paint (Y12).
D10	Incineration on land	7	Waste collected from households (Y46), residues arising from industrial waste disposal operations (Y18), oil/water mixtures (Y9). No Y code specified: contaminated soil, sewage sludge and meat and bone meal.
D9	Physical-chemical treatment	4	Residues arising from industrial waste disposal operations (Y18), oil/water mixtures (Y9), inorganic cyanides (Y33), wastes from production, formulation and use of paints (Y12).
D1	Deposit into or onto land (landfilling)	3	Three large shipments of unspecified wastes from Switzerland to France, residues from incineration of household waste (Y47), household waste (Y46), asbestos waste (Y42) and contaminated soil (no Y code).
D5	Specially engineered landfill	3	Halogenated organic solvents (Y41), ethers (Y40), residues from incineration (Y47), inorganic fluorine compounds (Y32) and hexavalent chromium compounds (Y21).

[Wielenga 2002]

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³² It should be noted that this waste was described as copper slag and blast furnace slag, which could be used as construction material after processing.



2.6 Summary of results

The information sources about waste treatment operations in Europe are fragmentary, use varying and non-uniform bases and contain heterogeneous information. Thus, a multi step approach was performed combining information

- about waste amounts,
- main waste treatment operations for selected waste streams,
- information about waste treatment installations and
- cross-border shipments of waste.

The findings of this task built the basis for the detailed analysis of waste treatment operations in section 3. Further and more detailed information about the relevance of the respective operation are included in that section, in the technical Annex of this part of the study (see page 94) as well as in Part B of the study.

The analysis of waste streams pointed out the relevance of wastes from agricultural activities. This includes a large portion of organic wastes such as "Animal faeces, urine and manure (including spoiled straw), effluent" (EWC 02 01 06) and "Waste from forestry exploitation" (EWC 02 01 07). Although no precise data are available about recovery of organic wastes, it can be concluded from practice in different Member States, that a large portion is used on agricultural areas. Another relevant part will probably be used in waste treatment facilities such as anaerobic digestion. Temporary and permanent storage of wastes as well as combustion of wastes are indicated as additional important waste treatment operations.

Waste from mining and quarrying and from construction and demolition activities make up the second biggest category of waste streams in Europe. It consists mainly of mineral components.

Municipal solid waste makes up the third biggest category. Most of this waste type is landfilled or incinerated in dedicated waste incineration plants. Co-incineration in production processes is another operation with increasing mass relevance.

The amount of classical separate collected wastes for recovery (scrap, paper/cardboard, packaging waste) is almost the same as of mixed municipal solid waste.

Hazardous waste makes up a portion of 2% of the total waste amount arising in the EU. It includes an extremely broad variety of materials and compositions.



Recovery of organic wastes, landfilling of mineral waste and mixed municipal waste as well as incineration in dedicated incineration plants and in production processes are the recovery and disposal routes in Europe.

The detailed view on selected waste streams gave additional evidence for the relevance of waste treatment operations:

- The mineral fraction from construction and demolition waste is used, after pretreatment, for construction; insulation and glass are recycled and landfilled.
- Non-hazardous metal wastes are mainly recovered in the steel and non-ferrous metal industry in part after pre-treatment (e.g. shredder).
- It can be concluded from activities in Member States that unspecific inhomogeneous wastes (e.g. mixed wastes from small- and medium-sized companies) that are not incinerated or landfilled are pre-treated by means of separation operations.
- Sewage sludge from non-industrial processes or installations as well as other organic wastes are widely used on agricultural areas, or treated in digestion and/or composting plants.
- Ash from power plants is used for construction purposes and substance from SO₂
 emission reduction in power plants is processed to gypsum for use in construction work.
- Complex products, which are subject to EU waste directives, undergo depollution and dismantling steps before mechanical separation.
- Recovery of paper/cardboard (including paper/cardboard packaging) is carried out in the paper industry after pre-treatment steps.
- Plastic packaging is recovered as material in the plastic industry but also in the steel industry by feedstock recovery.
- Glass packaging is mainly recovered in the glass industry.
- Waste oils are combusted after re-processing to industrial fuel or they are rerefined.
- Different sources with focus on hazardous wastes point out the relevance of physical-chemical treatment operations, deposit and storage, incineration and recovery of metals and organic components.

The analysis of reported cross-border movements showed a dominance of wastes containing metal and oil/water mixtures. The operations in the receiving countries aim at the recycling of metals (R4), recycling/reclamation of inorganic (R5) and organic substances (R3). Incineration is an important recovery and disposal step in the receiving countries. Furthermore, disposal operations are dominated by physical-chemical treatment (D9) and permanent storage (D1, D5).

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The analysis showed that several waste treatment operations are performed in practice that combine different types of waste recovery operations (e.g. energy and material recovery) and recovery and disposal aspects (e.g. treatment of spent fixer solutions). Some operations emerged with increasing relevance which have been out of the focus of discussion some ten years ago (e.g. feedstock recovery in blast furnaces; several techniques for the treatment of heterogeneous wastes like gasification of plastic waste and shredder light fraction and the mechanical biological treatment of mixed solid waste). Some relatively new specialised operations decompose complex materials aiming at providing raw materials for new products at the direct production of new products (e.g. feedstock recovery and precipitation of PVC).

Filling of mines is mentioned more and more as treatment path for a broad variety of wastes, which do not derive from mining and quarrying activities.



3 Detailed analysis of waste treatment operations

Neither the WFD nor any other waste regulation defines the term 'operation' and currently there is no consistent use of the terms 'waste treatment operation', 'process' or 'operation' in waste management-related literature or discussions.

Recent judgements of the European Court of Justice³³ do not give comprehensive clarification of this question.

For the purpose of this study the term 'unit operation' (UO) is used as a term for the smallest part of an operation which must still be able to be operated as an isolated entity. It is rather a neutral element with regard to its purpose.

The term '**process**' is used in this study for a combination of "unit operations" and has a defined purpose. It is not necessarily waste-related.

The term 'waste treatment operation' is used very similar to the term 'process'. It can be a combination of unit operations or a single unit operation and is always connected with wastes.

The following chapter describes waste treatment operations briefly. A detailed technical description is to be found in the technical annex of this part of the study (see p. 94). Exemplary mass flows are taken as bases, which are suitable to illustrate the respective issue. Operations were described for which there could be ambiguity in their classification in a disposal and/or a recovery entry and options were elaborated which could help differentiating between the competing entries. These options can not be realised as isolated elements. Section 3.3 thus summarises the results and links the elaborated options.

³³ e.g. SITA (former Verol) case C-116/01 considering combined processes and their characterisation:

[&]quot;Where a waste treatment process comprises several distinct stages, it must be classified as a disposal operation or a recovery operation [...] taking into account only the first operation that the waste is to undergo subsequent to shipment" [C-116/01 ECJ, 49]. "An operation classified as waste recovery may be followed by a disposal operation of the non-recoverable fraction of that waste" but the classification of the first operation as a recovery operation is not affected by the fact that it is followed by an operation to dispose of the residual waste" [C-116/01 ECJ, 43].



3.1 Legal Background

3.1.1 Distinction between recovery and disposal

The Waste Framework Directive (WFD) emphasises the preservation of natural resources as an essential objective of **recovery** of wastes: "Whereas the recovery of waste and the use of recovered materials should be encouraged in order to conserve natural resources" [WFD recital 4].

Therefore, article 3.1 emphasises as essential objective of **waste management** procedures the recovery of waste by means of recycling, re-use or reclamation or any other process with a view to extracting secondary raw materials.

Instead of a definition for 'disposal', the WFD refers to Annex IIA of the Directive that lists operations, which remove wastes finally from material cycles.

Article 3.1 highlights one function of 'disposal' by pointing out the removal or destruction of substances that may hinder recovery of wastes:

- "1. Member States shall take appropriate measures to encourage:
- (a) firstly, the prevention or reduction of waste production and its harmfulness, in particular by:
- the development of appropriate techniques for the final disposal of dangerous substances contained in waste destined for recovery;" [WFD Article 3.1]

With this, disposal is described as a function, which is part of treatment for the recovery of wastes. It differs from the disposal operations mentioned in Annex IIA.

Article 1 b of the WFD mentions "pre-processing, mixing or other operations resulting in a change in the nature or composition of this waste". Appropriate entries reflecting this type of operations may be entry D9 of Annex IIA and R12 of Annex IIB.

The aim of protection of human health and the environment must be met by all waste management measures: "Member States shall take the necessary measures to ensure that waste is recovered or disposed of without endangering human health and without using processes or methods which could harm the environment" [WFD Article 4].

This is also emphasised once again through the almost identical introductory text to the lists in Annex II A and Annex II B:



- "In accordance with Article 4 waste must be recovered without endangering human health and without the use of processes or methods likely to harm the environment" [WFD Annex II B].
- "In accordance with Article 4 waste must be **disposed** of without endangering human health and without the use of processes or methods likely to harm the environment" [WFD Annex II A].

In addition to the wording of the WFD recent decisions by the European Court of Justice (ECJ) as well as the opinions expressed by Advocate General Jacobs and the Waste Shipment Regulation are looked upon in order to clarify the distinction between recovery and disposal operations.

It has been stated in the ASA case that Annexes A and B of the Waste Framework Directive list only the "most common disposal and recovery operations" [C-6/00 ECJ, 60] and that the enumeration is not precise and exhaustive. Furthermore, some operations "are capable of falling within the wording of operations mentioned in Annex II A and B to the Directive" [C-6/00 ECJ, 61]. Nevertheless, those operations have to be classified "either as disposal or recovery of waste", in order to apply the Directive [C-6/00 ECJ, 62]. It may not be possible to classify a single operation simultaneously as both a disposal and a recovery operation [C-6/00 ECJ, 63]. The decision has to be made according to the Directive and on a case-by-case basis [C-6/00 ECJ, 64].

In the SITA (former Verol) case C-116/01 the topic of the classification of combined processes arose. "Where a waste treatment process comprises several distinct stages, it must be classified as a disposal operation or a recovery operation [...] taking into account only the first operation that the waste is to undergo subsequent to shipment" [C-116/01 ECJ, 49]. "An operation classified as waste recovery may be followed by a disposal operation of the non-recoverable fraction of that waste" but the classification of the first operation as a recovery operation is not affected by the fact that it is followed by an operation to dispose of the residual waste" [C-116/01 ECJ, 43].

A criterion, which could support the decision-making process, might be the statement that "recovery operation generally implies a prior treatment of the waste" but it does not follow from any provisions of the Directive that a prior treatment of the waste "is a necessary condition for classifying an operation as recovery" [C-6/00 ECJ, 67].



The principal objective of the waste recovery operation is "that the waste serves a useful purpose in replacing other materials which would have had to be used for that purpose, thereby conserving natural resources" [C-6/00 ECJ, 69]³⁴.

Advocate General Jacobs discussed the overriding purpose as being "the correct criterion for determining whether that operation should be classified as disposal or recovery" [C-6/00 Jacobs, 86].

"The decisive question is whether the waste is used – or reused - for a genuine purpose" meaning "if waste were not available for a given operation, would that operation none the less be carried out using some other materials?" [C-6/00 Jacobs, 86].

Who pays for the treatment of the waste might give an indication of whether "the waste is used for a genuine and independent purpose". "Where waste is for recycling, the holder of the waste is paid by the recycler" [C-6/00 Jacobs, 88]. Even though Jacobs states that this "preposition is not absolute", it might prove to be useful in some cases.

With the background of export of wastes Article 7.4 (a), fifth indent of the Waste Shipment Regulation (WSR) mentions as reasons for possible objections to the planned shipment of waste

- ratio of the recoverable and non-recoverable waste,
- the estimated value of the materials to be finally recovered or
- the cost of the recovery and the cost of the disposal of the non-recoverable fraction.

To facilitate this decision, inter alia, the following information has to be submitted.

- the planned method of disposal for the residual waste after recycling has taken place,
- the amount of the recycled material in relation to the residual waste,
- the estimated value of the recycled material. [Article 6 (5), indents 3-5]

Advocate General Jacobs states that the "last three indents of Article 6(5) suggest that the proposed recovery operation would not make economic or environmental sense. [...] although the community waste legislation enshrines the primacy of re-

³⁴ The question as to whether this criterion is fulfilled was to be decided by the national court in this specific case [C-6/00 ECJ, 70].



covery over disposal, that does not mean that any proposed recovery operation must be approved: the legality of recovery operations is itself subject to the overriding consideration of environmental protection" [C-6/00 Jacobs, 68].

3.1.2 Definition of recycling

In court case C-444/00 the European Court of Justice deals with the definition of recycling under the Packaging Directive 94/62/EC. The definition of recycling in this context applies for the waste addresses by the Packaging Directive.

"92. Furthermore, recycling is not defined in Directive 75/442. Should that term, as envisaged by Directive 75/442, not have the same meaning as the term appearing in Directive 94/62, only the latter term would be applicable to packaging waste. As is clear from paragraphs 53 and 57 of this judgement, even though Directive 75/442 is the framework legislation and is relevant when interpreting and applying Directive 94/62, that does not prevent the provisions of the latter, as special legislation, from prevailing over those of Directive 75/442.

57. Accordingly, Directive 94/62 must be considered to be special legislation (a lex specialis) vis-à-vis Directive 75/442, so that its provisions prevail over those of Directive 75/442 in situations which it specifically seeks to regulate." [C-444/00 ECJ]

Article 3(7) of Directive 94/62/EC defines recycling as follows:

"'recycling' **shall mean the** reprocessing **in** a production process **of the** waste materials **for the** original purpose **or for** other purposes **including organic recycling but excluding energy recovery**".

The definition contains several parts:

- a) reprocessing
- b) production process
- c) original purpose
- d) other purposes

These terms have been interpreted in the Judgement of the European Court of Justice C-444/00:

a) Reprocessing

"Reprocessing of packaging waste must enable new material, or a new product possessing characteristics comparable to those of the material from which the waste was derived, to be obtained" [C-444/00 ECJ, 73].



b) Production process

A (production) process "requires the packaging waste to be worked in order to produce new material or to make a new product" [C-444/00 ECJ, 66].

c) Original purpose

"This means that the waste must be transformed into its original state in order to be useable, where appropriate, for a purpose identical to the original purpose of the material from which it was derived" [C-444/00 ECJ, 67].

d) Other purposes

"Those other purposes may be of any kind so long as the reprocessing of the packaging waste does not take the form of energy recovery, since that is expressly excluded by Article 3(7) of Directive 94/62, and is not effected by means of disposal, a method which would run counter to the very concept of recycling as a form of waste recovery" [C-444/00, ECJ 69].

Based on the above findings and the requirements of Article 174 (1) and (2) EC the ECJ stated that "by interpreting the definition of recycling in Article 3(7) of Directive 94/62 as meaning that the reprocessing of packaging waste must enable new material, or a new product possessing characteristics comparable to those of the material from which the waste was derived, to be obtained, a high level of environmental protection is ensured" [C-444/00 ECJ, 73].

Furthermore, "it is only at that stage that the ecological advantages, which led the Community legislature to accord a degree of preference to this form of waste recovery, are fully achieved, namely a reduction in the consumption of energy and of primary raw materials (see the 11th recital in the preamble to Directive 94/62)"[C-444/00 ECJ, 74].

Beside the interpretation of recycling as laid down in the Packaging Directive the ECJ also distinguished between reclamation and recycling while using the term reclamation solely for operations recovering raw materials.

"Recycling can be clearly distinguished from other recovery- or waste-processing operations referred to by the Community legislation, such as reclamation of raw materials and compounds of raw materials (points R 3, R 4 and R 5 of Annex II B to Directive 75/442), pre-processing, mixing or other operations, which result only in a change in the nature or composition of the waste (see Article 1(b) of Directive 75/442)" [C-444/00 ECJ, 66].



3.1.3 Summary

According to the WFD and the judgements of the ECJ the main criterion for the identification of recovery operations is the substitution of primary raw materials. 'Disposal' is defined within the WFD by a non-conclusive list of operations in Annex IIA. This list comprises operations that remove wastes permanently from material cycles. The function of disposal to remove substances from wastes for recovery (Article 3.1(a) of the WFD) cannot be reflected by this Annex.

The WFD mentions waste treatment operations, which change the nature or composition of a waste (Article 1b of the WFD). With the background of transboundary shipment of waste the ECJ states inter alia in case C-6/00 that an operation must be characterised as either recovery or disposal operation.

The WFD distinguishes between different forms of recovery operations like recycling, re-use or reclamation (Article 3.1 (b)) or regeneration and re-refining in Annex IIB without giving definitions. With the background of the Packaging Directive, the ECJ points out the importance of the production of a new product which is comparable to those from which the waste was derived.



3.2 Analysis of waste treatment operations

3.2.1 Scrap in electric arc furnaces

Ferrous scrap is reprocessed into a product in a single unit operation (electric arc furnaces (EAF)). In subsequent operations the resultant slag is either recovered or disposed of.

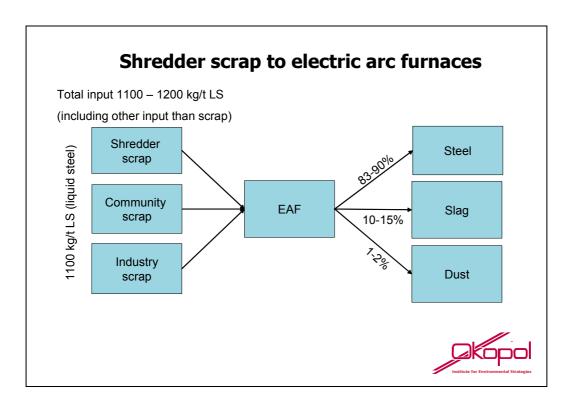


Figure 5: Scrap in electric arc furnaces

The operation can be characterised as recovery operation without ambiguity. The waste is processed almost completely into a product. Thus, a substitution of primary raw material takes place, which would otherwise be needed for the manufacture of the product. A suitable entry would be R 4 "Recycling/reclamation of metals and metal compounds".

The output of the process (steel) has characteristics, which are very similar to the initial material (steel product). The ECJ designates this in connection with the Mayer-Parry case C-444/00 and the Packaging Directive as essential prerequisite for the process type 'recycling'. A differentiation of operations where raw materials are reclaimed (reclamation) is not possible through this designation R4, which summarises both types of operation (see also discussion of shredding of ferrous scrap in the technical annex on p. 94 and Part B).



In a simplified steel production chain (iron ore – pig iron - liquid steel – product) the scrap is reintroduced into the production cycle on the level of pre-products, avoiding the energy intensive step of reducing iron ore to pig iron. The available entries of Annex IIB do not enable a distinction to be made between recovery from oxidised iron (equals iron ore) and recovery from metallic steel.

3.2.2 Fibre reinforced plastics in cement production

Fibre reinforced plastics ("composites") are used in clinker production. The inorganic part substitutes natural siliceous, aluminium and calcium compounds. The organic part contributes to the energy input of the operation.

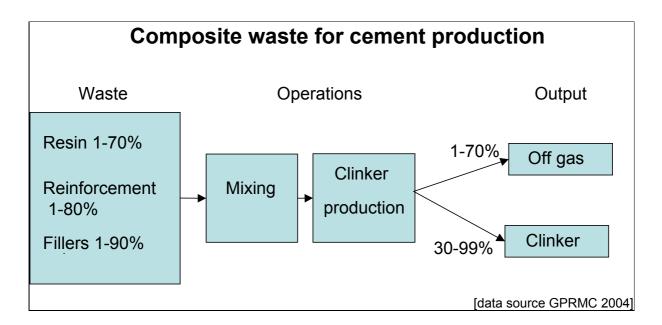


Figure 6: Fibre reinforced plastics in cement production

The organic part in composites varies between 10% and 70%. Utilisation as energy carrier or as mineral resource essentially dominates under quantitative aspects.

If, in view of these different compositions, the lower calorific value is related to the overall waste, then a very low value can result, for example with extruded profiles with a polymer share of 20-30%, while it can be relatively high with composite tanks and vessels.

A characterisation of the process according to the entries of Annex II is most likely to be possible if a process can be assigned to two entries (in this case R1 + R5). This is possible with regard to most of the functions of the characterisation of waste treat-



ment operations as long as for both aspects a characterisation as recovery takes place.

If the sequence of the processes is considered within the unit operation "Cement works" according to the decision of the ECJ in the Verol/Sita Case -<u>and</u> the calorific value of the organic share is taken into account, then there would be a characterisation as utilisation of the energy content". With this procedure the problem of different characterisation depending on the organic share would, to a wide extent, be avoided.

The decision of ECJ was found with the background of waste export and the clarification of doubtful cases. For the calculation of the recovery rates of the ELV, WEEE and Packaging Directive the context of these directives and their objectives can then be best taken into account if both the energetic and the materially used share are considered.

In cases where an overall characterisation without differentiation is necessary, the technical conditions are best taken into account if no further breakdown of the unit operation takes place. The setting of the system limits in this case is unquestionable.

With regard to functions of the characterisation where an assignment to one of the entries is necessary there are different possibilities:

- approach where the composition of the waste is the basis for the characterisation (share of combustible components)
- approach where the effect of the waste in the operation is used as a basis (e.g. actual net calorific output)

A characterisation of the waste treatment operation as such ('use of composites in cement kiln') is not possible. A differentiation according to the composition of the waste or the effect of the waste in the process is necessary anyhow.

With the employment of composites in the cement works in any case unspecific characteristics of both main components are used (Energy content and volume).

3.2.3 Smelting of lead acid batteries

Lead acid batteries (without sulphuric acid) are fed into a shaft furnace where they are smelted. The CO rich off-gas is usually post-combusted.

The operation combines different types of waste treatment operations:



- a) in part respectively incomplete combustion of organic compounds³⁵,
- b) pyrolysis of organic compounds in a reducing furnace atmosphere,
- c) smelting of lead and lead compounds,
- d) post-combustion of the off-gas.

A separation of steps a) to c) is, technically seen, only possible with difficulty. Above all the steps a) and b) run closely interlinked with each other. The energy required for the process is produced through the exothermal oxidation of the plastics share

If the first step a) of the process chain is applied for the classification then entry R 1 "Use principally as a fuel or other means to generate energy" would be sensible. If it is taken into account that steps a) and b) run closely interlinked and both are therefore considered together, then a classification as R 3 "Recycling/reclamation of organic substances ..." would result. However, an allocation taking into account quantitative aspects, whereby an allocation to entry R 4 "Recycling/reclamation of metals and metal compounds" would result, appears sensible.

If the system limits are set according to the unit operations, then it results that, in addition to the output of lead and/or lead compounds and slag there can additionally be an output of CO-rich gas. If the system limits are set according to the plant discharges then this output stream is dispensed with due to post-combustion. The latter setting of the system limits appears practical, as the gas <u>has to</u> be post-combusted due to the content of organic pollutants.

The process handles the quantitatively dominant materials (lead and lead compounds) in a manner that, finally, specific characteristics can be utilised. With the consideration of the overall waste treatment operation unspecific characteristics are used (energy potential) from the share of plastics.

For application relationships of the characterisation with which it depends on a general classification (e.g. with a background of export) a classification as R4 under quantitative aspects is sensible.

For the calculation of utilisation quotas a global characterisation of the process does not correspond with the objective quota instruments of the Packaging, ELV and WEEE Directive.

³⁵ Additionally the resulting compounds in the off-gas are combusted in a post-combustion chamber. The organic input is therefore completely oxidised in the installation.



3.2.4 Feedstock recovery in blast furnaces

Organic-rich waste is fed into the hot zone of the blast furnace.

In a process orientated view the waste has a reducing effect on the iron ore. The energy content of the waste additionally results in thermal energy. In a waste orientated view the waste is partly oxidised by oxygen from ambient atmosphere and partly by oxygen from iron ore. The specific characteristics of the process can be taken into account in the best way with a process-orientated view. The decisive question is whether the same process would be possible if only the heat would be transferred to the iron ore. The answer is "no". The reduction potential of the chemical compounds generated from the waste would not be useable if there were no direct contact between the chemical compounds and the iron ore because the chemical energy of the plastics could not be used.

Recovery of plastics is not done in this operation in a way that the material integrity of the organic matter is kept. The input material is not transferred to "new" or other organic matter but into non-organic substances (CO, CO₂).

The original material (mainly polymers) is no longer available for material cycle.

If the waste does not meet certain minimum qualities no substitution of primary raw materials is achieved in the process. The effect of the waste in the process can be estimated in the majority of cases based on the composition of the wastes to be employed. The existing Annex II does not foresee the coupling of waste composition and process.

Also in the normal case, that a substitution of primary raw materials takes place in the process a characterisation is without doubt not possible within the existing Annex II. There is no recycling and no reclamation, as the material is transformed in a form that precludes a further usage in the economic cycle. None of the existing entries covers all aspects of the waste treatment operation in a process-related visible manner. An assignment to an entry such as, for example, "Use of chemical energy of a waste in a production process" would be possible. Viewed technically, within the existing entries, an assignment to R1³⁶ combined with R3³⁷ or an assignment to R1 combined with R5³⁸ would be most appropriate.

In comparison with the characteristics of the original plastic only unspecific characteristics of the waste are used in the process, because primary energy carriers are substituted.

³⁶ Used principally as a fuel or other means to generate energy

³⁷ "Recycling/reclamation of organic substances which are not used as solvents", if the plastic as initial material represents the basis

³⁸ "Recycling/reclamation of other inorganic materials" if the actual reduction-affecting materials form the basis of the characterisation



3.2.5 Gasification at the "Schwarze Pumpe" secondary recovery centre

At the "Schwarze Pumpe" installation organic-rich wastes are converted into inorganic gases and – in subsequent steps – into methanol.

A part of the organic input is oxidised (exothermally) in the gasifier.

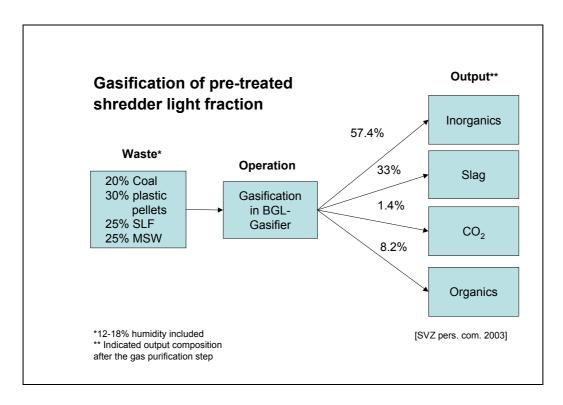


Figure 7: Gasification of SLF

A characterisation as recovery operation is possible on the basis of the criterion "substitution of primary raw materials". Depending on the setting of the system limits different classification can take place:

- a) reclamation: (R 5 Reclamation of other inorganic materials); reclamation of mainly inorganic synthesis gas (syngas), which serves as raw material for the manufacture of products, if the system limit is set before the production of methanol.
- b) recycling: R 3 Recycling of organic substances; production of methanol, if the system limit is set with the production of methanol³⁹.

In Case b) the structure of Annex IIB is not suitable to differentiate between different forms of recycling. While with material recycling essentially conversion processes

³⁹ The plant operators set the system limits with the production of syngas.

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take place and the molecular structure of the material remains as it was, with the "Schwarze Pumpe" process the complex molecules are broken down and reformed again. This corresponds with reclamation as raw material in the production processes. Through the breakdown of the molecules the possibility of using the specific characteristics of the plastics is lost.

The plastics employed are used within the scope of the pyrolytic processes of the first unit operation in part as energy supplier. The specific peculiarities of pyrolytic processes could then be best taken into account if the unit operations of the respective process configuration are evaluated as a whole (see also the excursus on pyrolytic processes on page 47). In doubtful cases a further sub-division into process steps within the unit operation is possible.

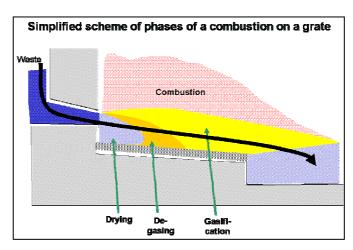
For the calculation of the reclamation quotas in the relationship of the respective directives presented, the taking into account of the respective energetically used shares of the waste is sensible (for this see also the example "Smelting of lead acid batteries" in Section 4.3). If the synthesis gas (syngas) is applied, for example, as reduction agent in the blast furnace, it should be examined whether the energetic utilisation predominates in the overall balance of the processes.



3.2.6 Excursus: Pyrolysis and combustion

Combustion of waste can be divided into four phases: drying – degassing – gasification – combustion. It has to be taken into account that the gasified components may burn but not the solid materials (see also figure on the right).

The four process steps in waste incineration normally take place in one unit operation It is, however, possible spatially to separate



the individual phases of the incineration⁴⁰. In this way drying, degassing and gasification can take place in one unit operation as, for example, extensively found in pyrolysis processes,. The resultant gases can finally be combusted in a subsequent unit operation (e.g. TwinRec process). The final combustion can also take place in a production process (e.g. cement works). In another case, the resultant gases are employed as reactive substance (e.g. in the blast furnace process as reduction agent). With a specific process control in the gasification it is possible to use the gases for material reclamation processes (e.g. "Schwarze Pumpe"-process).

No common specifications exist for the consideration of combined unit operations as waste treatment operation. The TwinRec process (see technical annex, p. 107) can thus be classified as R 5 "Recycling/reclamation of other inorganic substances" (if the system limit is set after the pyrolysis step), or as R 1 "Used principally as a fuel or other means to generate energy", if the system limit is set after the final combustion process. If the gas from pyrolysis is employed as energy carrier in the cement works then, with an isolated consideration of the pyrolysis, characterisation as R 5 "Recycling/reclamation of other inorganic materials" would be possible. If the subsequent step of the cement works is included then a classification as R 1 "Used principally as a fuel or other means to generate energy" would be sensible.

A further important point with characterisation of pyrolytic processes is the question of energy generation. If there is no additional input of heat energy form outside – which is the case in the majority of cases with waste treatment processes - then each pyrolytic breakdown of complex molecules is also always connected with exothermal oxidation (either completely to CO₂ and H₂O or incompletely to CO). Through this combustion procedure the energy is provided which is required for drying, degassing and gasification. In the case of the "Schwarze Pumpe" process, with the employment of shredder light fraction there results a raw gas with 20% CO₂. The share of incompletely oxidised carbon is ca. 30% (as CO). If the further purified gas is used in the blast furnace as reduction agent, complete oxidation from atmospheric oxygen also takes place there for a part. While with each individual step of the treatment chain the share of combustion lies below 50%, it is certainly possible that, in the combination the main part of the organic input is combusted.

⁴⁰ The term 'combustion' is used in this study for the exothermic oxidation of wastes. It does not connect in any way to entry D10 of Annex IIA or entry R1 of Annex IIB of the WFD



3.2.7 Recovery of spent acids

Basically, there are two different types of recovery operations for spent acids. In the example of spent sulphuric acid these are

- thermal decomposition resulting in SO₂ as a raw material for H₂SO₄ production or
- physical processes such as concentration or evaporation.

Decomposition and subsequent H_2SO_4 production is in most of the known cases carried out in production plants, where both unit operations are combined. Thus, the SO_2 does not usually leave the plant. In accordance with the above described manner of procedure, the decomposition is therefore treated as one waste treatment operation with final production of H_2SO_4 .

The level of the reintroduction of the material into the production procedure varies depending on the principle of the process. While, with regeneration the feedback takes place as final product, the SO_2 has the character of a raw material or preproduct.

A differentiation according to the described operation principles is possible within the existing Annex IIB:

- "R 5 Recycling/reclamation of other inorganic materials" for operations where the acids are decomposed
- "R 6 Regeneration of acids or bases" for physical regeneration of acids

3.2.8 Recovery of catalysts

Catalysts are regenerated in that their surface is reactivated. The thus-handled catalysts can again be employed for their original purpose. This can take place in very different ways according to the great variety of catalysts.

With the reactivation there is no physical conversion of material and, in most cases, no breakdown of the active material to molecular of structural level⁴¹.

In the example of thermal regeneration of activated coke (see technical annex, page 112) the spent granular coke is reactivated with steam at 750° to 800°C. The whole

⁴¹ In some cases (e.g. reactivation of platinum catalysts) additional chemical reactions are performed (e.g. chlorine treatment). This however does not contradict the basic operation principle of regeneration.



of the main part of the active coke, at the end of the process, is again available as reactive coke.

The thermal regeneration of catalysts is characterised in that the material is neither chemically or physically modified, rather the adsorbed material is again separated out. The output of the process is a product which is almost of equal value to the input. Therefore, systematically, the process corresponds with the processing of equipment or equipment components before reuse.

Annex IIB of the WFD (depending on the type of catalyst) enables solely the assignment of the process to the entries R3 to R5. A differentiation between regeneration and the processes where the catalyst is separated into individual components and a new catalyst is produced⁴², is not possible.

Different to the cases of solvents and acids/bases there is no similar entry for the regeneration of catalysts. The entry R 8 "Recovery of components from catalysts" on one hand does not focus on the specific characteristics of regeneration, but rather covers all of recovery. On the other hand, it refers to "components". With regeneration, however, very often the catalyst is reactivated as a whole.

In order to make possible a similar differentiation of recovery operations as with solvents or acids/bases for catalysts also, a specific entry "Regeneration of catalysts" can be incorporated. Failing this an entry for the general process principle of regeneration could be incorporated.

⁴² E.g. reclamation of the mineral core and re-smelting of the active metallic surface



3.2.9 Distillation of organic solvents

Solvent waste is distilled in batches or continuously in electrically or steam heated vessels. The input of the operation is manifold (e.g. waste from organic chemical processes, wastes from the manufacture, formulation, supply and use of coating, adhesives, sealants and printing inks, wastes from chemical surface treatment and coating of metals or other materials, wastes from shaping and physical and mechanical surface treatment of metals and plastics, other waste organic solvents, coatings, inks, adhesives and sealants such as those from separate municipal collection⁴³).

The outputs of the operation are a gaseous phase, solvents, water and sludge. The share of the output fractions varies significantly according to the input material. Most distillations end up in about 5% water output, but depending on the economic value of the input solvents, high water contents up to 80% are accepted and thus found in the output.

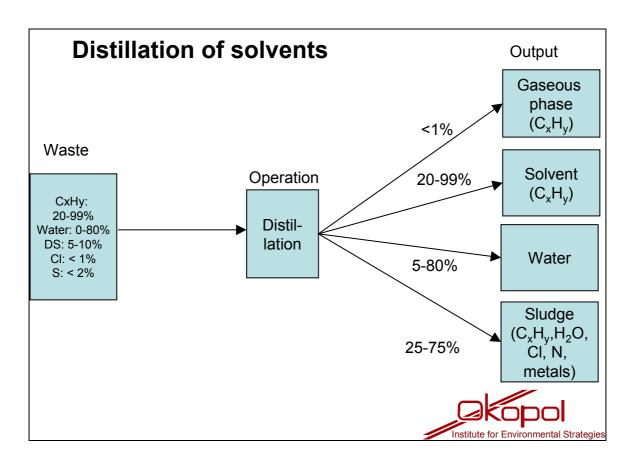


Figure 8: Distillation of solvents

⁴³ Often solvents are processed separately and distilled solvents are returned to the supplier. This situation is not taken into consideration in this section because of the sometimes unclear legal status of the waste solvents.



Depending on the input into the process (particularly with batch processes) the distilled solvent can achieve the same qualities as for the original product. This is, above all, the case if the re-distilled returns to the waste producer.

In other cases, for example with the mixing of different solvents, there are changed qualities which, for example, are traded as mixed qualities for cleaning purposes.

Depending on the input to the process the requirements of regeneration or recycling would be fulfilled.

Annex IIB gives as entry R 2 "Solvent reclamation/regeneration". Both variants of solvent distillation presented can be covered through this.

The in part high water content of solvent wastes means, with the application of the quantity criterion (>50% recovered), that in many cases no classification as recovery operation would take place. Solvents represent the end-product of a manifold production chain. To what extent one is thus concerned with a product that, under ecological aspects has to be considered as being particularly valuable, cannot be decided on the currently existing methodical basis (for this see the discussion of a "sustainability factor" in the section "Recovery of fixer solution").

3.2.10 Composting of native organic solid waste

In composting plants, a part of the organic matter of waste is decomposed by the aerobic activity of micro organisms. Through the warming of the materials and conversion of organic material into CO_2 , there results an off-gas quantity that, on average, corresponds to ca. 30-40% of the input.

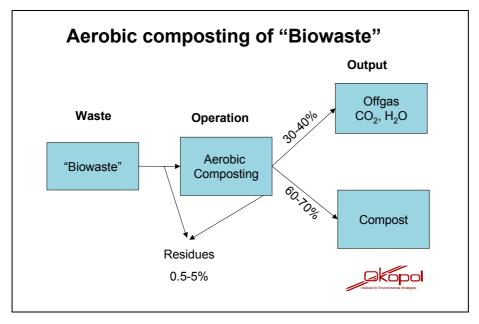


Figure 9: Composting of native organic solid waste



Depending on its quality, compost is used for soil improvement. It may or may not comply with existing quality standards. National legal regulations for compost quality and national standards are applied. On a EU level, the Eco-label for soil improvers⁴⁴ describes quality requirements.

Annex IIB provides the entry R 3 "Recycling/reclamation of organic substances which are not used as solvents (including composting and other biological transformation processes)" for the characterisation of this operation. However, no quality requirements are combined with this entry.

Entry R10 "Land treatment resulting in benefit to agriculture or ecological improvement" emphasises the positive effect which must be achieved through the employment of the waste. If quality requirements for the output of the aerobic composting plant are met there is a high probability that the positive effects required in entry R10 are reached. The composition of the input or its origin can be applied as indicator for the expected quality of the output. Separately collected native organic wastes regularly achieve corresponding qualities with an appropriate process control⁴⁵.

Under the assumption that appropriate quality requirements are coupled with entry R10⁴⁶, the combination of entry R3 and entry R10 (e.g. "Reclamation of organic substances which can be used in subsequent R10") is thus seen as possible approach in order to be able to take into account the quality aspect.

3.2.11 Mechanical biological treatment of mixed solid waste

Mixed solid waste is treated in mechanical biological treatment plants (MBT) by separation of substances which disturb the process, optimisation of particle size, separation of materials with a high calorific value (e.g. plastics) and a biological treatment step (anaerobic and/or aerobic).

^{44 2001/688/}EC

⁴⁵ It can be regularly expected that the output does not meet existing national quality requirements if the input waste does not derive from separate collection.

⁴⁶ E.g. in accordance with 2001/688/EC



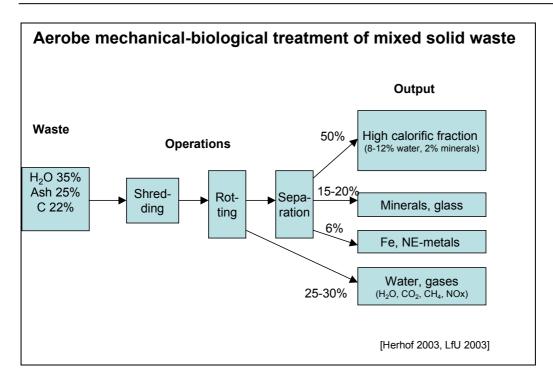


Figure 10: Aerobe mechanical biological treatment of mixed solid waste

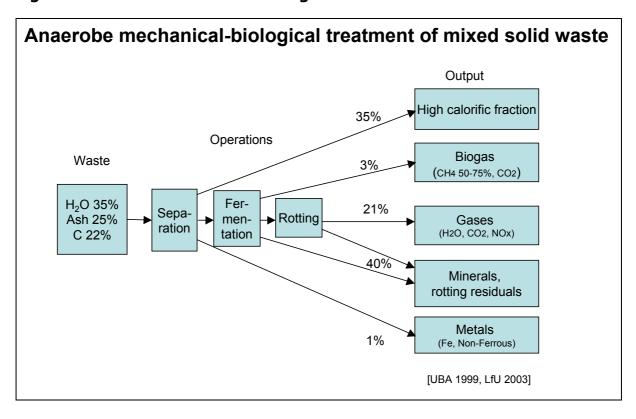


Figure 11: Anaerobe mechanical biological treatment of mixed solid waste

As with composting the biological treatment is also the characteristic unit operation with MBT. The difference in the composition of the respective outputs results, on one



hand, from the different inputs. On the other hand, however, also with the differences with the execution of the biological treatment step.

A combination of input and process for the characterisation of a process is not taken into account in the entries of Annex IIB which come into question. Such a procedure would lead to a very large number of entries. A detailed differentiation of processes, for example dependent on the degree of transformation of the biologically degradable component of the waste, is also not possible using Annex IIB.

If the objective is pre-treatment before deposition then D 9 "Physico-chemical treatment not specified elsewhere in this Annex which results in final compounds or mixtures which are discarded by means of any of the operations numbered D 1 to D 12 (e.g. evaporation, drying, calcination, etc.)" comes into consideration as possible entry.

The output with appropriate process control in many cases meets the qualitative requirements for the subsequent utilisation in combustion processes, which are also characterised as processes of entry R1. If future quality standards valid Europe-wide are available⁴⁷, composting and MBT may be characterised as R3 (Reclamation of organic substances). With this, the prerequisite must be met that more than 50% of the input exists in this form.

In the case of composting the process aims at a final process in which specific characteristics are used. in the case of MBT unspecific characteristics of the output are used in the final energetic recovery operations.

If the quality criteria are not met then a characterisation as recovery operation is not practical. The existing Annex II offers here only the possibility of characterising the process in this case as disposal operation. Here, as an alternative, the creation of a new annex, which contains processes with which the waste treatment process is not completed (pre-treatment operations), is possible. The existing Annex II contains such entries respectively with "D"— reference:

"D 8 Biological treatment not specified elsewhere in this Annex which results in final compounds or mixtures which are discarded by means of any of the operations numbered D 1 to D 12

D 9 Physico-chemical treatment not specified elsewhere in this Annex which results in final compounds or mixtures which are discarded by means of any of the operations numbered D 1 to D 12 (e.g. evaporation, drying, calcination, etc.)"

Such a procedure, however, makes it necessary that, with a characterisation of processes, complete process chains are taken into account. In practice this is associated

⁴⁷ E.g. as result of the CEN Working Group TC 343.



in part with considerable difficulties. The establishment of a new annex for intermediate operations, in which the waste treatment is not completed, would, however, be problematic for example in connection with exports (for this see also the discussion of recent legal cases in Section 3). With this background, there is the possibility of classifying operations as recovery only if the main part of the output meets certain quality requirements.

3.2.12 Anaerobic digestion

In anaerobic digestion plants organic material is partially decomposed by microorganisms into CH₄ and CO₂ (Biogas). The operation comprises typically the following unit operations:

- Pre-treatment: separation of materials which disturb the process or which have a negative effect on the quality of the output
- Anaerobic digestion: typically the different phases of the digestion process (hydrolysis, acid phase, acetic acid phase, and methane phase) take place in one reactor.
- Post-treatment: the digestion residue is post-treated in order to stabilise the material and to enable subsequent biological activity.

Depending on the input wastes the resulting material may or may not be used as fertiliser / for soil improvement.

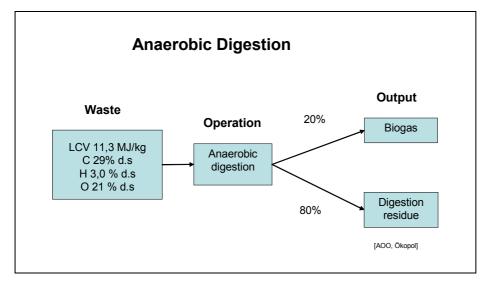


Figure 12: Anaerobic digestion

In addition to the aspects discussed in connection with composting and MBT the production of biogas, which can be utilised as energy, is taken into account here. This sub-stream makes up a share significantly below 50%. In the following combus-



tion process unspecific characteristics of the gas are used. Reasons for the application of a "sustainability factor" similar to those for metals (see Chapter 3.2.21, 3.2.22 and 3.2.23) are not available.

Composting (Chapter 3.2.10) and MBT (Chapter 3.2.11), and digestion (Chapter 3.2.12), with biological treatment, display similar process principles. With all three processes no primary raw material is replaced rather materials are created which have the potential to do this in the following steps. A principle differentiation of the processes⁴⁸ is only possible if an orientation to the quality of the output takes place.

An appropriate differentiation, for example adopting the entries R3 in Annex II, would considerably expand the scope. Therefore the transfer into a subordinate set of rules and standards appears sensible.

3.2.13 Use of sewage sludge on agricultural areas

In this exemplary operation sewage sludge is applied on agricultural areas.

Entry R10 of Annex IIB of the WFD says: "Land treatment resulting in benefit to agriculture or ecological improvement".

As described above there is no definition of when there is a "benefit to agriculture or ecological improvement" available at an EU level.

The requirement that, with recovery operations, primary raw materials have to be substituted, is potentially fulfilled due to the nutrient-rich organic substances. Therefore a characterisation as R3 "Recycling of organic substances" would come into consideration.

Using the example of the application of sewage sludge on agricultural areas, the interlinking of protected assets (protection of soil and groundwater/water conservation) and waste management is clear. Here it has to be taken into account that regulations which arise from protected assets are often "defensively" oriented. Fulfilment of the "defensive" requirements of Directive 1986/278/EEC⁴⁹ does not necessarily mean that the "positive" objective of entry R10 is achieved⁵⁰.

⁴⁸ Also with regard to the question of whether the requirements are actually fulfilled for a characterisation as R-process

⁴⁹ The purpose of this Directive is according to Art.1: "Regulate the use of sewage sludge in agriculture in such a way as to prevent harmful effects on soil, vegetation, animals and man, thereby encouraging the correct use of such sewage sludge". In order to reach this objective the Directive sets out in Art. 4 "Values for concentrations of heavy metals in soil to which sludge is applied, concentrations of heavy metals in sludge and the maximum annual quantities of such heavy metals which may be introduced into soil intended for agriculture". More specific requirements concerning the use of sewage sludge regarding pollutant limit values, test methods etc. have been drafted in Working Documents on sludge by the European Commission [European Commission 2000a].

⁵⁰ Furthermore there are other relevant parameters (e.g. PAH, PCB etc) which are not regulated by Directive 1986/278/EEC.



The adoption of individual protected asset-related requirements would lead to an increased expansion of Annex II. Therefore it appears sensible to take into account such requirements through flanking specific regulations⁵¹. An interlinking between the areas of the regulations can be adopted through respective referencing.⁵².

If, with such a background, the quality requirements on the material are not fulfilled, entry D 2 "Land treatment (e.g. biodegradation of liquid or sludgy discards in soils, etc.)" would come into consideration. It would be questionable whether the legal requirements for disposal of wastes can be fulfilled like that⁵³.

3.2.14 Filling of Mines

Mines are filled in order to avoid the destabilisation of the surface (underground workings) or for site restoration purposes (open pits).

National rules for underground stowage have been set out, for example, by Germany in the Ordinance on Underground Waste Stowage (Stowage Ordinance).

Under the assumption that these mines would be filled even without the presence of waste, depending on the make-up of a classification to the R 3 "Recycling/reclamation of organic substances", R 4 "Recycling/reclamation of metals and metal compounds" or R 5 "Recycling/reclamation of other inorganic materials" would be conceivable. If required a classification to R 7 "Recovery of components used for pollution abatement" could also come into consideration. In the majority of cases one is, however, concerned with wastes which must show a certain stability which is best achieved through mineral wastes. In any case, however, unspecific characteristics of the waste are used (volume).

The question of whether the lead requirement of substitution of primary raw material, or the fact that the material is permanently removed from the material cycle is here predominant cannot be answered from the technical point of view. A possible option would be the development of a new entry which takes into account that the material is permanently deposited and removed from the economic cycle (e.g. "use of waste for filling of mines").

⁵¹ As already mentioned there are still no Europe-wide quality criteria in existence on which the meeting of requirements of entry R10 can be checked.

⁵² With regard to such an interlinking, further intensive discussion certainly needs to be held if, for example, the reduction aim of waste management has to be connected with soil and groundwater, and groundwater protection objectives. It would, for example, also need to be taken into account that sewage sludge results from a treatment process which is carried out to remove pollutants from a material stream (wastewater treatment). The process thus follows the disposal principle of the WFD. The pollutants deliberately filtered (sewage sludge) is again fed into the biosphere with the application of sewage sludge.

⁵³ During the investigations carried out no case was identified where this entry could be applied.



However, if the requirement of substitution is not met entries D 1 "Deposit into or onto land" or D 5 "Specially engineered landfill" would be suitable for a characterisation.

3.2.15 Treatment of cathode ray tubes

Cathode ray tubes (CRT) are crushed and cleaned (coating). The resultant glass mix can be used in the following steps for the filling of mines.

In another possible process the panel and cone glass are separated from one another. The panel glass of cathode ray tubes can be recycled to new panel glass after the separation from the cone glass.

In both cases no primary raw material is replaced. The requirement for reclamation of raw materials would be fulfilled if the output streams met certain quality requirements (R 5 Reclamation of other inorganic materials) ⁵⁴. As a rule this is the case ⁵⁵.

In the first case, the volume of the glass is used and the material is permanently removed from the material cycle. The lead content of the glass mixture from the shredders is tolerated because it undercuts, for example, the threshold value of the corresponding German ordinance. In the second case, a recycling as closed loop is the objective of the process.

The existing Annex II does not make possible any differentiation of the characterisation with regard to the subsequent disposal or recovery paths. A possible option in a restructured Annex IIB would be to distinguish between the usage of specific characteristics and unspecific characteristics in the following processes.

3.2.16 Treatment of oil contaminated garage waste including oil filters

Garage waste comprises a wide variety of different fractions which occur during car repair activities such as papers, metals, worn parts and plastics. Oil filter waste from car repair shops are most of the times collected together with other fractions. The composition of the waste thus varies significantly.

In this waste treatment operation the metallic and non-metallic shares are separated in various unit operations. The output of the operation is ferrous metals, oil and a

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⁵⁴ Assuming that the filling of mines is characterised as recovery

⁵⁵ For the production of panel glass there are quality requirements of a certain range at manufacturer level. Requirements on wastes for backfilling mines are in part regulated nationally. Common European Standards do not exist. The range of acceptable compositions for materials in stowing is very large.



high calorific fraction. The output share varies according to the input material, to the type of unit operations used and to the desired output quality.

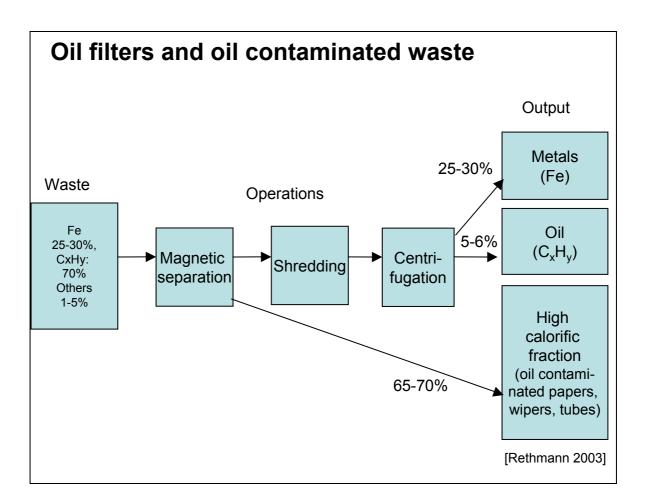


Figure 13: Treatment of oil contaminated garage waste including oil filters

To start with, no primary raw material is substituted in this process. For the larger part of the sub-streams resulting from the treatment (high calorific fraction) currently there are quality criteria only at a national level or between producer and user. In future a Europe-wide Standard for the high calorific fraction can result from the work of the CEN TC 343 "Solid Recovered Fuels" working group.

For most processes, whose main principle is the separation of fractions, there is the problem that, depending on how the plant is run, almost any composition of the output fractions can result.

Fundamentally the possibility exists that processes are characterised as recovery operation if the main part of the output meets certain quality requirements. With the background of a characterisation at EU level these would be requirements recognised



EU-wide⁵⁶. In this case, a classification as R3 "Reclamation of organic substances" can take place if the quality requirements are fulfilled.

If these requirements are not fulfilled then, for example in connection with the export of wastes, the mechanism for disposal operations would come into effect. The criterion of substitution would, in this case, not be fulfilled. The existing Annex II here offers solely the possibility of classifying such non-recovery operations as disposal operations.

With the characterisation of sorting operations it is to be taken into account that their method of operation is very variable and can be modified quickly and without great expense. Therefore, the question arises of whether such processes are at all capable of being generally characterised. A check of whether the methods of operation are maintained on which the characterisation is based is, in many cases, only possible at great expense.

A modified structure of Annex II would be conceivable in the relationship presented, with which the sorting processes would be assigned a category "other operations" in a separate Annex. Otherwise, as a rule, a characterisation as non-recovery = disposal operation appears more sensible, from which deviations can be made if this is verified in a suitable manner.

3.2.17 Sorting of mineral waste from construction and demolition

A mineral fraction, a metal fraction and a residue containing, for example, wood, roofing felt and plastics are separated in this waste treatment operation within different subsequent unit operations.

The characterisation of this process contains a similar problem as, for example, is presented in the example "sorting of garage waste". Here also one is concerned with a process with which no primary raw materials are replaced. The output streams can, depending on the composition, meet or also not meet the quality requirements of subsequent recovery processes.

In the example of the sorting of mineral waste, a use of non-specific characteristics takes place in any case in the subsequent disposal processes.

⁵⁶ For national considerations such as, for example, the question of responsibility for tendering for wastes for disposal, an orientation on national requirements is, on the other hand, conceivable.



As presented in the example of the utilisation of sewage sludge on agricultural areas, an interlinking here with requirements of other protected assets (soil-, groundwater-, water protection) is to be taken into account.

If the requirements of such "flanking" areas of regulation are fulfilled for the predominant portion of the output, then the process can be characterised as R5 (Reclamation of inorganic substances).

3.2.18 Sorting of non-mineral waste

Non-mineral waste from construction and demolition sites as well as mixed municipal solid waste is sorted in different mechanical unit operations.

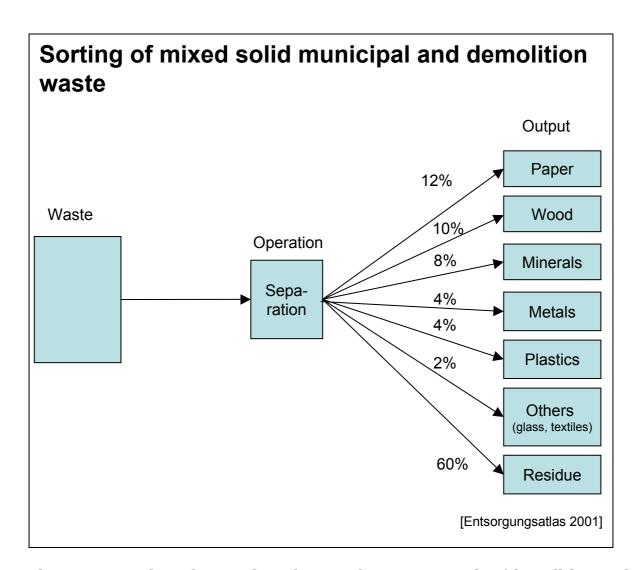


Figure 14: Sorting of non-mineral waste from construction/demolition and municipal solid waste



As other sorting and separation operations the process may be performed with varying efficiency. The output ratio is not fixed and whether output quality standards are met or not depends, inter ail, on the way the operation is carried out (in addition to variations in the composition of the input). In this exemplary process a general characterisation of the process is often not possible.

For all three sorting processes presented there is the problem that, with a classification of the process as non-recovery = disposal operation, the materials disposed of in these plants would be wastes for disposal. these would thus also be subject to the regulations for wastes for disposal as, for example, the tendering responsibility.

A possible option here is the establishment of an annex for "intermediate operations". For the export of wastes to such processes the procedure for disposal operations would, in accordance with the criteria of the WFD, apply. An alternative for this would be the establishment of such an appendix as part of Annex IIB. With this, however, it must be ensured that the Member States have a legal basis to object to such despatch, which correspond with the character of the operation (e.g. objections can be raised if the efficiency of the separation of fractions is lower than that in the own country).

3.2.19 Sorting of EAF slag

A magnetic pulley separates metallic and non-metallic components of the slag. In a subsequent step the slag is crushed into defined size classes.

A speciality of this process is that the slag, in comparison to other mineral substances from sorting processes, displays a constant quality⁵⁷. Thus a general classification of the process would be possible assuming that material produced is actually reclaimed as R5.

As the production of slag does not follow market demand, but is rather independent from steel production, this criterion is to be taken into account particularly. Taking into account this aspect at the level of the process characterisation within the scope of Annex II is, however, methodically difficult as here individual considerations have to take place.

⁵⁷A differentiation, with regard to slag from special steel works and bulk steel works is necessary due to the potentially higher pollutant contents with special steel slag. Slag from ladle metallurgy must in any case be differentiated from the EAF slag dealt with here.



3.2.20 Shredding of metal waste

In the shredding process, complex metal goods are separated into a metal fraction and one or two non-metal fraction(s) (shredder residue or shredder light fraction SLF and shredder heavy fraction SHF).

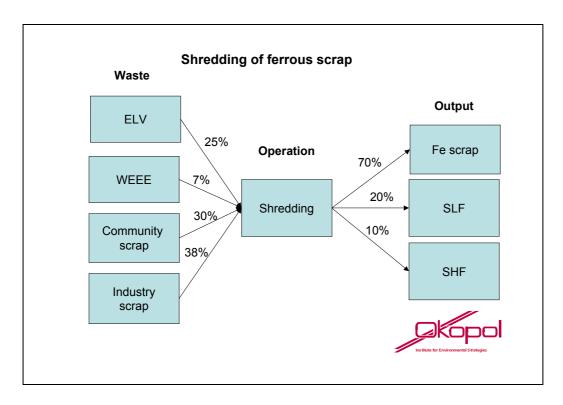


Figure 15: Shredding of ferrous scrap and possible targets of output streams (example)

No substitution of primary raw material takes place within the process. Rather substances are produced through separation steps that can meet the requirement of substitution in the subsequent processes. Viewing the quantitative dominant output metal a characterisation as R 4 "Recycling/reclamation of metals and metal compounds" can take place. A differentiation between processes with which primary raw materials are actually substituted and those with which the potential of substitution exists is not possible using the existing Annex II.

The verification that the metal fraction is actually suitable to substitute primary raw material can be furnished based on various indicators. In fact shredder scrap is traded on the market with positive value and for many years employed in steel works as raw material. The "European Steel Scrap Specification" (ESSS) describes the expected quality characteristic for shredder scrap as Type E40. National standard specifications (e.g. the Austrian "Ö-Norm"), in comparison with this, have a stronger binding character but a regionally limited validity. Agreements between shredders and



the steel works posses the greatest binding character in everyday commercial life. They apply, however, only between the two respective contractual partners.

The requirement that the output of a process has to fulfil certain quality requirements in order that the process can be classified as "reclamation", results implicitly from the objectives of the WFD. A stipulation as to how these requirements have to be structured under waste management aspects of the European Directive is, however, not available. Existing quality descriptions are, to the vast majority, oriented on technical production requirements and take up aspects relevant to waste management only insufficiently (for this see also Part B, summary and conclusions).

Furthermore it is to be taken into account (for example for the calculation of recycling rates of the Packaging, ELV and WEEE Directive), that with this process one is not concerned with a recycling operation in accordance with the judgement in Case C-444/00.

3.2.21 Mechanical separation of waste cables

Cables are cut into pieces and shredded. The separation of plastics and metal is usually carried out using metal separators.

The quantitative ratio of copper to other materials varies significantly according to the range of origins of the cable. While a plant that processes the most varied sorts of cables can achieve copper shares of 60% as an annual mean, the share of copper in cables from activities according to Annex I of the WEEE Directive is often smaller than 40%.

The copper output of a cable dismantler working with the latest state of the art meets the quality requirements of the corresponding European Standard Specification (copper content of 95%-99.9%).

The disposal paths of the residual fraction are manifold. In many cases it will be submitted to final disposal operations as a mixed fraction.

In practice, in Member States, the process is classified as recovery operation, even if the reclaimed copper share is <50%. Fundamental reason for this is that the copper fraction is assigned a higher ecological value. With this, however, no common or systematically derived criterion for the determination of this value exists. Often the price and/or the estimations of the "ecological rucksack" are decisive.

Purely economic approaches (EUR per tonne of reclaimed material) have the disadvantage that price variations with raw materials can influence the characterisation of waste treatment processes. In addition, the prices cannot be equated one-to-one with the ecological burdens of a material.



Up until now adequate criteria have been developed neither at the EU level nor at the level of the Member States. The "Thematic Strategy on Sustainable Use of Resources"⁵⁸ mentions different approaches for the assessment of the environmental burden of materials. It does, however, determine that, up until now, no clear, applicable and comprehensive concept is available (see also the discussion in the section "Recovery of fixer solution").

3.2.22 Hydrometallurgical treatment of electroplating sludge

Hydrometallurgical treatment of electroplating sludge is, for example, precipitation where an acid, alkaline or other solution selectively dissolves certain precious metals and leaves others unaffected. The composition of the sludge depends highly on the production process from which it arose. The desired product and the operations involved to achieve this produce, considerably affect the amount and kind of metals to be found in the sludge.

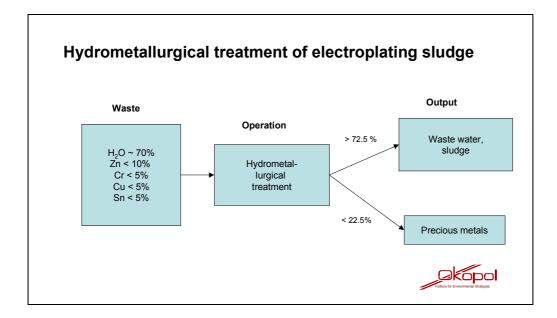


Figure 16: Hydrometallurgical treatment of electroplating sludge

In the example of the hydrometallurgical treatment of electroplating sludge metals are also recovered, however, as opposed to, for example copper from processing cables, they occur in contaminated forms which have an influence on the ecological situation with subsequent recovery. Therefore, with the application of the price crite-

⁵⁸ Towards a Thematic Strategy on the Sustainable Use of Natural Resources COMMUNICATION FROM THE COMMISSION TO THE COUNCIL AND THE EUROPEAN PARLIAMENT COM(2003) 572 final



rion for the characterisation of waste treatment operations, the criterion of the contamination and/or the type of bonding must also be taken into account.

3.2.23 Recovery of fixer solution

Fixer solution waste is treated in an electrolytic reactor. The output of the operation is, on the one hand, a fraction with 60-80% silver content, on the other hand a residue of the fixer solution.

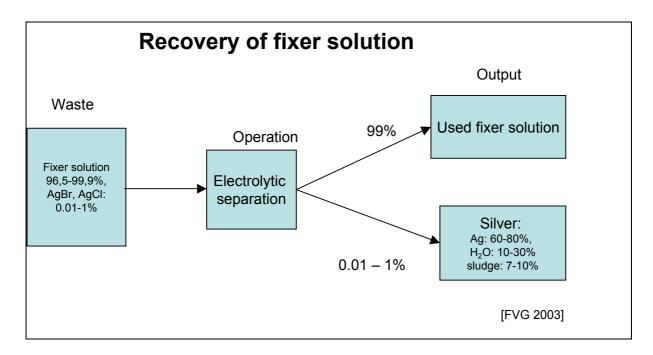


Figure 17: Recovery of fixer solution

Over 99% of the output the waste treatment operation are disposed following additional treatment. As a rule, the process is recognised as recovery process (see above for the dissuasion in connection with the processing of cables).

As long as there is no factor which enables taking sustainability aspects into account, one preliminary possibility is to use the price of the material instead. In this approach, the price of the primary equivalent of the recovered raw material can be taken into account in cases of doubt. Steel respectively ferrous scrap may be taken as a basis for comparison purposes. The price for simple high grade steel is for example between 0.1 - 0.2 EUR/t). For silver the London Metal Exchange (LME) fixing in 2004 is, for example, ca. 140 - 190 EUR/kg. The wholesale price for copper which is comparable with copper from cable treatment in 2004 is ca. 1.4 to 1.6 EUR/kg (see example above for cable treatment).



For both examples described above classification was as recycling process (fixer solution: silver content often below 2%⁵⁹; electroplating sludge: metal content below 20%). A similar procedure would also be possible for the process "multi-step mechanical separation of waste cables", with which copper with high purity is produced.

This procedure would be, however, associated with significantly greater methodical difficulties for materials other than metals.

3.2.24 Multi-step chemical physical treatment of oil-water emulsion for de-emulsification

Oil-water emulsions are separated by different unit operations into a water, a sludge and an oil fraction. The water fraction is usually fed into the municipal wastewater treatment system, the oil fraction is used for combustion and the sludge is disposed of or incinerated.

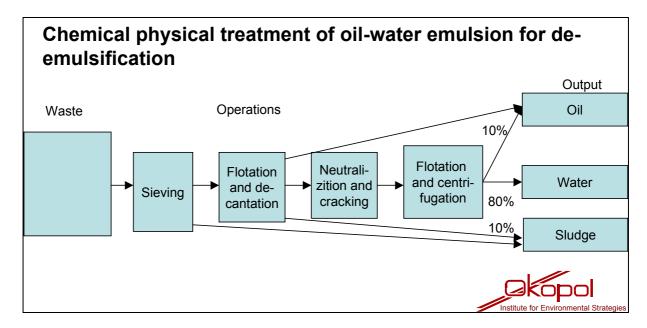


Figure 18: Chemical physical treatment of oil-water emulsion for deemulsification

For the greater part of the output of the process entry D 6 "Release into a water body except seas/oceans" comes into consideration. The combustion of the oil and/or sludge containing oil does not have the character of an utilisation of particularly resources. Therefore, with regard to its characterisation, this process is to be differentiated from the recovery of silver from fixer solution (see above).

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⁵⁹ LME fixing for silver ca. 140 – 190 EUR/kg



Further aspects, for example with regard to the efficiency of the separation of individual substances or the quality of the output (oil content of the water) can therefore remain unconsidered.

From this, taking into account the quantitative criterion, results a characterisation as D 9 "Physico-chemical treatment not specified elsewhere in this Annex which results in final compounds or mixtures which are discarded by means of any of the operations numbered D 1 to D 12 (e.g. evaporation, drying, calcination, etc.)".

A possible alternative would be a classification in a new Annex to be developed for intermediate operations. The WFD, under the keyword "Prevention" in Article 3.1, also mentions such processes with which substances contained in wastes for recovery are separated.

3.2.25 Precipitation of PVC

In the operation as performed by VINYLOOP⁶⁰ soluble parts of the waste are dissolved by solvents. The insoluble parts are separated, for example, by centrifugation or decanting. The dissolved PVC is extracted from the solution by evaporation of the solvent. After centrifugation the PVC is dried and used for tarpaulin and canvas.

The parts separated out during pre-treatment and filtering are incinerated.

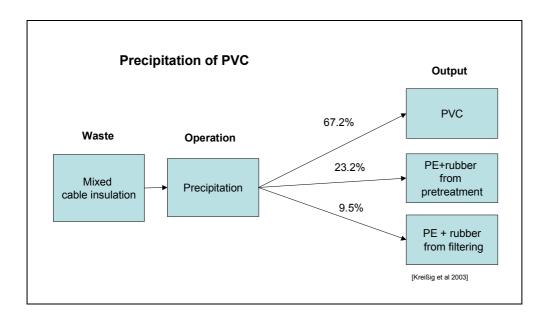


Figure 19: Precipitation of PVC

⁶⁰ [Vinyloop 2003]



With regard to the reclamation of PVC as well as the average quantitative conditions of the output to be expected the process can be characterised as R3 "Recycling/reclamation of organic substances which are not used as solvents (including composting and other biological transformation processes)"⁶¹.

Specific characteristics of the PVC can continue to be used.

A return feed in the production process of PVC takes place principally at the level of pre-production.

3.2.26 Feedstock recovery of PVC

In a waste treatment process operated by RGS90 PVC is broken down chemically and thermally. The output fractions are salt (~40%), oil (~25%) as well as a mineral residue.

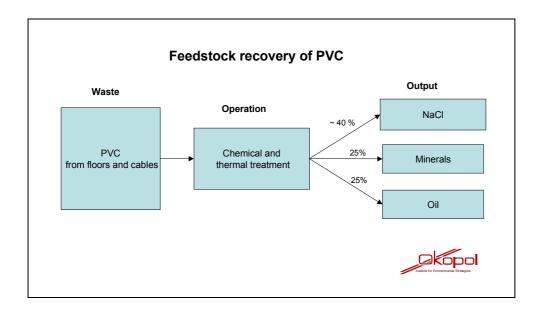


Figure 20: Feedstock recovery of PVC

Here, in comparison with the Vinyloop process, a breakdown into the basic components of PVC takes place. The output could again be added at the raw material level of the production process of the PVC. The oil would be employed as energy carrier in the production processes⁶².

⁶² With regards to its principles the process is similar to the employment of PVC in specially equipped waste incineration plants. There the organic part is combusted, the mineral part removed as grate ash and the chlorine part collected in the off-gas washer and converted to salts. The important difference is that, in the RGS90 process the recovery of oil and its combustion are spatially separated.

⁶¹ Provided the material meets corresponding quality criteria.



With the inclusion of the quantitative share of the output the operation can be characterised as R 5 "Recycling/reclamation of other inorganic materials"⁶³.

The specific characteristics of PVC are lost in the process.

The entries of Annex IIB are not suitable for the representation of the various principles of Vinyloop and RGS90.

A possibility of differentiating within the specified structure of Annex IIB would be the comparison of input and output of the waste treatment operation. Thus, in the example of the VINYLOOP process, organic matter is again reclaimed from organic material. In the case of the RGS90 process inorganic matter is recovered from organic matter if one considers the PVC as complete substance. If one refers the classification to the components of the PVC, then a combination of R3 (organic components of PVC to oil) and R5 (chlorine to sodium chloride) would be available.

3.2.27 Chemolysis of polyurethane

The molecular chains of polyurethane are split into a mixture of polyalcohol, and low-molecular urethanes are filtered out.

Different to the RGS90 process for PVC with chemolysis, organic molecules are recovered polyurethane.

Provided that appropriate quality requirements are met the process can be characterised as R3 (Reclamation of organic substances). A differentiation to material recycling of polyurethane in this case is also not possible with the existing Annex II.

3.2.28 Grinding of polyurethane

In this waste treatment operation polyurethane is ground and unwanted substances are removed.

Under the assumption that appropriate quality requirements are fulfilled a characterisation as R3 can also take place here. If quality requirements are not met the operation might be characterised as non-recovery operation in a new Annex.

⁶³ Here also the prerequisite applies that corresponding quality criteria have to be met.



3.2.29 Use of photochemical waste for SNCR

Spent fixer solution and spent developer solution pass several treatment unit operations and are subsequently used to reduce nitrogen oxide from off-gases for example in the cement industry or in waste incinerators (selective non-catalytic NO_x reduction (SNCR)).

In the operation the treated original waste substitutes other ammonium solutions. However, with this operation it is permanently removed from production cycles. Additionally, no reclamation of raw materials takes place. A characterisation for example as R5 free of doubts would not be possible.

A suitable formulation of an appropriate entry in this case would emphasise the fact of "application" or "use" of the waste instead of recycling or reclamation.

3.2.30 Drying of sewage sludge

Sewage sludge from industrial or municipal wastewater treatment is mechanically dewatered e.g. by decantation, presses and extruders.

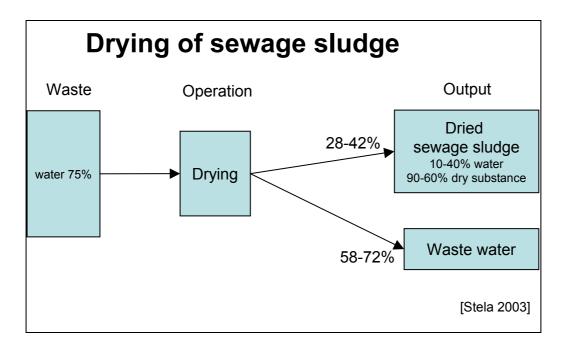


Figure 21: Drying of sewage sludge

With the dewatering of sewage sludge there is no determination of the subsequent recovery or disposal path. A characterisation as an R operation is therefore not possible. According to the systematic applied a classification as non-recovery operation would have to take place. In the existing Annex II there would only be a possibility for this through a characterisation as disposal operation of Annex IIA (D9) (see also Para. 4.12 and 4.13).



3.2.31 Mechanical soil cleaning

Contaminated soils are cleaned by washing and separation. In the first case the contaminants are dissolved or suspended in the washing agent which is subsequently treated by conventional wastewater treatment operations. In the second case, the contaminants are concentrated in a smaller volume of material by separating fine particles⁶⁴. The technology is applicable for different types of contamination such as, for example, heavy metals and organic substances.

Within this operation no primary raw materials are substituted. The three examples described on page 151 of the technical annex show that, depending on the contamination and the particle distribution of the input waste and the performance of the operation, the contamination of the output differs largely. In fact, due to costs reasons, soil cleaning is performed generally only in those cases where it is possible to recover a part of the output.

With organic material a characterisation as R 3 and with inorganic material as R5 could take place. However, here the question of the output qualities appears to be problematic. This is not defined uniformly across Europe. Here, as in other cases described (see above), with those wastes which are processed for employment in the biosphere, it is to be taken into account that an interlinking of waste management and requirements based on protected assets (e.g. soil protection, groundwater protection) up until now has been insufficient only. Furthermore, in some countries waste treatment paths exist which are classified as recovery with which even increased pollutant contents are accepted (e.g. as landfill construction material or for the covering of landfills).

Different to the employment of contaminated soil in cement works, specific characteristics of organic material can be used following a mechanical soil treatment.

With inorganic material there is no similar differentiation between the cement works disposal path and mechanical processing of soil.

⁶⁴ Contaminants are bound to the particle surface. By extracting the fine particles with its large surface per volume unit a reduction of the concentration in the remaining fraction can be achieved.



3.2.32 Mixing/blending of hazardous waste

Hazardous waste is mixed and blended to achieve certain physical and chemical characteristics. The output is a mixed and blended hazardous waste that meets client requirements for co-combustion operations.

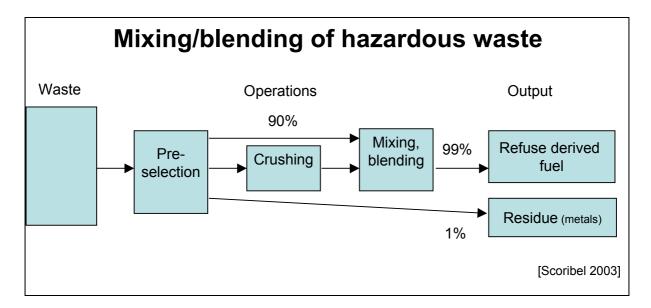


Figure 22: Mixing/blending of hazardous waste

No primary raw materials are substituted in the process.

If, in the future, the output material meets the requirements of the European Standard⁶⁵ (which, for example, can emerge from the work of CEN TC343), then a characterisation as R3 (or R5 in the case, for example, of mineral wastes) would be conceivable within the sense of the procedure in the other example cases.

Article 1 (b) of the WFD inter alia emphasises, that the mixing of wastes can lead to new wastes:

"'producer' shall mean anyone whose activities produce waste ('original producer') and/or anyone who carries out pre-processing, mixing or other operations resulting in a change in the nature or composition of this waste;"

Whether with this process one is concerned with a quality-assured material which posses to a sufficient degree the potential for the substitution of primary raw material can be decided in the individual case only.

⁶⁵ Such a standard must take into account ecological aspects to a sufficient degree. For this see also Part B of this study.



If a secondary fuel is created in the process then an extensive examination appears sensible into the example for each individual fraction which must meet the respective recovery requirements⁶⁶.

3.2.33 Dismantling/depollution of ELV

According to the ELV Directive depollution by removal of components which contain hazardous substances is mandatory for all ELV.

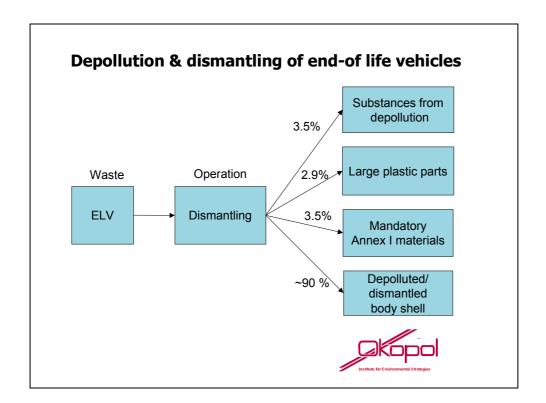


Figure 23: Dismantling/depollution of ELV

Disposal operations are undertaken with this treatment process. These are to be evaluated in connection with Article 3, Para. 1 of the WFD.

"Member States shall take appropriate measures to encourage:

- the development of appropriate techniques for the final disposal of dangerous substances contained in waste destined for recovery". [WFD Art. 3.1]

Such a solution is in the existing Annex II not systematically reproducible.

⁶⁶ Further existing requirements under waste law such as, for example, the ban on mixing wastes must, in any case, be observed.



A possible option would be the expansion of Annex IIA by an appropriate entry ("Treatment operations, where dangerous substances are removed from waste destined for recovery"). Otherwise the process could be viewed as integral part of the subsequent recovery and/or treatment process. Though with this the problem would arise of having to take into account treatment chains for the evaluation of a process.

With regard to the export of wastes the first option appears advantageous, especially if one is concerned with red-listed waste with vehicles which have not had their hazardous material removed. For the calculation of the recovery quota of the ELV Directive there is, due to the specific definitions of the Directive, no difference, so long as with the first option no finalised recovery is assumed. The consequences for the approval of dismantling firms as disposal plant appears problematic if the process would be characterised as non-recovery = disposal operation.

3.2.34 Removal of hazardous substances from waste fridges

Hazardous substances such as chlorofluorocarbons (CFC) or hydrochlorofluorocarbons (HCFC) are extracted from the cooling system. Hazardous substances are extracted from the foam and captured.

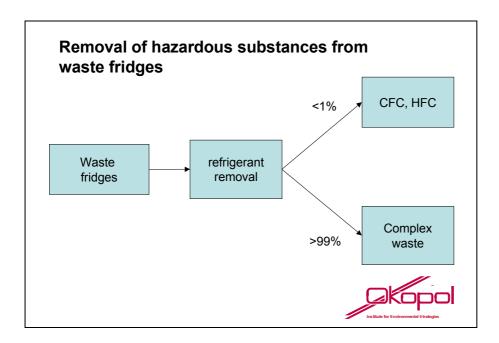


Figure 24: Removal of hazardous substances from waste fridges

The observations made in connection with the removal of hazardous materials from ELV apply analogously for this process.



With the background of the export of wastes it is of significance, precisely with the disposal of refrigerator equipment, that certain standards are met⁶⁷. The classification of such processes as D – processes of Appendix II allows the shipping country considerable possibilities for objection.

3.2.35 Cap-cutting of gas discharge lamps

After cutting off the caps of the gas discharge lamps the mercury and luminescent substances is blown out by compressed air.

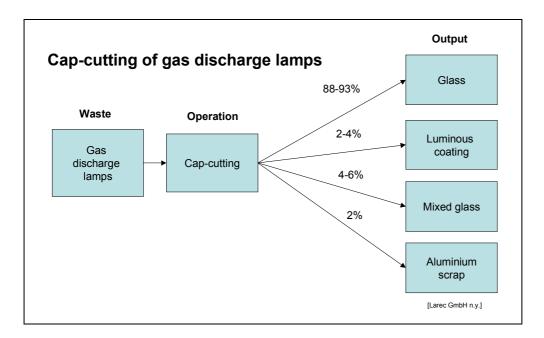


Figure 25: Cap-cutting of gas discharge lamps

While with both of the last-mentioned processes the output has to pass through further treatment before primary raw materials are actually substituted, with this process the utilisation of the output can take place without further treatment steps. The recovery chain, corresponding with Option 2 in Section 3.2.33, which is to be considered, would thus be shorter here and no further breaking down of the output in the sub-stream would take place. A corresponding characterisation of the process as R5 appears, however, as impractical for systematic reasons as, through this, numerous process-specific regulations would be necessary.

⁶⁷ The background is not the least that the question of whether all essential substances are actually removed and correctly disposed of can be checked only with great difficulty.



3.2.36 Storing of gypsum from off-gas cleaning

Flue gas desulphurisation gypsum (FDG) is stored in separate areas before being sold for the production of wallboard and/or cement.

The Landfill Directive 99/31/EG excludes sites as being landfills if they store waste prior to recovery for less than three years or prior to disposal for less than one year⁶⁸. The period can only be applied if FDG is considered as waste until it is actually used. The waste shipment regulation 259/93/EEC states in different articles that the "consignee has to provide as soon as possible and no later than 180 days following the receipt of the waste a certificate to the notifier that the waste has been either disposed of [...] or recovered in an environmentally sound manner."

A characterisation of the operation as either R13 or D 15 can only be carried out, if sufficient certainty exists with the type of subsequent process. This certainty does, however, exist in many cases.

Therefore it is possible that, as a rule, a characterisation as D15 takes place. If, in the individual case, it is verified that the requirements corresponding to R 13 are fulfilled, a classification as recovery is possible. This verification can above all be produced if one is concerned with a material with stable, positive market value.

3.2.37 Neutralisation of waste acids

In this operation different waste acids are mixed and neutralised. The input of the operation is waste acids and bases (e.g. sulphuric, hydrochloric, hydrofluoric, phosphor and nitric acids, calcium hydroxide, soda and ammonia).

⁶⁸ "storage of waste prior to recovery or treatment for a period less than three years as a general rule or storage of waste prior to disposal for a period less than one year"



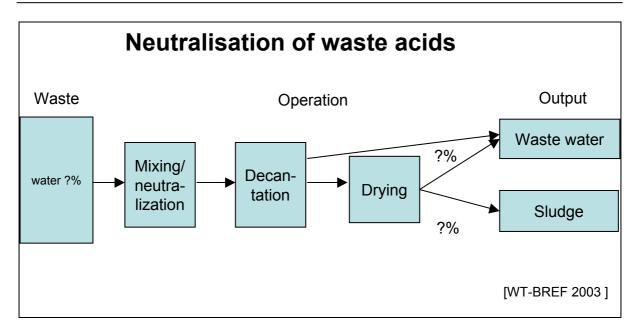


Figure 26: Neutralisation of waste acids

The output of the process can be combined in numerous ways depending on the input. A general classification as recovery operation is therefore not possible. The processes for neutralisation of acids actually carried out in Europe in many cases aim at the final disposal. Therefore it appears sensible to characterise the process generally as D 9 "Physico-chemical treatment not specified elsewhere in this Annex which results in final compounds or mixtures which are discarded by means of any of the operations numbered D 1 to D 12 (e.g. evaporation, drying, calcination, etc.)". If, in the individual case, it is verified that recovery operations take place a corresponding classification can be undertaken.

3.2.38 Landfilling of mixed solid waste

Waste is permanently stored on authorised areas (fenced in, geological barrier, gas drainage layer, water drainage layer), compacted and finally covered with a top soil cover (soil or impermeable material).

In accordance with the quantitative criterion presented this process can, without doubt, be classified as D 1 "Deposit into or onto land (e.g. landfill, etc.)" or D 5 "Specially engineered landfill (e.g. placement into lined discrete cells which are capped and isolated from one another and the environment, etc.)" respectively.



3.3 Summary and conclusions

Selected waste treatment operations⁶⁹, for which there could be ambiguity in their classification in a disposal and/or a recovery entry, were chosen in order to identify criteria that could help differentiating between competing entries. The following table provides an overview of the results separated by treatment operations. In order to take interdependencies between the criteria and options into account⁷⁰, sections 3.3.1 to 3.3.9 summarise the results and conclusions in a more comprehensive view. Main aspects of those sections are:

- system boundaries,
- · substitution of primary raw materials,
- function of the characterisation,
- mass aspects,
- quality requirements,
- combined mass and quality requirements,
- systematic differentiation of recovery options,
- steering of waste.

The following table gives an overview of the findings in section 3.2. In order to enhance readability criteria, which are relevant for more than one operation are not repeated every time.

Table 9: Overview of results

Operation	Ambiguity	Criteria, options, comments
Scrap in EAF	no	differentiation between reclamation operations (e.g. generation of shredder scrap) and recycling operations is not possible with entry R 4
Fibre reinforced plastics in cement kilns	classification as either energy re- covery or material recovery	 classification as combination of R1 and R5 where possible (depending on the function o the classification); classification according to the composition of the waste (relation of combustible and non-combustible parts) or the effect of the waste in the operation (e.g. net calorific output) if a classification as either R1 or R5 is necessary; process orientated classification according to ECJ judgement in Verol/Sita case, where appropriate
Smelting of lead acid batteries	classification as either energy re- covery or material recovery	 setting of system boundaries according to plant limits classification as combination of R1 and R5 where possible (depending on the function o the classification); waste orientated classification according to the composition of the waste (relation of combustible and non-

 $^{^{69}}$ Other than operations R1 and D10 – see scope of the study in section 1.

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⁷⁰ Vorgriff und zu kompliziert für Fußnote



Operation	Ambiguity	Criteria, options, comments		
	. 5 5	combustible parts) if a classification as either R1 or R4		
		is necessary		
Feedstock recovery in blast furnaces	no appropriate entry (R1, R3)	 new entry (combined with a restructuring of Annex IIB) balancing aspects for a characterisation as either R1 or R3 if existing entries shall be kept (in this case 'reclamation' must be interpreted very wide) 		
Gasification at 'Schwarze Pumpe'	ambiguity in finding an appropriate entry	 setting of system boundaries decisive for characterisation as R3 or R5 energy recovery as a first process step when unit operations are differentiated application of mass aspect (predominant part of the waste is recovered as material) differentiation between 'recovery via decomposition' and 'direct recovery without decomposition' not possible with entry R3 		
Recovery of spent acids	R5, R6	differentiation according to the level of re-introduction into production process or the direct use after treatment is possible within given Annex IIB		
Recovery of catalysts	no appropriate entry for regenera- tion of catalysts (R3, R4, R5, R8)	 additional entry parallel to entry R6 restructuring of Annex IIB (e.g. entry for regeneration operations) 		
Distillation of organic solvents	mass aspects	 characterisation according to share of recovered solvent (case by case) developing method reflecting the ecological 'value' ('eco-value factor') of the recovered material and adapting the mass criterion by this factor 		
Composting of native organic solid waste	quality of the out- put	 combining entry R3 and entry R10 developing harmonised quality requirements which must be fulfilled for a characterisation as R3 (reclamation) 		
Mechanical biological treatment	quality of the output	 focussing on single operations instead of treatment chains (where appropriate) and using the quality of the out as decisive criterion developing harmonised quality requirements which must be fulfilled for a characterisation as R3 (reclamation) new Annex for non recovery operations, which are not final disposal operations 		
Digestion	different output streams	 application of the mass criterion (characterisation with regard to materials with a mass relevance >50%) differentiation of the use of specific and unspecific properties of the waste/material application of harmonised quality requirements 		
Use of sewage sludge on agricul- tural areas	quality require- ments; aspects of soil/water protec- tion	 developing harmonised quality requirements for output of digestion operations harmonise waste management requirements and soil/water protection 		
Filling of mines	balancing diverging aspects; missing entry in case of recovery	 developing quality requirements on EU level for materials appropriate for substitution of primary raw materials in this operation new entry taking into account both aspects (substitution of primary raw material and permanent removal of material from material cycles) restructuring Annex II taking into account a differentiation between the use of specific and unspecific properties of the material 		
Treatment of	differentiation of	taking into account a differentiation between the use of		



Operation	Ambiguity	Criteria, options, comments
cathode ray tubes	different types of	specific and unspecific properties of the material (possi-
	recovery operations	bly combined with a restructuring of Annex II)
Treatment of	mass and quality	apply combined mass and quality criteria
contaminated	aspects	4,100
garage waste		
Sorting of mineral	quality aspects;	developing harmonised quality requirements for use of
waste	aspects of	mineral waste as construction material
	soil/water protec-	harmonise waste management requirements and
	tion	soil/water protection
		new Annex for non recovery operations, which are not
		final disposal operations
Sorting of mixed	quality aspects	developing harmonised requirements for sorting output
non-mineral	1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1	with regard to the recovery type 'reclamation'
wastes		new Annex for non recovery operations, which are not
		final disposal operations
Sorting of EAF	actual fate of the	take actual fate of the output of waste treatment opera-
slag	output	tions into consideration if there is not constant positive
5		market value for that material
Shredding of	quality require-	developing quality requirements for material from rec-
metal waste	ments	lamation operations
motal Wasts	I I I I I I I I I I I I I I I I I I I	differentiation of entries for recycling and reclamation
		operations
Recovery of fixer	mass aspects	developing a method for applying an 'eco-factor' reflect-
solution	mass aspects	ing the ecological 'value' of a reclaimed material
Physical-chemical	mass aspects	application case for an 'eco-factor' and a differentiation
treatment of oil-	mass aspects	between the use of specific and unspecific material
water emulsions		properties in subsequent recovery steps
Water cirialsions		new Annex for non recovery operations, which are not
		final disposal operations
Precipitation of	distinction of differ-	restructuring of Annex IIB based on a systematic differ-
PVC	ent types of recov-	entiation of recovery paths
	ery	Citation of recording patric
Feedstock recov-	quality aspects,	comparison of input and output of recovery operations
ery of PVC	distinction of differ-	(organic input to inorganic output) only applicable if
.,	ent types of recov-	PVC as a whole is taken into consideration (instead of
	ery	the organic and inorganic components)
		differentiating between the use of specific and unspe-
		cific properties
		restructuring of Annex IIB based on a systematic differ-
		entiation of recovery paths
Chemolysis of	distinction of differ-	restructuring of Annex IIB based on a systematic differ-
polyurethane	ent types of recov-	entiation of recovery paths
	ery	, , , , , , , , , , , , , , , , , , , ,
Grinding of poly-	quality aspects	development of harmonised quality requirements
urethane	133, 359000	and the state of t
Use of photo-	no appropriate	include entry emphasising the 'use' or 'application' of
chemical waste	entry	waste properties in a process
for SNCR		
Drying of sewage	missing determina-	new Annex for non-recovery operations which are not
sludge	tion of subsequent	final disposal operations
-:2090	operation	harmonised quality requirements for the application of
		sewage sludge
Mechanical soil	quality aspects,	application of combined mass/quality requirements
cleaning	mass aspects,	differentiation between the use of specific and unspe-
	soil/water protec-	cific properties of the output
	tion	new Annex for non-recovery operations which are not
	1	Annex to her recovery operations which are not

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Operation	Ambiguity	Criteria, options, comments	
		final disposal operations	
Mixing/blending of hazardous waste	mass aspects	 application of combined mass/quality requirements new Annex for non-recovery operations which are not final disposal operations 	
disman- tling/depollution of ELV	missing entry	new Annex for non-recovery operations which are not final disposal operations	
Removal of haz- ardous sub- stances from waste fridges	missing entry	new Annex for non-recovery operations which are not final disposal operations	
Cap-cutting of gas discharge lamps	quality require- ments, missing entry	 development of quality requirements for glass output for the EU new Annex for non-recovery operations which are not final disposal operations 	
Storing of gyp- sum	missing evidence for recovery	applying as general rule entry D15 and as exception R13 if recovery within the timeframe is proven	
Neutralisation of waste acids	uncertainty about subsequent opera- tion	 characterisation according to fate of the output as long as quality requirements and market / price aspects with regard to the output do not deliver sufficient evidence for subsequent recovery operations applying general rule (D9) and exception (R5 if appropriate) if recovery is proven 	
Landfilling of mixed solid waste	-	-	



3.3.1 System boundaries

The example of the TwinRec process (see text box) illustrates the relationship between the characterisation of the operation and the setting of system boundaries.

If system boundaries are set according to the plant limits, a complete oxidation of the organic compounds takes place. If the unit operation describes the system boundaries, then the output is an energy-rich gas and slag.

TwinRec Process

Shredder Light Fraction is introduced into a fluidised bed gasifier in the presence of little oxygen and heated to about 580°C. Ferrous and non-ferrous metals and large inert materials are separated and a combustible gas is produced. Due to the low temperature within the gasifier and the reducing atmosphere metals are not oxidised. The organic material breaks down into shorter hydrocarbons in the gasifier. The produced gas is combusted in a subsequent cyclonic combustion chamber at temperatures between 1350°C to 1450°C and

Neither the WFD nor any other waste regulation defines the term "operation" and currently there is no consistent setting of the system boundaries for waste treatment operations.

The examples analysed in this study show that a sensible setting of the system boundaries is best if these are closely oriented to the plant limits. This also corresponds best with the characterisation of recovery and disposal operations as it is done in day-by-day practice.

3.3.2 Substitution of primary raw materials

The substitution of primary raw materials represents the lead criterion for the characterisation of waste treatment operations in the WFD and the judgements of the ECJ. Here, with the analysed operations, it can be differentiated between

- operations in which this substitution actually takes place (as a rule these are production processes) and
- operations producing materials, which have the potential for the substitution of primary raw materials.

With the background of characterisation of waste treatment operations at the level of the European Union it is concluded that this potential can be verified only if quality requirements are met which are accepted EU-wide (see below "Quality requirements").

Consequently, all other processes which do not meet these requirements have to be characterised as non-recovery operations. The existing Annex II offers only the pos-



sibility to classify them as disposal operations⁷¹. In many cases, this does not seem to be appropriate.

In addition final disposal as a 'function' of waste treatment operations e.g. according to Article 3.1 of the WFD cannot be covered in an appropriate way with the existing Annex IIA.

Recovery of wastes often takes place in multi-step process chains. A characterisation of the individual process elements within such a chain regularly presumes that the complete chain is considered. In practice, however, this is often not or only with great efforts possible, due to the fact that no clear compelling determination of the subsequent waste treatment operation takes place from the composition of the output substances. Furthermore, Annex II of the WFD is directed at the characterisation of individual operations and not of chains. Therefore, in the analyses undertaken, the processes were considered individually.

With this background possible options with regard to a potential review of Annex II of the WFD are:

- a) Following operations are assigned to Annex IIB;
 - operations where primary raw materials are actually substituted,
 - operations producing raw materials, which meet harmonised quality criteria for the substitution in subsequent processes.
 - All other operations are assigned to Annex IIA. This option, however, appears problematic as, for example, the approval situation of many waste treatment plants would change as pre-treatment processes would also then have to be approved as disposal operations.
- b) All operations, which do not meet the 'substitution' requirements but are not independent disposal operations, will be assigned to a new Annex IIC. The operations of this new Annex IIC will be characterised in accordance with the respective application context (see section 3.3.3). This option presumes amendments to the text of the WFD. The strength of this procedure would be that the operations could often be characterised without the need to evaluate subsequent steps of the recovery chains.
- c) In Annex IIB an entry for intermediate operations before recovery will be used⁷². In order to be able to assign operations to this R-entry, the respective subsequent processes must be taken into account. Like this numerous opera-

⁷¹ See also chapter 3.1 – ECJ case 6/00

⁷² To some extent in accordance with Entry D9 of Annex IIA. This option, however, would not be systematically completely unproblematic as, with this, processes would be assigned to Annex IIB, which do not meet the lead requirement of the WFD on recovery (substitution of primary raw materials).



tion <u>chains</u> instead of individual operations would need to be considered. In accordance with this option, chains have to be defined and characterised (may be differentiated by the context or the function of the characterisation e.g. for the export of wastes). In addition to this, the necessity arises to control whether the wastes are actually going the route, which was the basis for the characterisation.

3.3.3 Function of the characterisation

Annex II of the Waste Framework Directive (WFD) and the characterisation of waste treatment operations either as 'R'- or 'D'-operations links very different areas of waste management. Those are for example the export of wastes, the approval of waste treatment plants, the responsibility of public authorities and, to some extent, the calculation of recovery and disposal quotas. There are, nevertheless, very different contexts, substantiation, and objectives in the given areas. Linking various functions through the assignment to an entry in the Annex of the WFD is a significant obstacle for a characterisation of waste treatment operations.

A possible future development could be a legal disentanglement of the codes of practice. With this, for example, the reference between the WSR and Annex II of the WFD would be rescinded and Articles 9 and 10 of the WFD would be amended with regard to the approval of plants, as well as Article 5 with regard to the responsibility of public authorities. Waste treatment operations of a possible Annex IIC (see above) could, for example, be treated as recovery operations in connection with the approval of plants and, in connection with the export of wastes, the mechanisms for disposal operations could be applied⁷³. Then, for example, if the removal of hazardous wastes from ELV were to be characterised as non-recovery operation and thus as disposal, ELVs would not automatically fall within the area of responsibility of the public authorities.

Relations not dealt with in the WFD such as the calculation of recovery quotas of the Packaging, ELV and WEEE Directives should not be linked with the characterisations of Annex II. The objectives of the directives as well as the structure of the instrument of the recycling quotas are much more to be considered if the process is evaluated according to its actual technical properties (e.g. D-functions and various R-operations are taken into account as parallel elements of a waste treatment operation).

⁷³ This appears to be sensible not least because the question of the necessary balance between positive aspects of waste imports (import of secondary raw materials) and negative aspects (inherent risks of the waste) cannot be decided on the basis of these processes.



3.3.4 Mass aspects

In the investigated cases only a more or less larger part of the waste is actually utilised. The remaining parts are either destroyed or separated and therefore treated according to the principle of disposal.

In most cases a characterisation of the operation is accomplished considering the quantity relevance of the respective components. As a rule, the requirement is based on a share > 50%. Here a common view of a minimum share is not present.

The examples of the recovery of silver from fixer solutions and the recovery of metal from electroplating sludge show the problems of a common quantity threshold. The operations are classified in Member States as recovery operations although, in most cases, significantly less than 10% of the original waste is actually reclaimed as raw material. Discussions with Member States show that often the (economical, but also ecological) value of the reclaimed metal is decisive for this. Clearly defined criteria do not exist. Purely economic approaches (EUR per tonne of recovered material) have the disadvantage that price variations with raw materials can influence the characterisation of waste treatment operations. In addition, the costs cannot be equated one-to-one with the ecological burdens of a material.

These two examples show the necessity of developing a factor for the characterisation of waste treatment operations which should be oriented to ecological burden of a product or raw material describing the ecological 'value' of a material. Until now, such a factor has been developed neither at the level of the European Union nor at the level of the Member States. The "Thematic Strategy on Sustainable Use of Resources" mentions different approaches for the assessment of the environmental burden of materials. Until now, a clear, applicable, and comprehensive concept is not determined. Therefore, within the scope of the study, the price of the primary equivalent of the reclaimed raw material was taken into account as preliminary alternative in cases of doubt⁷⁵. Both described examples are therefore classified as reclamation operation (fixer solution: silver content often below 2%⁷⁶; electroplating sludge: metal content below 20%). A similar procedure would also be possible for

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⁷⁴ Towards a Thematic Strategy on the Sustainable Use of Natural Resources COMMUNICATION FROM THE COMMISSION TO THE COUNCIL AND THE EUROPEAN PARLIAMENT COM(2003) 572 final.

 $^{^{75}}$ E.g. through comparison of the price with simple high grade steel (ca. 0.12 - 0.16 EUR/t). This procedure is, however, associated with significantly greater methodical difficulties for materials other than metals.

 $^{^{76}}$ LME fixing for silver ca. 140 – 190 EUR/kg.



the operation "multi-step mechanical separation of waste cables", where copper with high purity is produced.⁷⁷.

It may be sensible to apply such an 'eco-value' factor also with the effect of raising the minimum requirement for the reclaimed portion above the general 50% value. For example, if only unspecific characteristics of the waste were utilised.⁷⁸.

Several waste treatment operations combine energy recovery and material recovery. For some purposes, there is a need to assign those operations to one of those principles. In line with the approach applied for the distinction between recovery and disposal the relation between components for energy recovery and components for material recovery in the original waste⁷⁹ is proposed as decisive criterion.

3.3.5 Quality requirements

For reclamation, for example according to the entries R3 to R5, it is decisive which materials are seen as secondary raw materials.

The examples "composting of separately collected native organic wastes" as well as "mechanical-biological treatment (MBT) of mixed wastes" can be used for illustrative purposes:

- in the case of the composting of separately collected native organic wastes a
 quality compost can be produced which is suitable for application as nutrientrich soil improver. Quality standards for such compost have, up until now,
 been elaborated at national level. A characterisation of the operation at European level based on the adoption of those existing standards is problematic as
 the standards in the Member States are in part different.
- the mechanical-biological treatment of mixed wastes is carried out with the aim of reducing the biological activity⁸⁰, to process the waste for a thermal

⁷⁷ Wholesale price ca. 1.4 to 1.6 EUR/kg. In the selected case the copper content of the cable was admittedly greater than 50%. Therefore there was already a classification as recycling process due to this part, independent of the whereabouts of the cable sheathing.

⁷⁸ Unspecific characteristics are considered to be characteristics which can also be met by numerous other sufficiently available substances (e.g. in cases where solely the volume of the material is used). For this see also below "Systematic differentiation of recovery options".

⁷⁹ in case of reclamation operations the output of the operation

⁸⁰ As a rule with the aim of subsequent landfilling.



treatment or for energy recovery. Quality standards for secondary fuels are currently being elaborated at CEN level⁸¹.

In both cases the process principles are very similar. The output, however, varies considerably. In the first instance, there is the possibility of taking into account the process as well as the input composition for the characterisation of the process. This would, however, lead to a very great number of different classifications.

Within the concept proposed, the characterisation of reclamation operations is, as a general rule, oriented to the composition of the output. An operation can then be classified as **reclamation** of secondary raw material if the major part of the output of the operation meets quality requirements, which are recognised within the European Union as secondary raw materials. In some waste treatment operations a major output is not identifiable (see for example VWSicon process, in which, in the respective process steps sub-quantities <50% are separated for the final recovery operation). In these cases the process-specific peculiarities can best be taken into account if the overall process chain is considered⁸².

With regard to quality aspects and the use of waste in production processes, it is proposed to take specific process conditions into account. In the exemplary case of feedstock recovery, applied wastes may have compositions through which, overall, no improvement of the total efficiency of the process is achieved⁸³. In order to prevent too detailed regulations a combination of waste quality requirements and operation characteristics is seen as most efficient (e.g. wastes must possess qualities which lead to an actual substitution of primary raw materials in the specific operation; see also the section "General legal aspects").

3.3.6 Combined mass and quality requirements

The example "sorting of garage waste" shows the need to combine mass aspects with quality requirements when waste treatment operations are to be characterised. In this exemplary operation almost arbitrary degrees of separation can be carried out in regular sorting processes. An orientation exclusively on the share of individual output fractions would, for example, open up the possibility of taking over the nonmetallic parts with the steel fraction and thus change the output relation. It also becomes apparent, that a reliable characterisation of waste treatment operations is

⁸¹ CEN TC 343 Solid Recovered Fuels.

⁸² See also the chapter "Substitution of primary raw materials" regarding the consideration of the various functions of the characterisation of recovery operations and the inclusion of intermediate operations

⁸³ The incentive for the operator to use waste results from the extra payments for the employment of waste.



best possible if only the output fractions, which meet the appropriate quality conditions, are taken into account.

3.3.7 Systematic differentiation of recovery options⁸⁴

The analysis of waste treatment operations covers inter alia different types of operation for the treatment of plastics:

- the mechanical processing and recycling,
- the breakdown of the plastic at molecular level (e.g. feedstock recovery in the gasification of the "Schwarze Pumpe" recovery centre),
- the utilisation of the chemical energy of the plastic for the reduction of ores (feedstock recovery in blast furnaces).

If one considers that feedstock recovery in blast furnaces is not included in Entry R1, all three operations can be allocated in the existing Annex II only to Entry R3 "Recycling/reclamation of organic substances which are not used as solvents". A differentiation by type of operation is not replicable.

This would be possible if the reintroduction of the waste into production processes would be differentiated between various levels⁸⁵. Taking into account the framework character of the WFD, a schematic rough differentiation which simply covers three stages is recommended:

⁸⁵ The feed back of wastes into the production cycle can take place directly or a raw material is reclaimed which can be fed back into the production cycle.

⁸⁴ As stated above energy recovery and thermal treatment are not within the scope of this study.



- Final product (In most of the cases this means that the wastes are re-introduced into the cycle at the same level as that from which they originate.),
- II. Pre-product,
- III. Raw material (from which pre-products are produced).

Final Product

Pre-Product

Raw material

Production process

Regeneration and the decomposition of acids have been investigated with regard to the recovery of ac-

ids. With regard to the described levels a clear distinction can be made:

In the first case the acids are reclaimed as acids without breakdown of the molecules. In the second case raw materials for the production of acids are generated. The existing Annex II already differentiates in both types of operation:

- R 6 Regeneration of acids or bases
- R 5 Recycling/reclamation of other inorganic materials

The above listed differentiation is oriented to production processes. A further differentiation can orient itself on waste characteristics:

- a) processes which utilise specific characteristics of the waste
- b) processes which utilise unspecific characteristics of the waste

Characteristics are seen as specific, if only this material or few others possess them. Unspecific characteristics are, for example, the volume or the energy content.

Further differentiation may be sensible in specific cases. Additionally, the analysis of the waste treatment operations shows that the employment of differentiation with some processes has to be adjusted case-specific. However, in order to keep the framework character of the WFD, another regulation level is proposed for this.

The following table applies the above described differentiation in simplified form onto the processes investigated. Here the potential utilisation of the operation output in the subsequent processes - as far as necessary - is included.



Table 10: Characterisation of waste treatment operations

Operation	Level of use of	Used waste
	waste	characteristics
Scrap in electric arc furnaces	II	a
Fibre reinforced plastics in the cement industry	III	b
Smelting of lead acid batteries ⁸⁶	II	а
Feedstock recovery in blast furnaces	III	b
Gasification at the "Schwarze Pumpe" recovery centre	III	b
Regeneration of catalysts from the petro-chemical industry	I	a
Recovery of spent acids	II	
Regeneration of spent acids	I	a
Recovery of catalysts	II	a
Regeneration of catalysts	I	a
Distillation of organic solvents	I	a
Composting of native organic solid waste	II	a
Mechanical-biological treatment of mixed solid waste	III	b
Anaerobic digestion (with subsequent use on agricultural areas)	II	a
Use of sewage sludge on agricultural areas	II	a
Filling of mines	III	b
Recycling of cathode ray tubes	II	a
Treatment of oil-contaminated garage waste including oil filters	III	b
Sorting of mineral waste from construction and demolition	II/I	b
Sorting of non-mineral waste (where characterised as R3)	III	b
Sorting of EAF slag	II	b
Shredding of metal waste	II	a
Mechanical separation of waste cables	II	a
Electrolytic regeneration of fixer solution	II	а
Hydrometallurgical treatment of electroplating sludge	II	a
Chemical-physical treatment of oil-water emulsion	II/III	b
Precipitation of PVC	II	а
Feedstock recovery of PVC	III	b
Chemolysis of polyurethane	II	а
Grinding of polyurethane	II/I	а
Mechanical soil cleaning	II	a

With such an newly structured Annex IIB, the substance-related differentiation (e.g. in entries R3, R4 and R5) could have less significance. The differentiation according to the level of re-introduction into production processes would be emphasised instead.

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⁸⁶ Characterisation based on mass relevance of lead and lead compounds



3.3.8 Steering of waste

The exemplary operation of the recovery of cathode ray tubes (CRT) illustrates the problem of the steering of wastes into priority waste treatment routes. Two possible paths were investigated:

- Panel glass of cathode ray tubes⁸⁷ can be recycled to new panel glass after the separation from the cone glass.
- Cathode ray tubes can, be used for the filling of mines after shredding.

While, in the first case, recycling meaning re-introduction into the material cycle is the objective of the process⁸⁸, the second case uses the volume of the glass and removes the material permanently from the material cycle. The lead content of the glass mixture from the shredders undercuts, for example, the limiting value of the corresponding German ordinance.

The existing Annex II is just a very crude basis for the support of the steering of wastes into the environmentally preferred waste treatment routes.

However, the actual steering, due to the respectively different and often complex situations, can be realised only by criteria, which are specific for the respective waste and/or waste treatment operation. The framework character of the WFD can best be taken into account in that here exclusively general definitions and principles are contained that deliver the basis for steering of via other regulations. Detailed requirements and criteria on priority waste treatment routes should be undertaken accordingly, as it is currently realised in some cases, in separate waste-, material- or product-specific regulations.

In addition, further flanking requirements from the respective area concerned in an effective protection of the environment are supportive for the steering of wastes (e.g. soil protection and the use of waste as construction material). The analysis of waste treatment operations revealed that a further harmonisation of, for example, soil protection regulations and waste management regulations, would be sensible.

88 Admixture to the primary raw materials.

 $^{^{87}}$ 2/3 of the tube mass.



3.3.9 Other issues

Many of the operations investigated were combinations of different operation steps. It was shown that, in general, their process-typical peculiarities could be best taken into account if the individual unit operations were not differentiated further (see, for example, pyrolytic processes on page 47). However, a differentiation of individual processes within one unit operation can contribute in cases of doubt to a further clarification.

The example of "feedstock recovery in blast furnaces" clarifies that, through processoriented considerations ("reduction of iron ore"), the process-specific peculiarities can usually be best taken into account. In cases of doubt, the aspect of raw material potential in the waste can be included for a characterisation of the operation through waste-oriented considerations ("oxidisation of organic waste").

The necessity of removing individual entries from the annex was in no case revealed. However, necessity of individual entries depends on the chosen overall concept.

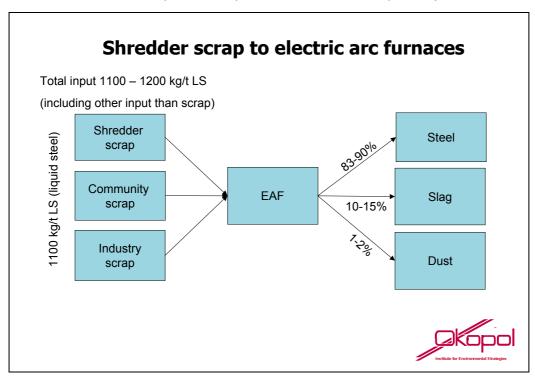
The investigation has also made it clear that considering all individual cases of waste treatment operations, which are currently employed in the EU, would contradict the framework character of the WFD. It therefore appears to be sensible to carry out detailed clarification at another subordinate regulation level.



4 Technical Annex

4.1 Shredder scrap in electric arc furnaces

The electric arc furnace is charged with a mixture of scrap and lime. It is melted using electric arcs from graphite electrodes at around 1200°C. Oxygen is introduced in order to oxidise e.g. carbon, silicon and manganese from the scrap metal. Carbon monoxide escapes as a gas. The oxides of the other elements are acidic and produce in combination with the basic lime a slag, which is poured of the surface. The melted metal itself is running through the furnace spout into a ladle. Further treatment of this crude steel takes place comparable to steel from primary raw materials.



Detailed discussion about the input and output fraction are presented in part B of the study.

4.2 Fibre reinforced plastics in cement production

Fibre reinforced plastics ("composites") are used in a wide variety of products. GPRMC [2004] estimates that 25% of this type of material is used in the transport sector, 27% for building/construction purposes and public infrastructure and 24% in electrical/electronic products and consumer goods and industrial equipment. No data are available about the amount of fibre reinforced plastic waste.



Composites waste can be used in clinker production. The inorganic part can substitute natural siliceous, aluminium and calcium compounds. The organic part contributes to the energy input needed of the process.

Composites contain resin, reinforcement material and fillers. Resins (average share 25-35%) consist of thermoplastics and thermoset resins. Reinforcement material (average share 25-45%) consists e.g. of glass fibres, carbon fibres, natural fibres. Fillers (average share 20-50%) are minerals like talc (CaCO₃), sand, kaolin ("clay") and alumina trihydrate [GPRMC 2004].

The composition of fibre reinforced plastics varies widely depending to the original product, thus the share of minerals which substitute raw material varies accordingly.

Table 11: Examples of fibre reinforced plastics

	Resin	Reinforcement	Filler
Typical average FRP	25-35%	25-45%	20-50%
Pultruded profiles	20-30%	70-80%	0-5%
FRP-Pipes industrial use	30-50%	50-70%	0%
FRP-Tanks and vessels	50-70%	30-50%	0-10%
FRP-Pipes with filler	30-50%	20-40%	30-40%
Polymer concrete	10-30%	0%	70-90%

[GPRMC 2004]

Table 12: Ash composition of fibre reinforced plastics

Ash compound	Share
SiO ₂	35.5%
CaO	35.0%
Al ₂ O ₃	24.3%
FeO₃	0.37
others	5%

[GPRMC 2004]

Composite waste is mixed with other raw material and fed into the rotary kiln of the clinker process where it is processed at about 1,450°C. The main output fraction of the operation is clinker.



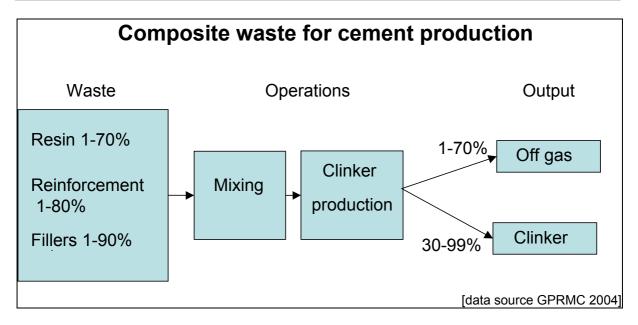


Figure 27: Composite waste used in cement industry

Virtually all inorganic components of the waste are transferred into the clinker. For the majority of inorganic components unspecific characteristics are used in the clinker (e.g. the volume of the material).

4.3 Smelting of lead acid batteries

Lead acid batteries (without sulphuric acid) are fed together with auxiliary materials like limestone and iron and additional energy carrier (coke) into a shaft furnace where they are smelted. The off gas from the furnace contains inter alia CO and organic components and is usually post-combusted.

Relevance

Around 60% of the lead consumed in EU-15 is made from secondary sources. Lead acid batteries are the main source for secondary lead.

Input description

The composition of lead acid batteries depends on the type and the size of the battery. Table 13 describes a rough average of compositions of starter batteries for passenger cars which have the highest market share of all lead acid batteries.



Table 13: Composition of lead acid batteries (averages)

Lead paste	40%
Lead and lead oxide	25%
Sulphuric acid	20%
Mixed plastics	10%
Polypropylene	5%

Table 14: Composition of a mixture of used lead acid accumulators

Component	Portion (mass %)
metallic lead	25-34
lead paste (lead sulphate, lead oxide)	31-40
sulphuric acid	11-28
Polypropylene	5-7
Separators	2-7
others	1-17

The Sb portion of the positive lead grid electrodes is in modern batteries ~2%. The overall Sb content in starter batteries is around 0.25% [Fellmuth 1999].

The organic input (plastics) (10% to 20 % of a battery without acid) into the shaft furnace is used as source of energy in the process and as a material which produces a reducing atmosphere.

The operation combines different types of waste treatment operations:

- pyrolysis of organic compounds in a reducing furnace atmosphere
- partly respectively incomplete combustion of organic compounds⁸⁹
- smelting of lead and lead compounds

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⁸⁹ Additionally the resulting compounds in the off gas are combusted in a post combustion chamber. The organic input is therefore completely oxidised in the installation.



The output of the process (related to the waste batteries input) is crude lead which is refined in subsequent steps and filter dust from off gas de-dusting.

In the case of lead acid batteries the majority of the waste consists of metals and metal compounds which are transferred predominately into metal output. A smaller part of the metal compounds are transferred into the off gas dust and the slag.

4.4 Feedstock recovery in blast furnaces

Technical description

Waste is fed into the hot zone of the blast furnace.

In a process orientated view the waste has a reducing effect on the iron ore. The energy content of the waste partly results in thermal energy.

In a waste orientated view the waste is partly oxidised by oxygen from ambient atmosphere and the resulting gases partly oxidised by oxygen from iron ore.

The combination and localisation of endothermic and exothermic reactions in the blast furnace is described in the box on the right.

Endothermic and exothermic reactions in a blast furnace [Jeschar 1996]

In the **upper furnace** the **endothermic** reaction

 $Fe_2O_3 + CO \times 2FeO + CO_2 + 8508 \text{ kJ/kmol}$

occurs. The exothermic reaction

FeO + CO \times Fe + CO₂ - 17038 kJ/kmol

occurs in the **lower furnace**. Parallel the **endothermic** bouldouard reaction

C + CO₂ X 2 CO +172465 kJ/kmol

occurs. The gasification of the waste is **exothermic** and **occurs right before the tuyères**

The oxidisation is incomplete and results in a CO rich off gas which can be used as energy carrier.

The input waste is carbon and hydrogen rich waste (e.g. plastics) from different sources which is usually pre-treated in order to achieve material specifications required by the blast furnace process.

The range of compositions of the input waste is limited by the requirements of the blast furnace process and payments which the blast furnace operator may get.

Some critical parameters are described in Table 15 and Table 16.



Table 15: Critical parameters for the use of plastic waste in blast furnaces

Parameter	affected aspect
C-H-ratio	reduction of iron ores
Mineral fraction like CaO, SiO ₂	e.g. disturbing substances, slag basicity, process efficiency
Cl, Zn	
Metal compound like Cu, Sn	product quality

Because the composition of wastes may has far reaching consequences for the characterisation of the operation three examples including a kind of worst-case-scenario will be described.

Table 16: Composition of different materials for feedstock recovery in blast furnaces

	Example 1	Example 2	Example 3
С	78 %	75 %	30 %
Н	12 %	10 %	4 %
Ash	5 %	10 %	58 %
SiO ₂	no data	3 %	23 %

Example 1 is pre-treated mixed plastic waste with a big portion of packaging waste. Example 2 is pre-treated mixed plastic waste with a high portion of treated shredder light fraction. Both examples show a high percentage of carbon and hydrogen and a portion of ash below 10%. All three wastes have almost the same C/H ratio. Example 3 is also a mixture of plastic wastes with a high portion of shredder light fraction. But this waste is not pre-treated in an optimal way for the use in the blast furnace. The effect of the high portion of SiO_2 and ash (which partly comprises the SiO_2) becomes clear in a calculation which is based on tests in a blast furnace. The figure below shows the results of this calculation. The plastic waste does not substitute primary energy carriers like heavy oil or coke. The reason for this effect is the high portion of minerals in the plastic waste and the fact that disturbing substances must be "neutralised" by adding additional mineral material to the input. For the other plastic wastes it is proven (example 1) or can be expected based on the waste composition (example 2) that they will have a positive effect in the process and will substitute coke and/or heavy oil.



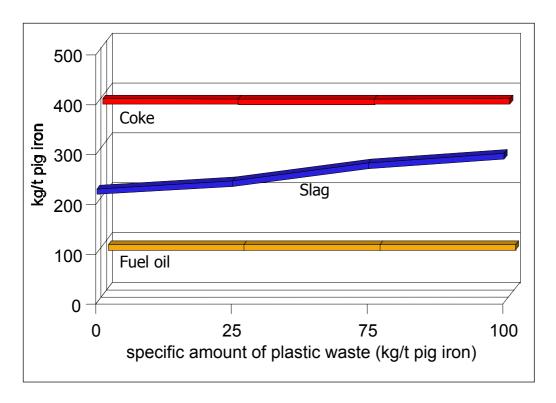


Figure 28: "Worst case scenario": Effect of plastic waste in a blast furnace

In case of example 3 a relatively high payment to the blast furnace operator would have been necessary for using the waste in the blast furnace. The payment will be significantly lower in the case of example 2 and was actually lower in the case of example 1.

The output of the blast furnace is pig iron, slag and a CO rich blast furnace gas. If the whole process of iron making in an integrated steel plant is taken into consideration like it is done for example in the IPPC Directive⁹⁰ it has to be taken into account that the blast furnace off gas is often used for energy production within the integrated steel plant. From this point of view the oxidisation of the waste in those cases has to be considered complete (CO_2 , H_2O).

The blast furnace process has a high relevance in view of achieving the targets of the Packaging Directive and may get a high relevance in view of the targets of the End of Life Vehicle Directive and the WEEE Directive. The current mass relevance is $\sim 100,000 \text{ t/y}$.

⁹⁰ (COUNCIL DIRECTIVE 96/61/EC of 24 September 1996 concerning integrated pollution prevention and control); Article 2 (Definitions) says:

[&]quot;3. 'installation` shall mean a stationary technical unit where one or more activities listed in Annex I are carried out, and any other directly associated activities which have a technical connection with the activities carried out on that site and which could have an effect on emissions and pollution;"



The question may be raised whether material properties of the waste are used in the process beyond delivery of heat. In order to answer this question [Jeschar 1996] asks whether the same process would be possible if only the heat would be transferred to the iron ore. The answer is "no". The reduction potential of the chemical compounds generated from the waste would not be useable if there were no direct contact between the chemical compounds and the iron ore because the chemical energy of the plastics could not be used.

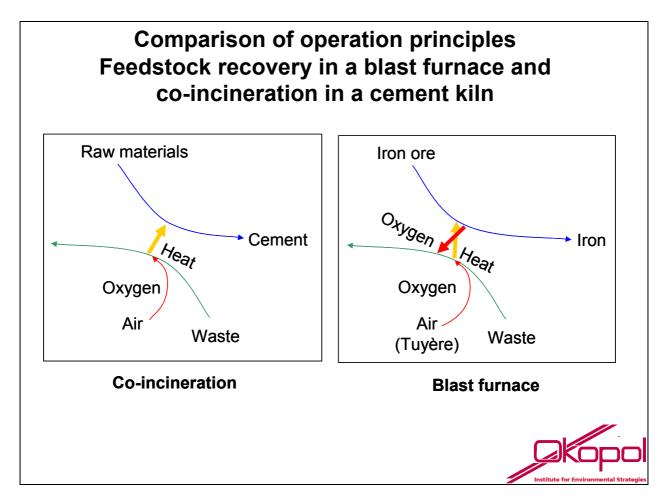


Figure 29: Comparison of operation principles

Recovery of plastic is not done in a way that the material integrity of the organic matter is kept. The input material is not transferred to "new" or other organic matter but into non organic substances (CO, CO₂).

The original material (mainly polymers) is not available for material cycle any more.



4.5 Gasification at the "Schwarze Pumpe" secondary recovery centre

The chosen operation of the "Schwarze Pumpe" Secondary Recovery Centre ("Sekundärrohstoffverwertungszentrum Schwarze Pumpe" (SVZ)) uses different solid and liquid wastes and coal⁹¹. First, the materials are fed into different gasifiers where they are gasified at 800°C to 1600°C⁹². The gasification process is a complex operation where the waste is partly used as a source of energy and partly transferred into a gas for further processing. Principally the operation can be divided into a drying step, a degassing step, a gasification step and an oxidising step⁹³. The outputs are raw gas and slag⁹⁴ (see Figure 30). The energy needed for the whole "gasification" operation derives from the wastes and coal introduced. In a subsequent step the raw gas is purified. The output is called "Syngas" which can be employed for the production of electricity but is predominantly used for the production of methanol.

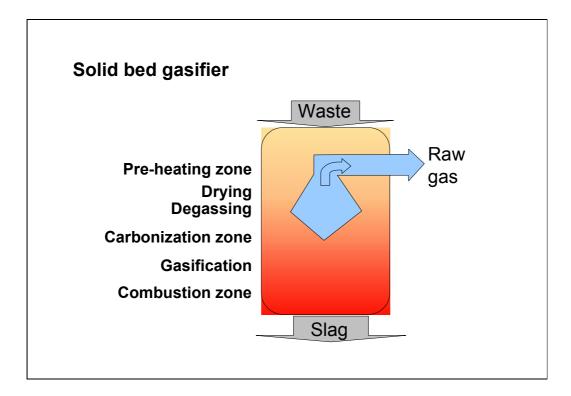


Figure 30: Simplified scheme of a solid bed gasifier

⁹¹ Coal is only used within the fixed bed and slag gasifiers. The endrained flow gasifier uses waste oil.

⁹² 25 bar, using steam and oxygen as gasification agents.

⁹³ These steps can hardly be seen as different unit operations because they take place in one unit with close interdependency.

⁹⁴ It is planned to fill the slag into mines or use it for construction purposes.



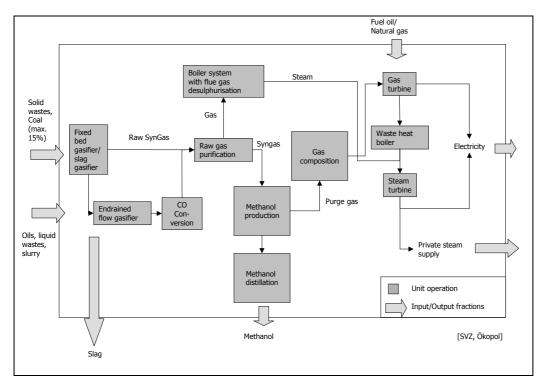


Figure 31: Process scheme of the SVZ

Critical parameters:

Syngas has to fulfil several requirements in order to be converted into methanol. The ratio of CO to H_2 has to be between 1 and 2.1 in order to have a conversion factor above 90% and to avoid large amounts of the H_2 going into the purge gas. The amount of H_2 should be quite high. If only biomass is gasified an exemplary composition of the raw gas produced is indicated in Table 17.

This raw gas has to be further conditioned to Syngas. Around 60% of the CO_2 have to be separated and the amount of H_2 has to be increased. An example of conditioned Syngas is indicated in Table 18.



Table 17: Composition of raw gas and syngas from biomass

Components	Raw	Syngas
	gas	
H ₂	37.3 %	63.5 %
СО	15.8 %	13.6 %
CO ₂	34.7 %	11.7 %
CH ₄	11.4 %	9.8 %
H ₂ O	0.5 %	0.4 %
N ₂	0.3 %	0.2 %

[Specht, Bandi 1999]

There are various possibilities for the production of methanol. The most common are from natural gas, lignite and biowaste. In this example a relevant amount of the CO_2 produced by the biomass gasification is not transferred into methanol but is released into the atmosphere.

Data obtained from the SVZ indicated the following proportions

Table 18: Composition of different SVZ gases

Components	Raw gas ⁹⁵	Syngas	Purge gas
H ₂	13.8	59.1	61%
СО	29.6	23.5	8 %
CO ₂	19.4	2.1	< 7%
CH ₄	27.6	11.6	28%
N ₂	7.7	2.9	< 10%
O ₂	0.23	0.2	max. < 0.2
CH ₃ CH ₃ (Ethan)	0.55	0.48	-
Other C _n H _m	1.12	0.12	-

[SVZ pers. com. 2003]

95 from BGL Gasifiers

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Purge gas consists mainly of H_2 and lower amounts of CH_4 . Contamination with hazardous substances is generally low.

Input description:

Shredder light fraction (SLF), municipal waste, sewage sludge, used plastics, residues of varnish and paint and other waste streams from different sources are introduced into the gasification process.

Figure 32 depicts the mass flows (simplified scheme).

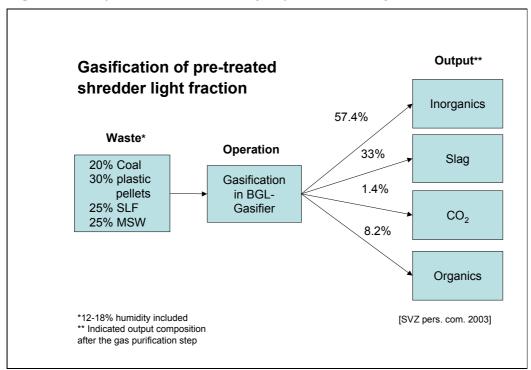


Figure 32: Gasification of pre-treated SLF

The SVZ process has the capability to convert mixed organic input into raw material of high quality. The "Syngas" meets the requirements for methanol production in the own installations. The methanol meets the requirements of international standards. The material is fed into the production chain as pre-product or raw material (see simplified scheme in Figure 33).



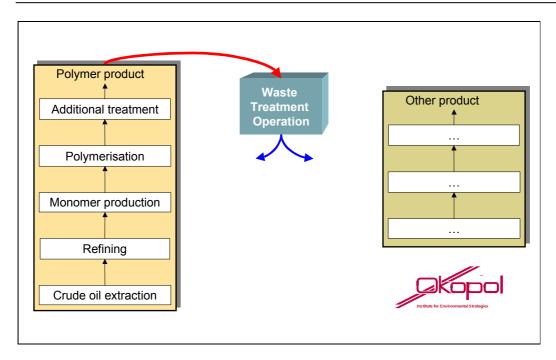


Figure 33: Simplified scheme of possible uses for methanol after waste treatment operation



4.6 Gasification and ash melting of the "TwinRec" process

Shredder Light Fraction is introduced into a Fluidised Bed Gasifier in presence of little oxygen and heated to about 580°C. Ferrous and Non-ferrous metals and large inert materials are separated and a combustible gas is produced. Due to the low temperature within the gasifier and the reducing atmosphere metals are not oxidised. The organic material breaks down into shorter hydrocarbons in the gasifier.

The produced gas is combusted in a cyclonic combustion chamber at temperatures between 1350°C to 1450°C and the fine minerals which are taken to the chamber with the gas are vitrified. The minerals are cooled down afterwards and form a granulate.

Figure 34 visualises the above describes process.

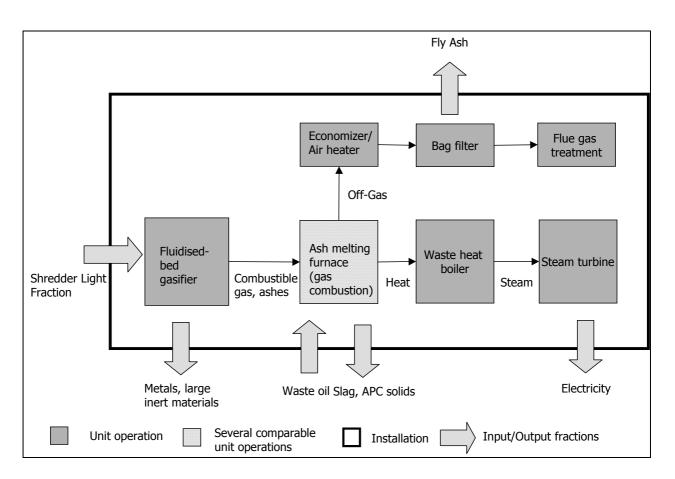


Figure 34: Process scheme TwinRec

The proportion of input and output fraction from the Twinrec process are indicated in Figure 35.



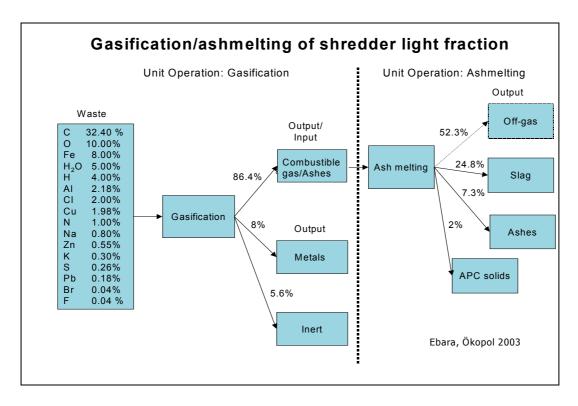


Figure 35: Proportion of input and output fraction from the Twinrec process



4.7 Recovery of spent acids

Basically there are two different types of regeneration of acids. In the example of spent sulphuric acid that are thermal decomposition resulting in SO_2 as a raw material for H_2SO_4 production or by physical processes like concentration or evaporation. The following tables give an exemplary overview for some physical H_2SO_4 and HNO_3/HF acids.

Table 19: Processes for regenerating spent acids from pickling plants using H₂SO₄

	Heptahydrate crystallisa- tion(with indirect cyclone- orvacuum cooling)	Retardation	Dialysis
Principle of regeneration	Regeneration of free H ₂ SO ₄	Regeneration of free H ₂ SO ₄	Regeneration of free H ₂ SO ₄
Regenerate / reg. acid	Free H ₂ SO ₄	Free H ₂ SO ₄	Free H ₂ SO ₄
Waste for disposal	(If Cr, Ni, Zn present)	Acidic FeSO ₄ for neutralisa- tion	Acidic FeSO ₄ for neutralisation
Free acid	> 99%	80-90%	75-85%

[DFIU 1999]

Table 20: Processes for regenerating spent acids from pickling plants using $HNO_3\ /HF$

	Solvent extraction	Crystallisation	Pyrohydrolysis	Process with bipolar
				membranes
Principle of regenera-	Total regeneration	Regeneration of free	Total regeneration	Total regeneration
tion		acids		
Regenerate / reg. acid	Total HNO₃ and HF	Free HNO₃ and HF	Total HNO₃ and HF	Total HNO₃ and HF
Waste for disposal	Metallic salt solution			
Regeneration rate total	HNO₃ 80-95%		HNO ₃ 80-90%	HNO₃ 90-95%
acid	HF 50-65%		HF 90-99%	HF 90-97%
Free acids		HNO ₃ 80-95%		
		HF 50-55%		
	Retardation	Dialysis	Outokumpu process	Kawasaki process
Principle of regenera-	Regeneration of free	Regeneration of free	Total regeneration	Total regeneration
tion	acids	acids		
Regenerate / reg. acid	Free HNO₃ and HF	Free HNO₃ and HF	Total HNO₃ and HF	whole HNO₃ and HF
Waste for disposal	Metallic salt solution	Metallic salt solution	Jarosite and Cr(OH) ₃	Metallic salt solution
Regeneration rate			HNO ₃ 90-95%	HNO₃ 75-90%
total acid			HF 96-99%	HF 85-95%
Free acid	HNO₃ 80-95%	HNO₃ 85-95%		
	HF 80-90%	HF 80-90%		

[DFIU 1999]



Regeneration of spent acids can be done by specific plants or as a part of other production processes. For decomposition the operations are often identical to production processes for primary material.

The level of re-introduction of the material into processes differs depending on whether physical regeneration (with subsequent re-use) or decomposition (with subsequent re-introduction in the production chain for sulphuric acids is done (see Figure 36).

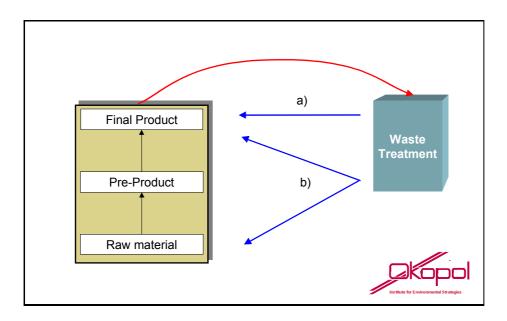


Figure 36: Level of re-introduction



4.8 Recovery of catalysts

Catalysts are used in several production processes and gas and liquid treatment operations. They comprise a vast variety of devices, materials and substances. They may be used for example in off gas treatment (e.g. Selective Catalytic NOx Reduction SCR), for production of synthetic organic chemicals or in the exhaust system of vehicles. They may solid bodies with active surface or just used once and remain in the product (e.g. plastic production).⁹⁶

In most of the waste relevant applications⁹⁷ two different forms of recovery of can be distinguished: The re-activating of catalysts and the recovery of components of the catalysts.

Recovery of catalysts gets additional relevance because of the mandatory dismantling of catalysts from end-of-life vehicles according to Article 6(3) in conjunction with Annex I(4) of the ELV Directive.

With the background of the terms of reference of this study two exemplary operations are described in this section.

4.9 Regeneration of catalysts from petro-chemical industry

Catalysts are used in the petro-chemical industry for cracking of heavy fuel components into light fractions.

Over time, coke will build up on the catalyst surface area, which reduces the catalyst activity. Those deposits may contain (depending on the actual process) SiO2,Al2O3, Fe2O3, heavy metal component (e.g. Nickeloxide), petrol-cokes, metalsulfides, or sodiumchlorides. The catalyst can be regenerated by burning the coke off with air⁹⁸., Through regeneration of catalysts approximately only 75 % of its former activity can be maintained. After a certain amount of regeneration cycles the catalyst is replaced by a new one.

An exemplary analysed of a spent Co-Mo-catalyst on an aluminium oxide-carrier from hydro treating is shown in the following table.

⁹⁶ Catalysts which remain property of the company where they occur are not covered in this section because they usually do not become waste.

⁹⁷ with regard to mass aspects

⁹⁸ In some operation it is necessary, the catalyst needs to be reconditioned by a combined treatment of air and HCl under high temperature after coke burning. This regeneration step is called 'oxy-chlorination'. After this step the catalyst is dryed with hot nitrogen and subsequently brought in its active condition by reducing the surface with hot hydrogen



Table 21: Analysis of a spent catalyst

Element	Impurities (w%)
AL	35
Мо	8.8
Со	3.2
V	1.2
Si	0.5
Ni	0.3
Fe	0.21
Na	0.2
As, P, Pb, W	Each < 0.5

[Hassan 2001]

Furthermore catalysts can contain 5-25 weight% carbon and sulphur.

Regeneration of catalysts is only carried out when the catalyst shall be used again for its original purpose. If components of the catalysts are recovered the recovery paths are from a principal point of view very similar to those of recovery of metals or inorganic materials.

Relevance:

Consumption of non-precious metal catalysts in Western Europe is estimated to be 70000 t annually [Hassan 2001].

4.10 Thermal regeneration of activated coke

Waste granular coke originates from off gas cleaning e.g. of chemical processes, printing industry, paint manufacturing. It is characterised by pollution with chlorinated hydrocarbons and/or other solvents. The composition of the impurities varies according to the solvents used in the process. The loading varies according to the time of operations which depends on the required clean gas characteristics.

The spent granular coke is reactivated with steam of 750° to 800 C in rotating drums, shaft kilns or fluidized bed reactors (minimizing abrasion). The amount of solvents or other loads depends on the type of adsorbed material, on the concentration of the material in raw gas or water, on the adsorption potential of the coke and



on the time of operation. By using a defined volume of oxygen and steam, solvents are oxidised almost without oxidising the coke.

The output of the operation is activated coke and a contaminated hot steam. The steam is oxidised and shock cooled by washers.

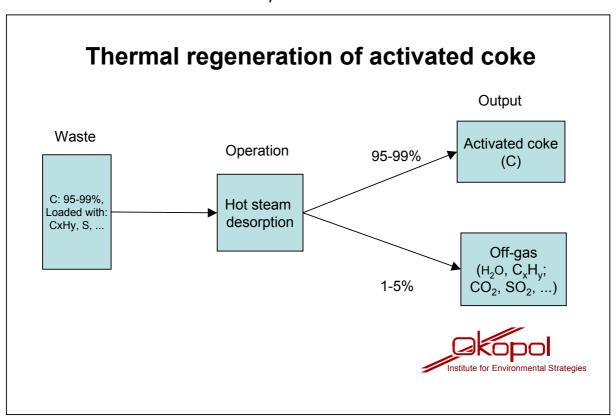


Figure 37: Thermal regeneration of activated coke

4.11 Distillation of organic solvents

Solvent waste is filled batch wise or continuously in electrically or steam heated vessels with max. 180°C (depending on desired output fraction) under a pressure of about 50 mbar, afterwards the distilled fraction is condensed in coolers.⁹⁹

The input of the operation is manifold and consists of waste from organic chemical processes, wastes from the manufacture, formulation, supply and use of coating (paints, varnishes and vitreous enamels), adhesives, sealants and printing inks, wastes from chemical surface treatment and coating of metals or other materials, wastes from shaping and physical and mechanical surface treatment of metals and

⁹⁹ Those cases where the solvent remain the property of the company where the spent solvent occurs are not covered in this section because those solvents usually do not become waste.



plastics, other waste organic solvents, coatings, inks, adhesives and sealants like those from separate municipal collection.

The output of the operation is emissions, solvents, water and sludge. The share of the output fractions varies significantly according to the input material. Most distillations end up in about 5% water output, but depending on the economic value of the input solvents, high water contents up to 80% are accepted and thus found in the output.

Most solvent waste is processed separately and distilled solvents are returned to the waste supplier thus solvents include a mixture of the solvents that were included in the waste but cleaned from impurities and water. A minor part of the distilled solvent output is not returned to the waste supplier but mixed to achieve certain product characteristics for selling on the market.

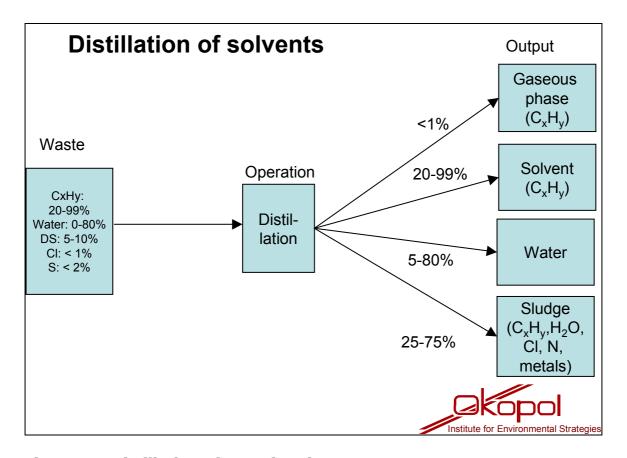


Figure 38: Distillation of organic solvents

The solvents from distillation may or may not be directly used as product again. This does not only depends on the quality / composition of the output but also on market



situation (demand for the respective solvent quality) and regional circumstances and the existence of consumers.

4.12 Composting of native organic solid waste

In aerobic composting plants a part of the organic matter of waste is decomposed by activity of micro-organisms. The biological (thermophilic) activity results in a warming or heating of the material. In well operated plants the achieved temperatures (up to 65°C to 70°C) are high enough to stop biological activity of several unwanted organic components of the waste (e.g. pathogenic organism, seeds).

The reduction of humidity of the waste is a result of the increased temperature during the process. The total loss of weight is often more than 40%.

The input material in this exemplary process is native organic waste from private households, garden and parks or commercial activities ("biowaste"). Its composition varies depending e. g on the region (urban – rural areas), the season (e.g. fall-winter differences) or the type of commercial activity. In order to ensure sufficient aeration in the process the waste must have sufficient structured components (e.g. branches, leaves) and is not too wet.

Different encapsulated systems are in use like drums, tunnels, boxes, containers, or housed systems like fields or different types of heaps. Systems which are not housed (open fields or heaps) are used as well depending on local permitting and situation.

A minor waste stream of materials which disturb the process or reduce quality of the operation output is separated.



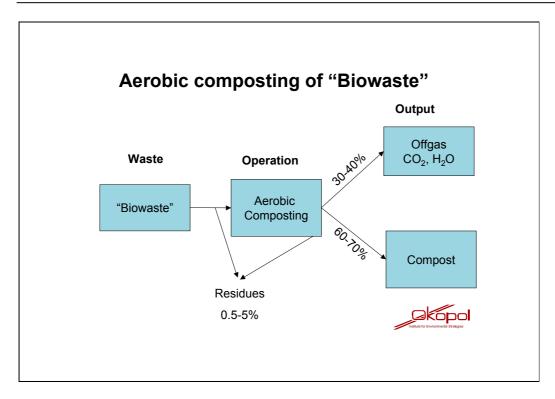


Figure 39: Composting of biowaste

Depending on its quality compost is used for soil improvement. It may or may not comply with existing quality standards. While there are legal regulations for compost quality on Member State level and national standards no common European quality standard is established so far.

Table 20 shows some guideline values for "Quality Compost" in Germany. The values correspond to the values of the German Biowaste Ordinance. The values are often differentiated by quality classes as shown in the example from Austrian Biowaste Ordinance (Table 21).



Table 22: Guideline values for heavy metal concentrations

Parameter	Guideline value
Pb	150 (mg/kg)
Cd	1.5 (mg/kg)
Cr	100 (mg/kg)
Cu	100 (mg/kg)
Ni	50 (mg/kg)
Hg	1 (mg/kg)
Zn	400 (mg/kg)
Organic substance	Compost II/III >15%(dm)
	Compost IV/V >30% (dm)

[RAL GZ 251]

Table 23: Quality Standards for Compost in Austria

Parameter	Quality Standard "A"	Quality Standard "B"
Cd	1	3
Cr5	70	250
Hg	0.7	3
Ni	60	100
Pb	120	200
Cu	150	400 (guiding value), 500 (limit value)
Zn	500	1200 (guiding value), 1800 (limit value)

[Austrian Biowaste Ordinance]

Within this operation no primary raw materials are substituted yet.

Entry R10 "Land treatment resulting in benefit to agriculture or ecological improvement" emphasises the positive effects of the use of waste.

If quality requirements (which do not exist on a European level) for the output of the aerobic composting plant are met there is a high probability that the output is capable to be used as a fertiliser or for soil improvement and that the required positive effects are reached.

It can be regularly expected that the output does not meet existing national quality requirements if the input waste does not derive from separate collection.



4.13 Mechanical biological treatment of mixed solid waste

Mixed solid waste is treated mechanically and biologically.

Mechanical biological treatment (MBT) is actually a combination of different co-ordinated unit operations. It comprises the separation of substances which disturb the process, optimisation of particle size, separation of materials with a high calorific value (e.g. plastics) and a biological treatment step. A large range of solid wastes with different compositions can be treated in MBT. Often heterogeneous wastes are used.

The facilities may vary significantly in their technologic construction, which is determined among other things by the waste types to be treated, by the aim of treatment and by the final destination of the produced material (landfill, energy recovery, waste incineration plant). They can be divided into operations which mainly aim at the generation of

- a) a remaining fraction suitable for landfill, a high calorific fraction and fractions for material recycling or
- b) fractions determined for material and energy recovery (dry stabilates) without producing a significant amount of waste for disposal on landfill.

The mechanical treatment uses aggregates for the reduction of particle size like crushing (e.g. single-screw crusher), cutting (e.g. rotor cutter, granulator) or shearing (e.g. worm mill) and separation by sieving, air stream separation, ballistic separation, Fe- and non-ferrous-separation, optical separation.

The biological treatment can be carried out under aerobe or anaerobe conditions.

The main mass effect of aerobe biological treatment (rotting, about 1-14 weeks) results from a drying of the material resulting from the heat development of microorganisms. Rotting uses encapsulated systems like drums, tunnels, boxes, containers, or housed systems like fields or different types of heaps, according to local conditions, costs and permission requirements. For rotting systems aeration is used.



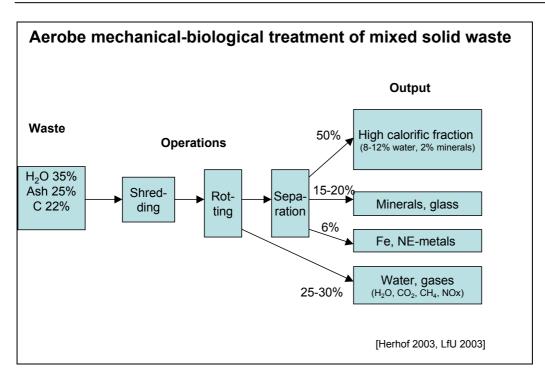


Figure 40: Aerobe mechanical biological treatment of mixed solid waste

One effect of a biological treatment carried out under anaerobe conditions (fermentation, about 3 weeks) is the production of biogas produced by micro-organisms. Fermentation may be carried out under wet, semi-dry or dry conditions, under mesophile or thermopile conditions and in one or in several stage digestions, in continuous, semi-continuous or batch reactor units. The feedstock is mixed with recirculated process water. Plastics, textiles, stones and metals can be separated in a pulper by means of a rake and a heavy fraction trap. Waste water from fermentation can be used for humidification of the annexed rotting unit, thus in general no waste water in produced by mechanical biological treatment.

If the treatment aims at the production of a landfill fraction, the fermentation is followed by a rotting operation (another 4-6 weeks).

The output of the operations is a fraction with high calorific value, a mineral fraction (ceramics, stones, glass) and metals. The output varies according to the aim of the operation described above.



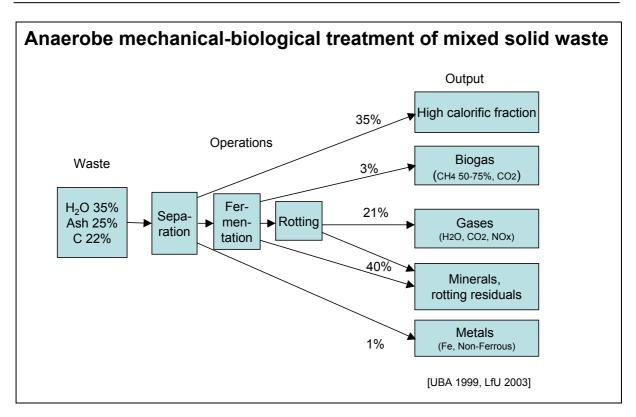


Figure 41: Anaerobe mechanical biological treatment of mixed solid waste

The operation principles are similar to aerobic composting respectively anaerobic digestion as described in the technical annex (p.115 and p.120). Input and the quality of the output are distinctive characteristics.

4.14 Anaerobic digestion

In anaerobic digestion plants organic material is partially decomposed by microorganisms into CH_4 and CO_2 (Biogas). The portion of CH_4 is between 65-70% and of CO_2 between 35-30% depending on the introduced waste. The operating temperature ranges between 35 to 55°C.

Input description:

The input material may comprise different separately collected native organic waste from different sources like e.g. households, commercial activities, gardens and parks and industry (mainly food industry).

Furthermore anaerobic digestion may be applied as waste treatment operation for sewage sludge and wastes from livestock farming.



The operation comprises typically the following unit operations:

- Pre-treatment: separation of materials which disturb the process or which have a negative effect on the quality of the output
- Anaerobic digestion: Typically the different phases of the digestion process (hydrolysis, acid phase, acetic acid phase, and methane phase) take place in one reactor. The operation may be performed as mesophilic (~30-35°C) or thermophilic (~50-60°C) reaction in one or two steps.
- Post-treatment: The digestion residue is post-treated in order to stabilise the material and to enable subsequent biological activity.

Figure 42 depicts an exemplary mass flow of an anaerobic digestion operation.

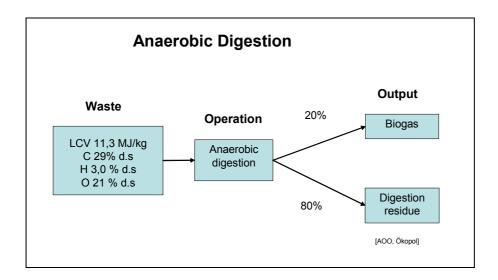


Figure 42: Anaerobic digestion of biowaste

Depending on the input wastes the resulting material may or may not be used as fertilizer or for soil improvement. In the operation itself no primary raw materials are substituted.

No European normative reference is available which defines which requirements must be met in order to achieve a "benefit to agriculture or ecological improvement" [Entry R10 of Annex IIB WFD] (see also above in section "Aerobic Composting").

The biogas can subsequently be combusted in order to produce energy.



4.15 Use of sewage sludge on agricultural areas

In 1986 the European Commission ratified Council Directive 86/278/EEC on the protection of the environment and in particular the soil, when sewage sludge is used in agriculture.

The purpose of this Directive is according to Art.1:

"regulate the use of sewage sludge in agriculture in such a way as to prevent harmful effects on soil, vegetation, animals and man, thereby encouraging the correct use of such sewage sludge"

In order to reach this objective the Directive sets out in Art. 4

Values for concentrations of heavy metals in soil to which sludge is applied, concentrations of heavy metals in sludge and the maximum annual quantities of such heavy metals which may be introduced into soil intended for agriculture".

The values coping directly with the composition of sewage sludge are indicated in Table 24.

Table 24: Limit values for heavy-metal concentrations in sludge for use in agriculture

Parameters	Limit values mg/kg dry matter	
	,	
Cd	20-40	
Cu	1000-1750	
Hg	16-25	
Ni	300-400	
Pb	750-1200	
Zn	2500-4000	

[86/278/EEC 2003]

Annex I C of Directive 86/278/EEC indicated limit values of heavy metals which may be added annually to agricultural land, based on a 10-year average (see Table 25).



Table 25: Limit values for annual sewage sludge application

Parameters	Limit values kg/ha/yr
Cd	0,15
Cu	12
Ni	3
Pb	15
Zn	30
Hg	0,1
Cr	-

[86/278/EEC 2003]

The average content of heavy metals in sewage sludge in Europe is indicated in Table 26.

Table 26: Average content in sewage sludge of selected heavy metals in Member States

Heavy Metals	Range in the Member States mg/kg dry matter ¹⁰⁰
Cd	0.4-3.8
Cr	16-275
Cu	39-641
Hg	0.3-3
Ni	9-90
Pb	13-221
Zn	142-2000

[European Commission 2001]

The limits set out in Directive 1986/278/EEC are widely fulfilled by European Member States.

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¹⁰⁰ different years mainly 1997



Entry 10 of Annex IIB of the WFD says: "Land treatment resulting in benefit to agriculture or ecological improvement". Fulfilment of the described "defensive" requirements of Directive 1986/278/EEC does not necessarily mean that the "positive" objective of entry R10 is reached. On European level no definition of when there is a "benefit to agriculture or ecological improvement" is available.

Furthermore there are other components which can decide about the beneficial character of the soil (limit values of PAH, PCB etc) which are not regulated by Directive 1986/278/EEC. More specific requirement concerning the use of sewage sludge regarding pollutant limit values, test methods etc. have been drafted in Working Documents on sludge by the European Commission [European Commission 2000a].

Relevance:

8.156 million tonnes of sewage sludge have been projected by the EEA to arise in selected Member States in 2000.

4.16 Filling of Mines

Mines are filled in order to avoid the destabilisation of the surface (underground workings) or for site restoration purposes (open pits), while also reducing land necessary for disposal.

The EEA has identified waste from mining and quarrying activities to be the second biggest waste flow within the European Union.

Different kinds of wastes which fulfil the respective requirements e.g. with regard to stability are used as input material (e. g. Mineral wastes arising from industrial applications as well as mine activities itself). Sometimes wastes are stabilized by mixing with cement .

The only European wide activity striving filling of mines is the proposal for a Directive of the European Parliament and of the Council on the management of waste from the extractive industries [2003/0107 (COD)], which does not cover materials which are introduced into mines but do not derive from them.

National rules for underground stowage have been set out e.g. by Germany in the Ordinance on Underground Waste Stowage (Stowage Ordinance). Some relevant parts of the Ordinance are quoted below.



"Wastes reaching the metal content value listed in Appendix 1 may neither be utilised to produce stowage materials nor for direct use as stowage materials if it is technically possible and economically viable to reclaim these metals from the wastes, and insofar as this is feasible while observing the permissibility requirements of such recycling." [Article 3, Stowage Ordinance 2002]

The content of Appendix I of the Stowage Ordinance is indicated in Table 27.

Table 27: Limit value concentrations for metals in wastes¹⁰¹

Metal	Concentration (g/kg)
zinc	≥ 100
lead	≥ 100
copper	≥ 10
tin	≥ 15
chromium	≥ 150
nickel	≥ 25
iron	≥ 500

"Wastes may only be utilised to produce stowage materials and/or for direct use as stowage materials if the limit values for solids and correlation values as listed in Appendix 2 Table 1 and Table 1a are not exceeded in the respective unmixed waste utilised, and the use of the stowage materials does not lead to harmful pollution of the groundwater or surface waters or any other negative impact on the quality of water bodies. In this context the limit values in eluates as listed in Appendix 2 Table 2 may not be exceeded in the stowage materials." [Art. 4 (1) Stowage Ordinance 2002].

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¹⁰¹ The concentrations indicated refer to the solids content of the respective waste.



The content of Appendix 2 Table 1 is indicated in Table 28.

Table 28: Limit values for solids¹⁰²

Element/compound	Concentration
	(mg/kg dry matter)
mineral hydrogen carbons	1000
BTEX	5
highly volatile halogenated hydrocarbons	5
PAHs	20
PCB	1
arsenic (As)	150
lead (Pb)	1000
cadmium (Cd)	10
chromium, total (Cr)	600
copper (Cu)	600
nickel (Ni)	600
mercury (Hg)	10
zinc (Zn)	1500
cyanide, total (CN-)	100

Table 28 "shall not apply to the utilisation of stowage materials in constructions in salt rock if a long-term safety documentation was submitted to the competent authorities." Art. 4(3) Stowage Ordinance



Table 29: Correlation values for solids

Element/compound	Concentration (mass-%)
Organic proportion of the dry residue of the original substance, determined as	
TOC	≤ 6
Loss on ignition	≤ 12

For characterising this operation it has to be kept in mind that the materials are permanently withdrawn from material cycles and that besides others generally unspecific characteristics of the waste are used (e. g. volume of the material).

4.17 Crushing and cleaning of cathode ray tubes

The Cathode Ray Tubes are shredded and the glass fraction is separated by mechanical processes. The different glass fractions are cleaned from the applied coatings using e. g. abrasive techniques or ultrasound.

Input description

The inputs of this waste treatment operation are most of the times household appliances like TV and computer screens or similar materials.

Two main types of glass can be identified within cathode ray tubes:

- Panel glass accounting for about 2/3 of the cathode ray tube mass, older types can still contain lead.
- Cone glass accounting for about one third of the cathode ray tube mass. The portion of lead is estimated between 14 and 24% depending on origin and age.

The composition according to two sources is shown in Table 30.



Table 30: Composition of cathode ray tubes

Fraction	Weight %	Components of the fraction
		(portion in weight %)
Luminous coating	0.04%	ZnS, Y203, CdS, Eu
Solder	2 %	PbO (70-80%)
		ZnO (10%)
		BrO ₄ (8%)
Fe-Metals	13 %	traces of Barium
Panel glass	60.8%	SiO (59-65%)
		BaO (0.3-13.2%)
		SrO (0.5-10.5%)
Funnel glass (tube neck and	25.5%	SiO (59-65%)
cone glass):		PbO (9.9-23.5)

[MUV BW 1998]

Table 31: Detailed composition of panel and cone glass

Substance	Panel glass		Cone glass	
	min	max	min	max
	in w%			
SiO ₂	60	63	53.5	55.3
Al ₂ O ₃	2.2	3.4	1.1	5.2
CaO	0.1	3.2	0.9	3.8
MgO	0.0	1.2	0.6	2.2
Na ₂ O	6.6	9.4	5.8	6.7
K ₂ O	6.6	8.4	7,.8	8.1
BaO	8.3	13.0	0.1	2.5
PbO	0.0	2.8	21.6	23.5
SrO	2.2	8.8	0.1	0.5
ZrO ₂	0,0	2,3	0,0	0,2

[UM NS 1996]



Output-description:

Information about the composition of the operation output is not available. The luminous coating is usually landfilled and the glass fraction is submitted to different treatment operations:

- secondary raw material for new cathode ray tubes,
- in lead or copper smelters,
- construction purposes,
- mine filling.

Relevance

606.000 tons of cathode ray tubes were put on the European market in 1995 [UM NS 1996]. It is estimated that around 500-700.000 end-of-life cathode ray tubes have to be treated annually in Europe [Schott 2002].

Directive 2002/96/EC on waste electrical and electronic equipment (WEEE-Directive) names television sets and other products or equipment for the purpose of recording or reproducing sound or images, including signals or other technologies for the distribution of sound and image than by telecommunications in Annex I B. For those products Article 7 (2 b) lays down recovery targets. Furthermore Annex II (1,2) states that cathode ray tubes have to be separated from any separately collected WEEE and that the fluorescent coating of cathode ray tubes has to be removed.

4.18 Treatment of oil contaminated garage waste including oil filters

Garage waste comprises a wide variety of different fractions which occur during car repair activities like papers, metals, worn off parts and plastics. Oil filters waste from car repair shops are most of the times collected together with other fractions. The composition of the waste varies thus varies significantly.

The waste input passes a magnetic separator to separate the high calorific fraction (paper, plastics, some worn off parts). The metal fraction is subsequently shredded and centrifuged to separate the oil fraction. Some operations add saw dust after shredding to use the abrasive effect to achieve a more oil free metal fraction in a following sieve and magnetic separation.



The output of the operation is ferrous metals, oil and a high calorific fraction. The output share varies according to the input material, to the type of unit operations used and to the aimed output quality.

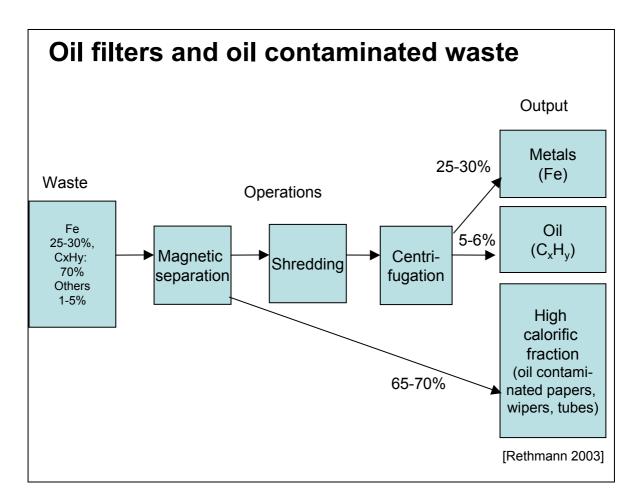


Figure 43: Treatment of oil contaminated garage waste including oil filters

4.19 Sorting of mineral waste from construction and demolition

The estimated mass relevance of mineral waste from construction and demolition in the European Union (15) is about 338 Mio. t/y [EEA 2002].

Mineral waste from construction and demolition passes a non-automatic separation of non-mineral waste, is crushed on- or off-side mostly by roller/jaw/cone/hammer crushers and sorted by magnets and sieves.

The input of the operation is mineral waste like concrete, bricks, tiles and ceramics, soil and stones, dredging spoil, track ballast, insulation materials, gypsum-based construction materials. Characteristic of construction and demolition waste is the heterogeneity of its composition depending on the different construction types, as



well as the multitude of materials, elements and aids used in the construction area [Schultmann/Renz 2000].

The output of the operation is a mineral fraction, a metal fraction and a residue containing e.g. wood, roofing felt, plastics.

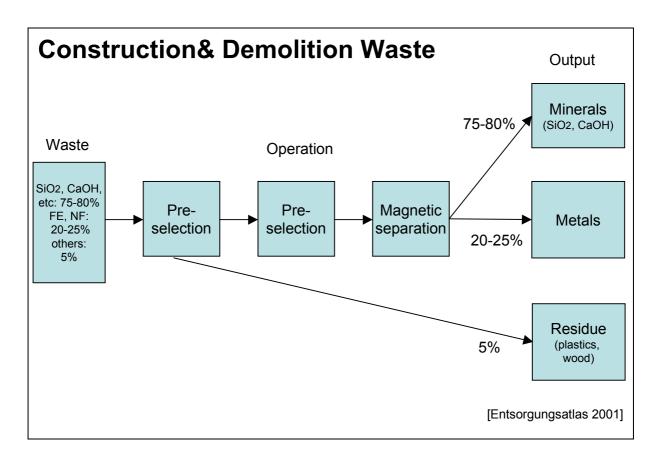


Figure 44: Mineral waste from construction and demolition

As other sorting and separation operations the process may be performed with varying efficiency. The output ratio is not fixed and whether output quality standards are met or not depends inter alia on the way the operation is carried out (in addition to variations in the composition of the input).



4.20 Sorting of non-mineral waste from construction/demolition and municipal solid waste

The sorting of non-mineral waste from construction and demolition and the sorting of municipal solid waste consist of a pre-sorting with caterpillars or excavators and a manual sorting on conveyor belts (handpicking). Some treatments also provide mechanical separation with air classifiers, drum sieves and magnets. For this purpose the size of the material is reduced by shredding, chipping and milling.

The input of the operation is non-mineral waste from construction and demolition sides as well as mixed municipal solid waste. The composition varies significantly.

According to the varying input material, the output of the process varies fundamentally. The figure shows mean values of different operations in North-Rhine-Westphalia/Germany of the years 1997-2000 [Ensorgunsatlas 2001].

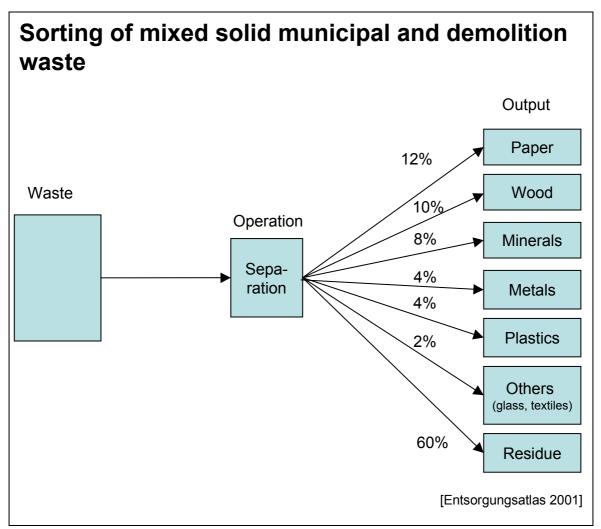


Figure 45: Sorting of mixed solid waste



Other operations may achieve only up to 20% sorted fractions and 80% residues as an average [Oldenburg 2001]. The sorted fractions mainly consist of paper, wood, minerals, metals, plastics and sometimes glass, textiles, rubber, non-ferrous and ferrous metals. The quality of those fractions and with this their applicability for recycling is influenced inter alia by the way the operation is carried out.

4.21 Sorting of EAF slag

A magnetic pulley separates metallic and non-metallic components of the slag.

Input description

The following table describes the composition of the slag which occurs during steel making in an Electric Arc Furnace (EAF).

Table 32: Composition of Electric Arc Furnace Slag

Components	%	%
	[Umweltbundesamt 1996]	[FGSV 1999]
Fe	10-32	20-30 103
CaO	24.9-45	24-36
free CaO	Max. 5	< 1
SiO ₂	10-18	10-18
Al ₂ 0 ₃	3-6	4-9
MgO	7-15	3-7
Cr ₂ O ₃	max. 2	1-3
MnO	-	4-8
P ₂ O ₅	-	0.5-1

The chemical composition of slag depends on the used raw materials and the metal-lurgical process [FGSV 1999].

¹⁰³ Sum of Fe, FeO, Fe₂O₃



Output

Around 60% of the EAF is landfilled and \sim 5% for plant internal use. The remaining 25 % are used e. g for construction purpose [BREF 2001, Euroslag 2003].

Relevance

Within the European Union 60 million tonnes of steel have been produced in electric arc furnaces in 1999. About 16.9 million tonnes of steel slag were produced in 2000 in the European Union. Thereof \sim 5 million consisted of EAF slag [BREF 2001, Euroslag 2003].

4.22 Shredding of metal waste

In the shredding process complex metal goods are separated in a metal fraction and one or two non metal fraction(s) (shredder residue or shredder light fraction SLF and shredder heavy fraction SHF).

Input

Post consumer scrap as main input source for shredders comprises different types of scrap (e.g. end of life vehicles, machines, construction material, electronic scrap) arising in different areas (community scrap, industry scrap, post consumer scrap). Only selective information is available concerning general scrap sources. Figure 46 shows estimation for Europe.

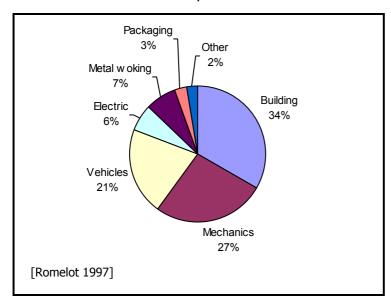


Figure 46: Origins of ferrous scrap in Europe



The following figure shows an example of the origin of input-materials at a European shredding company.

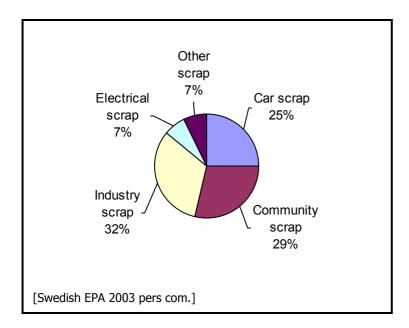


Figure 47: Exemplary origin of scrap in one Member State

Heterogeneity, physical structure of the material and wide varying characteristics and origins of the scrap used as shredder input make it virtually impossible to describe the composition of the input material M1. An impression of the product-related variety of the composition can be gained from looking at the deliveries made to shredder companies. Table 33 describes an exemplary cut-out from a two weeks survey chosen at random in 1995 within the scope of a study conducted by the German Federal Environment Office.



Table 33: Frequently Found Products in Mixed and Collected Scrap

Waste from mechanical work-	Drums	Cooking pots	Stove pipes
shops	Meshed garden fencing	Corkscrews	Pans
Reinforcing iron	Garden chairs	Blades	Screws
Exhausts	Dish washers	Hot-plates	Drawers
Car doors	Beverage cans	Pot lids	Car bumpers
Sheet metals	Hooks	Cooking pans	Shock absorbers
220 I barrel lids	Radiators	Car wings	Steel wheel rims
Cans with harmful residue adhesions	Cooker sheet metal	Refrigerator insert grids	Heat exchanger grids
Buckets	Cooking surfaces	Fridge doors	Washing stands
Shelves	Cooker parts	Pipes	Washing machines
Bicycles	Chimney pipes	Deckchairs	Washing machine drums
Bicycle tyres		Punched sheet metal	Angled brackets
Bicycle wheels	due	Kitchen appliances	Spark plugs
Bicycle handlebars	Folding chairs	Car bonnets	

[UBA 1996a]

It is obvious that virtually every substance used during production and/or in products may be found in the original scrap in widely diverging concentrations respectively.

According to the output streams from shredding (\sim 70 % shredder scrap, \sim 25 % shredder light fraction and \sim 5 % shredder heavy fraction) it can be estimated that the non ferrous portion of scrap is around 30 %.



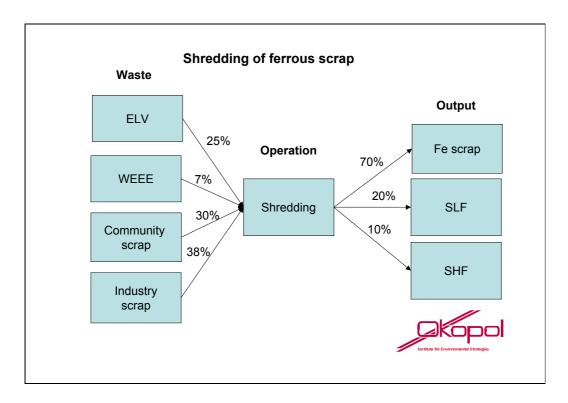


Figure 48: Shredding of ferrous scrap and possible targets of output streams (example)

Output

While shredding is never a precise 100% separation shredding scrap contains non ferrous components. Additionally the ferrous material itself contains usually different alloys and carbon. Cast iron as an example with extraordinary high contents of non ferrous components is an alloy of iron and carbon (ca. 2 to 4.4 wt%) which also typically contains silicon, manganese, sulphur, and phosphorous.

Shredding is usually optimised to meet quality requirements related to the ferrous scrap output. The ferrous portion of shredder scrap is usually between 92% as a minimum and 95%. It may be up to 98% only for special purposes. The remaining share comprises a wide range of substances (organic matter, minerals, non-ferrous metals).

Detailed descriptions of scrap compositions in view of substances with hazardous potentials are rare and usually not representative because of the broad variety of scrap types and the difficulties of taking representative samples from heterogeneous materials.

No quality requirements with a formal status of European Standards are established.



Shredder scrap is one of the scrap categories covered by the "EUROPEAN STEEL SCRAP SPECIFICATION" (ESSS) (see section "Scrap" in Part B of this study for details).

Beside the European **specifications** national **standards** exist. The Austrian Ö-Norm S 2080-3 for example puts some criteria in more concrete terms. For the description of impurities it refers to the National Chemical Law. It requires that no hazardous substance or preparation is allowed which would make the scrap a hazardous waste (according to the national definition)¹⁰⁴. Mixing of scraps is prohibited according to the National Waste Management Law.

Usually additional specific **terms of supply** will be fixed between supplying and receiving institution. They may also comprise environment related requirements.

While terms of supply are binding for the direct contractors national standards can be used as a basis for quality description on a regional (Member States) level. The general conditions of the "European Steel Scrap Specifications" describe conditions which are "practically achievable in customary preparation and handling of the grade involved" [ESSS].

 $^{^{104}}$ The content of hydrocarbons is limited to 0.2%.



4.23 Mechanical separation of waste cables

Cables are cut into pieces and shredded. The separation of plastics and metal is usually done by metal separators. The different plastics are separated for example via gravity, centrifugal or electrostatic separation.

Input description

The following table describes the consumption of materials for cables in Western Europe.

Table 34: Consumption of materials for cables in Western Europe in 1992

Material	Weight %
Copper	41.2 %
PVC	16 %
PE	9.1 %
Fillers	8.3 %
Aluminium	7.1 %
Elastomers & others	6.9 %
Iron	6.3 %
Lead	3.8 %
Optical fibre	1.2 %

[Helmesjö, Hjertberg 2001]

The composition of new cables is the same as the composition of scrap cables [Helmesjö, Hjertberg 2001, Cablo, pers. comm.]

Cable waste from dismantlers who usually separate copper and aluminium varies widely depending on the origin and the age of the waste cables. PVC compounds, Polyethylene (PE), cross-linked PE (X-PE) and rubber are the components mostly found in waste cables.

A reference composition is presented in Table 35.



Table 35: Reference composition of waste cables

Material	Weight %
PVC cables	68 %
PE/PEX cables	28 %
Rubber	2 %
Copper	1.5 %
Aluminium	0.5 %

[Kreißig et al 2003]

The predominant part in the above reference composition are PVC cables. Its average composition is indicated in Table 36.

Table 36: Average composition of PVC cables

Material	Weight %
PVC	39 %
Filler	31 %
Plasticizer	26 %
Stabiliser	2 %
Pigments	1 %
Chlorinated parafines	1 %

[Kreißig et al 2003]

Output description

Copper granulate (~ 53%) with a copper content of 95-99.9% is either sold to copper smelters, to brass production companies or to chemical industry.

Plastic (31% PE and PVC) is submitted to different treatment paths. PE with a low chlorine content is used in cement kilns and as secondary raw material, while PVC (minimum purity 85%) is recycled as material in the transport and gardening industry. Encapsulation material (\sim 16%) is disposed of [Cablo Metal recycling, pers comm.].



Relevance

3.2 million tons of cables have been consumed in Western Europe in 1999. No data on waste cables could be made available.

Annex II (1) of the WEEE Directive states that external electric cables have to be removed from any separately collected WEEE.

4.24 Electrolytic regeneration of fixer solution

Fixer solution waste is collected mainly from photo laboratories, hospitals and printing industry. The estimated waste amount is about 0.37 litres per inhabitant [RethmannPhoto 2003] which results in about 150,000 tonnes in EU-15, assuming a density of 1.1 kg/l and 380 million inhabitants.

It is treated in an electrolytic reactor with pH-regulating chemicals (voltage 3 V, current 80 A) and stirred about 12 hours on approximately 30°C.

A silver content of more than 1% will disturb the fixing process thus in general the silver content in spent fixer solution is below 1% [Ökopol 1997]. The fixer solution contains a mean of 0.3-0.4% silver [FVG 2003].

The output of the operation is on the one hand a fraction with 60-80% silver content, impurities and water can be further processed in the metal industry, on the other hand a rest of the fixer solution.

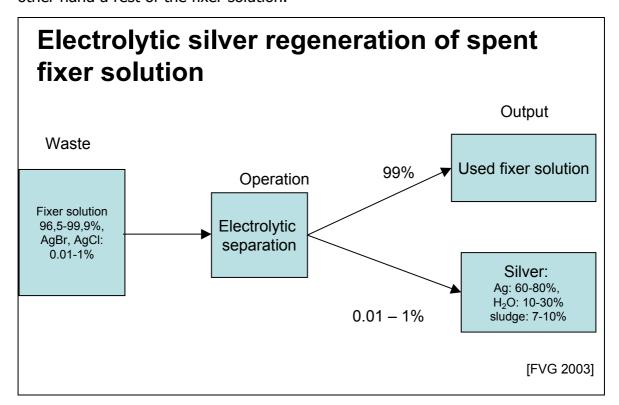


Figure 49: Electrolytic silver regeneration of spent fixer solution



4.25 Hydrometallurgical treatment of electroplating sludge

Hydrometallurgical treatment of electroplating sludge is for example precipitation where an acid, alkaline or other solution selectively dissolves certain precious metals and leaves others unaffected.

Input

The composition of the sludge depends highly on the production process from which it arose. The desired product and the operations involved to achieve this produce highly affect the amount and kind of metals to be found in the sludge.

Table 37: Composition of different electroplating sludge in w% dry matter

Composition	Cr₃-sludges	Cu-sludge	Zn-sludge	Cd-sludge	Ni-sludge
% H₂O	69.1	69.5	72.5	74.3	65.0
Al	1.2	1.5	0.7	0.8	0.8
Ca	8.1	9.2	7.6	2.3	5.7
Cd	0	0	0.3	0.1	0
Со	0	0	0	0	1.8
Cr	12.8	1.1	3.0	2.8	3.8
Cu	1.9	13.3	1.6	3.2	1.2
Fe	3.2	8.6	15.8	4.7	7.5
Mn	0.07	0.08	0.25	0.11	0.02
Ni	3.0	1.0	1.5	1.9	10.0
Pb	0.04	0.46	0.07	0.07	0.08
V	0	0.01	0	0	0.02
Zn	6.4	7.8	10.0	22.5	0.9
Sn	0	0.1	0.03	0	0.26
Na	2.5	1.0	1.6	0.8	9.6
K	0.07	0.57	0.6	0.7	0.08

[Müll und Abfall1987]

A recent study summarises the environmental relevant substances which occur in electroplating sludge



Table 38: Environmental relevant substances occurring in electroplating sludge

Element	occurrence	Max. in wt% dm	Average wt% dm
Cr	Nearly at all times	30	< 5
Cu		20	< 5
Zn		35	< 10
Sn	regularly	13	< 5
Ag	sometimes	4	< 0.1
Ва	_	35	< 0.1
Со	_	0.3	< 0.1
Мо	rarely	0.5	< 0.01
Nb		0.05	< 0.01
Se		0.1	<0.01
Zr		0.05	< 0.01

[Kersting 2003]

The output to metallurgic treatment of electroplating sludge is closely connected to the overall load of precious metals. Figure 50 indicates an exemplary composition of electroplating sludge and is based on an efficiency of the process of 90%.

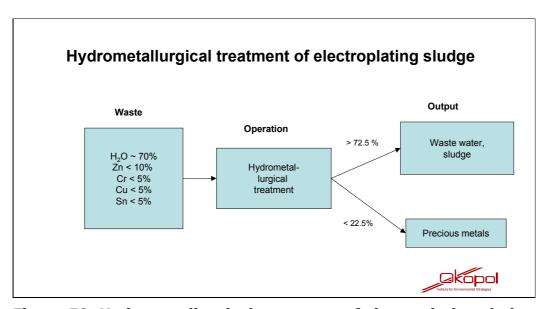


Figure 50: Hydrometallurgical treatment of electroplating sludge



4.26 Multi-step chemical physical treatment of oil-water emulsion for deemulsification

The input of the operation is a mixture of oil and water of different composition, mainly resulting from metal industry and from oil water separators e.g. of garages, gasoline stations, vehicle washing. It is characterised by organic compounds, minerals, heavy metals, detergents and varying water content between 60-90%.

Oil-water emulsion passes a sieve and a reactor for sedimentation which effectuates the extraction of sands and the skimming of free oil. The liquid output is homogenised by stirs for sample analysis, neutralised by HCl or Na₂S and cracked mainly by FeCl₃. Afterwards the oils are separated from waters by a batch flotation and a centrifuge. Waste water is treated biologically with activated sludge.

The output of the operation is a water fraction, a sludge fraction, and an oil fraction with broad varying shares according to varying input fractions. The fate of the water fraction is the municipal waste water treatment, the oil fraction is or used as refuse derived fuel or for material oil recovery; the sludge is disposed or incinerated.

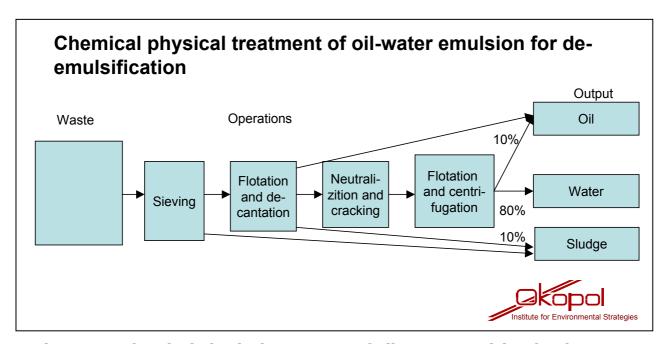


Figure 51: Chemical physical treatment of oil-water emulsion for deemulsification



4.27 Precipitation of PVC

Depending on the introduced wastes and the desired output fraction the waste is cleaned, sorted by colour and grinded. The soluble parts of the waste are then dissolved by solvents. The insoluble parts are separated e.g. by centrifugation or decanting. The solved PVC is extracted from the solution by evaporation of the solvent. After centrifugation the PVC is dried and used for tarpaulin and canvas.

The parts separated during pre-treatment and filtering are incinerated [Vinyloop 2003].

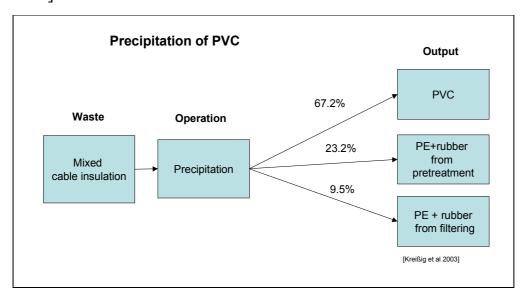


Figure 52: Precipitation of PVC

4.28 Feedstock recovery of PVC

This Process carried out by RGS 90 Industrimiljø includes hydrolysis of granulated PVC waste in sodium hydroxide solution at a temperature of $250\,^{\circ}$ C, to convert the chlorine from the PVC waste into salt dissolved in water. The salt can be extracted by vacuum crystallisation using heat. The dechlorinated PVC waste is heated towards $600\,^{\circ}$ C in an oxygen free atmosphere. This results in the production of chlorine free oil and a solid residue containing the mineral fillers, most of the heavy metals from pigments and stabilizers, and carbon [RGS 90 2002]



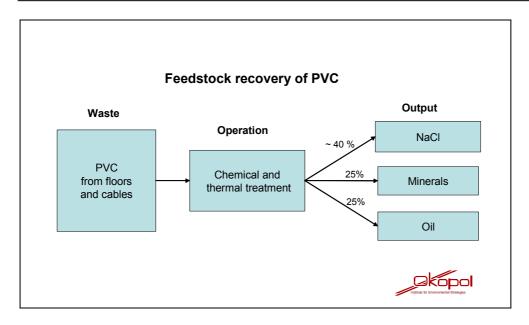


Figure 53: Feedstock recovery of PVC

Input: PVC waste from floors and mixed PVC cable waste

Output:

Three main fractions can be identified as an output of this process.

- 1. Salt which can be used for industrial applications like PVC industry of as salt for roads.
- 2. Chlorine free oil with an organic content of approximately 1 ppm¹⁰⁵. It can be used as feedstock for the petrochemical production.
- 3. A solid residue containing the mineral fillers, most of the heavy metals from pigments and stabilizers, and carbon. This composition can be used to produce the sandblasting material Carbogrit if mixed with raw materials and then melted at 1450°C. The high content of carbon in the residue will be used in the Carbogrit process. The lead contained in the solid residue evaporated during the Carbogrit production into the flue gas cleaning system. It can enriched in the fly ash and extracted [RGS 90 2002].

 $^{^{105}}$ The limits given by oil companies is 5 ppm.



4.29 Chemolysis of polyurethane

In order to produce polyol, polyurethane production waste is reduced in a cutting mill to a size of approx. 5 cm. It is then continuously fed into a depressurised reactor that already contains process reagents as a receiver - depending on the type of reclaimable material polyol, glycol or carboxylic acid as well as catalysts and deamination agents. The molecular chains are split through continuous stirring at temperatures of around 200 $^{\circ}$. At the end of the reaction process (duration approx. 7 hours) the resulting liquid mixture of polyols and low-molar urethanes is filtered. Residues (< 1 w%) consisting of foreign matter are removed [H & S Anlagentechnik GmbH, pers. comm.]

Input description:

The range of composition is limited by the requirements of the applied depolymerisation technique (Hydrolysis, Glycolysis, Alcoholysis etc.). Usually production waste is used as an input for the process. Polyurethane itself is made out of Isocyanat (e.g. Toluene diisocyanate) and Polyols (e.g. Polyesther or Polyether).

Critical parameters:

The purity of plastics types is crucial for the quality of the desired output fraction "Tailored" plastic complicate the chemical recycling because the adequate reactants and applications for the product have to be found.

Output description:

Depending on the introduced waste plastic and operation different applications are possible. The glycolysis of polyurethane foam for example produces different Polyols (depending on the Glycol used) and can usually only form rigid PU foams.

Relevance:

100,000 tonnes PU per year are treated annually, approximately 2,000 t/year are depolymerisated [Weigand, Strobbe 1995].



4.30 Grinding of polyurethane

Unwanted metal is removed and the polyurethane is grinded into different diameters depending on the application to follow.

Output description:

Depending on the introduced waste plastic and operation different application are possible.

Relevance:

1,000 tonnes PU per year are grinded annually [Weigand, Strobbe 1995].

About 100,000 tonnes waste PU are being treated in Western Europe [Weigand, Strobbe 1995].

4.31 Use of photochemical waste for SNCR

Spent fixer solution and spent developer solution are separately collected mainly from photo laboratories, hospitals and printing industry. The estimated waste amount is about 0.75 litres per inhabitant [RethmannPhoto 2003] which results in about 300,000 tonnes in the European Union (15), assuming a density of 1.1 kg/l and 380 million inhabitants.

Waste fixer solution and waste developer solution pass several unit operations to end up as a mixture that can be used to reduce nitrogen oxide from off gases e.g. in cement industry or waste incinerators (selective non-catalytic NOx reduction (SNCR).

Spent fixer solution is characterized by 85% water content, about 15% thiosulphate and a pH value of 3,5-7,5 [Ökopol 1997]. The remaining ammonium content is about 2% [Baumann 1999, NRW-LUA 2003, RethmannPhoto 2003].

Each of the spent solutions is filtrated to separate particles, afterwards with the spent fixer solution an electrolytic regeneration of the silver content is carried out (compare p.141).



The non-silver output of the electrolytic regeneration is diluted at a ratio of about 1:1 with spent developer solution. Waste developer solution is characterized by 95% water content, about 1% sulphite, less than 1% organic compounds like hydrochinone and a pH value of 9-13. [Ökopol 1997]. Most frequently used developer solutions have no ammonium combinations [Baumann 1999].

The output of the operation is a solution with about 0.6-2% ammonium [Baumann 1999]. This solution is mixed with uric acid to achieve a material for the selective non-catalytic NOx reduction (SNCR) in off gases e.g. of cement industry.

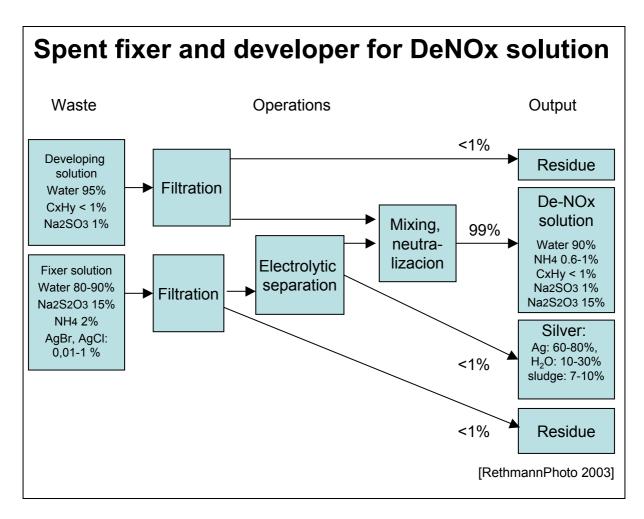


Figure 54: Mixing of photochemical waste for DeNOx solution

In combustions plants like waste incinerators the solution is spread into the hot zone after the combustion zone ($\sim 800\text{-}1000^{\circ}\text{C}$). The NO_x is reduced by ammonium (e.g. $4\text{NO} + 4\text{NH}_3 + \text{O}_2 \rightarrow 4\text{N}_2 + 6\text{H}_2\text{O}$).

In this operation the treated original waste substitutes other ammonium solutions. Often those substituted solutions are treated wastes as well.



4.32 Drying of sewage sludge

Sewage sludge from industrial or municipal waste water treatment is collected and treated to reduce the water content. From an annual production of some 5.5 million tonnes of dry matter in 1992, the Community is heading towards nearly 9 million tonnes by the end of 2005 [EC 2003].

The input of the recovery operation is sewage sludge from industrial or municipal waste water treatment containing poorly biodegradable trace organic compounds, nutrients such as nitrogen and phosphorous, heavy metals and potentially pathogenic organisms (viruses, bacteria etc) [ICON 2001].

Sewage sludge can be mechanically de-watered e.g. by decantation, presses and extruders. Extruders produce pellets that may be further dried e.g. on perforated conveyor belts which pass a drying zone with hot air. The retention time can be adjusted to the desired output characteristics like content of dry substances, stabilization or disinfection [Stela 2003].

The output of the operation is dried sewage sludge and waste water. The proportion and composition of the output fractions varies significantly according to the technology and the desired output characteristics (dedication to waste incineration, use as solid recovered fuel, spreading on land or landfilling).

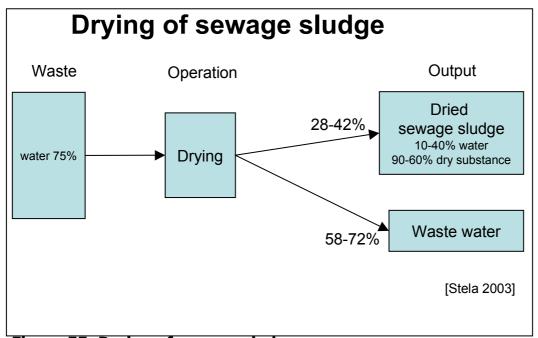


Figure 55: Drying of sewage sludge



4.33 Mechanical soil cleaning

Contaminated soils are cleaned by washing and separation. In the first case the contaminants are dissolved or suspended in the washing agent which is subsequently treated by conventional wastewater treatment operations. In the second case the contaminants are concentrated in a smaller volume of material by separating fine particles¹⁰⁶. The technology is applicable for different types of contaminations like e.g. heavy metals and organic substances.

Three examples are shown in the following figures:

- a) sand which is contaminated with heavy metals (HM)
- b) soil which is contaminated with hydrocarbons (HC)
- c) soil which is contaminated with heavy metals and hydrocarbons (HC + HM)

The following figure shows the distribution of the particle sizes.

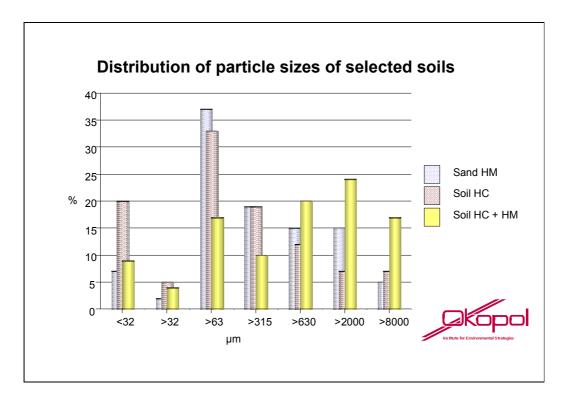


Figure 56: Distribution of particles sizes

¹⁰⁶ Contaminants are bound to the particle surface. By extracting the fine particles with its large surface per volume unit a reduction of the concentration in the remaining fraction can be achieved.



The following figure shows the input and output streams of the cleaning operation a).

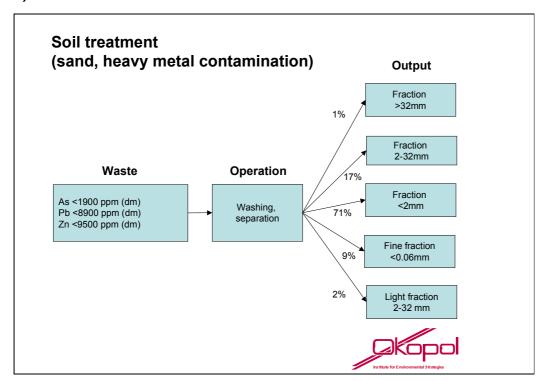


Figure 57: Treatment of sand contaminated with heavy metals

The following figure shows the input and output streams of the cleaning operation b).

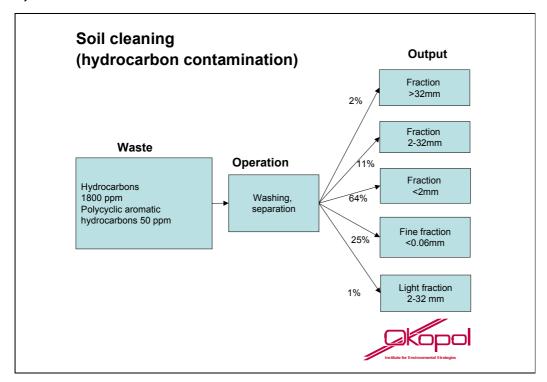


Figure 58: Treatment of sand contaminated with hydrocarbons



The following figure shows the input and output streams of the cleaning operation c).

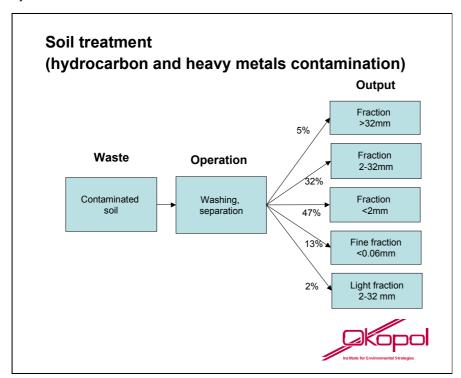


Figure 59: Treatment of sand contaminated with heavy metals and hydrocarbons

Within this operation no primary raw materials are substituted. The three examples show that depending on the contamination and the particle distribution of the input waste and the performance of the operation the contamination of the output differs largely. Due to costs reasons soil cleaning is performed generally only in those cases where it is possible to recover a part of the output. For the output fractions no normative reference is available on European level.

4.34 Mixing/blending of hazardous waste

Hazardous waste is mixed and blended to achieve certain physical and chemical characteristics.

The input material may consist in different solid and liquid waste like halogenated and non-halogenated solvents, hydrocarbons and waste oils, oily sludge, paint sludge, varnishes, glues, mastics, inks, sludge and fluids from manufacturing materi-



als, distillation residues, used catalytic converters, activated charcoals, heavily polluted soils, carbon black, absorbents and adsorbents, filtration soils and filter cakes, purification, decanting and sewage sludge, soiled packaging, plastic and rubber wastes, small quantities of toxic wastes, tar, textile wastes, sawdust, waste water [Scoribel 2003].

The waste is analysed in a pre-selection unit, solvents and waste water are grouped and mixed to meet the client requirements; sludge and pastes are crushed and mixed with sawdust (impregnation base) in an automated process.

The output is a mixed and blended hazardous waste that meets client requirements e.g. of cement industry.

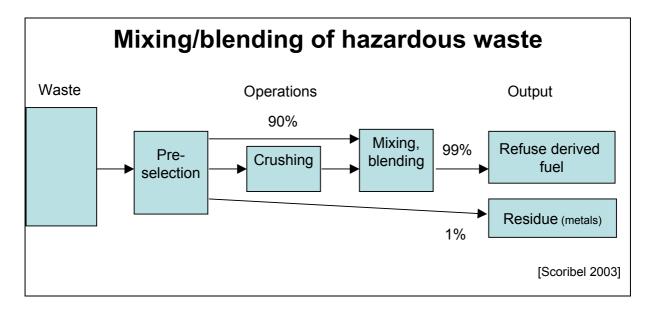


Figure 60: Mixing/blending of hazardous waste

4.35 Dismantling/depollution of ELV

According to the ELV Directive depollution by removal of components which contain hazardous substances and dismantling steps are mandatory for all ELV.

Battery-powered and pneumatic tools are commonly used for the dismantling steps and fluid removal pumps and drainage systems for the depollution

The following depollution steps are mandatory:



- removal of batteries and liquified gas tanks,
- removal or neutralisation of potential explosive components, (e.g. air bags),
- removal and separate collection and storage of fuel, motor oil, transmission
 oil, gearbox oil, hydraulic oil, cooling liquids, antifreeze, brake fluids, airconditioning system fluids and any other fluid contained in the end-of-life vehicle, unless they are necessary for the re-use of the parts concerned,
- removal, as far as feasible, of all components identified as containing mercury.
- Dismantling of the following heavy metal containing parts:

Entry No. ¹⁰⁷	Description	
5	Batteries which contain lead	
6	Vibration dampers made of lead	
7	Wheel balance weights made of lead	
11	Solder in electronic circuit boards and other electric applications (Dismantling if, in correlation with entry 14, an average threshold of 60 grams per vehicle is exceeded. For the application of this clause, electronic devices not installed by the manufacturer on the production line shall not be taken into account.)	
12	Copper in brake linings containing more than 0,5 % lead by weight	
14	Electrical components which contain lead in a glass or ceramic matrix compound except glass in bulbs and glaze of spark plugs (for components other than piezo in engines) (Dismantling if, in correlation with entry 11, an average threshold of 60 grams per vehicle is exceeded. For the application of this clause, electronic devices not installed by the manufacturer on the production line shall not be taken into account.)	
18	Absorption refrigerators in motor caravans which contains hexavalent chromium	
19	Discharge lamps and instrument panel displays which contain mercury	
21	Batteries for electrical vehicles which contain cadmium	

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¹⁰⁷ in the **new** Annex II of the ELV Directive



Dismantling operations

The following components must be dismantled:

- catalysts,
- metal components containing copper, aluminium and magnesium if these metals are not segregated in the shredding process,
- tyres and large plastic components (bumpers, dashboard, fluid containers, etc), if these materials are not segregated in the shredding process in such a way that they can be effectively recycled as materials,
- glass.

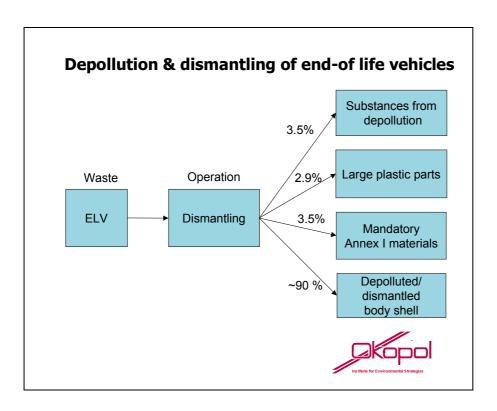


Figure 61: Mass flow from depollution/dismantling of ELVs

Relevance:

In the recital clauses of Directive 2000/53/EC (ELV Directive) 8-9 million tonnes of wastes from ELV are mentioned. EEA reports an amount of 8-10 million tonnes per year for reporting EEA Member States [ETC WMF 2003a]. The *projected* number of ELV is described as 13 million for 2000^{108} .

¹⁰⁸ http://waste.eionet.eu.int/wastebase/quantities, waste type: End-of-life vehicles, year: 2000. Data for AT, BE, DK, FI, FR, DE, GR, EI, IT, LU, NL, PO, ESP, SE and UK.



4.36 Removal of hazardous substances from waste fridges

Refrigerants like chlorofluorocarbons (CFC) or hydrofluorocarbons (HFC) are extracted from the cooling system. The isolating foam will be removed and the CFC/HFC are extracted by being pressed out of the foam.

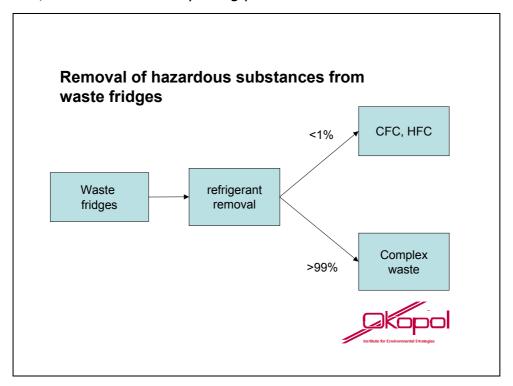


Figure 62: Removal of refrigerants from waste fridges

Relevance

The WEEE Directive names cooling appliances, refrigerators, freezers etc. in Annex I B in Article 7 (2 d). For those products Article 7 (2 a) lays down recovery rates Furthermore Annex II states that chlorofluorocarbons (CFC), hydrochlorofluorocarbons (HCFC) or hydrofluorocarbons (HFC) and hydrocarbons (HC) have to be removed from any separately collected WEEE.



4.37 Cap-cutting of gas discharge lamps

Before the cap cutting metal components and lamp ends and lead containing components are separated from the gas discharge lamp. These parts of the lamps are further separated and cleaned.

The glass mixture containing lead is submitted to lead smelter. The aluminium scrap is used at scrap processing facilities. The luminous coating is landfilled.

From the remaining tubes the mercury and luminescent substance is blown out by compressed air, which is landfilled afterwards.

The stripped tubes are then crushed and cleaned via rotating sieves and submitted to glass smelting factories [Larec 2003].

Another possibility for gas discharge lamp recovery would be to shredder them in a specialised installation. The mercury is captured from the off gas by using activated coke. The efficiency of this operation is usually lower than with cap-cutting as the separation of all components is done after the shredding step.

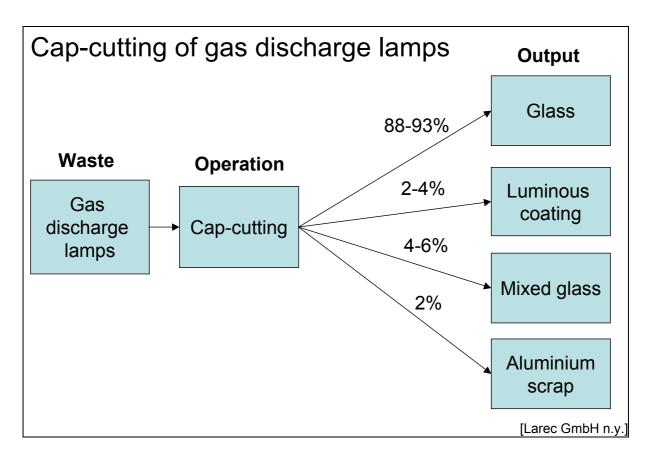


Figure 63: Cap-cutting of gas discharge lamps



Relevance

Around 110 million compact fluorescent lamps (one type of gas discharge lamps) have been sold in 1997 in Western Europe [AEA 1999]. The WEEE Directive names gas discharge lamps explicitly in Article 7 (2 d). Regarding WEEE sent for treatment in accordance with Article 6, Member States shall ensure that, "by 31 December 2006, producers meet the following targets:

for gas discharge lamps, the rate of component, material and substance reuse and recycling shall reach a minimum of 80 % by weight of the lamps."

Furthermore Annex II states that gas discharge lamps have to be removed from any separately collected WEEE and that the mercury shall be removed.

4.38 Storing of Gypsum from off-gas cleaning

Flue gas Desulphurisation Gypsum (FDG) is stored on separate areas before selling for the production of wallboard and/or cement.

Input description:

Origin: Within the adsorption step of a flue gas scrubbing unit the SO2 is removed by introducing $CaCO_3$ and $CaSO_3$ is generated. The released oxygen reacts with CaSO3 to Gypsum ($CaSO_4$). All $CaSO_4$ can be oxidised by setting the right ph-value and introducing atmospheric oxygen. The gypsum is dried and den stored for further application.

The range of composition is limited by the requirements of the flue gas scrubbing process.

Table 39: Quality criteria of FDG gypsum

Component	Portion in %
CaSO ₄ x 2H ₂ O	>95
Free moisture	< 10%
MgO	<0,1
Cl	< 0,01
SO ₂	< 0,25

[Eurogypsum, n. y.]



Critical parameters:

It remains unclear if the gypsum will actually be used after a certain period of time.

Output description:

The gypsum remains unchanged on the storing site.

Relevance:

Around 7.6 million tonnes of flue desulphurisation gypsum have been produced in Europe in 1999 and Germany had the highest share with 5,7 million tonnes. Around 6% (456,000 tonnes) of this amount is temporarily stockpiled for future utilisation [ECOBA 2001]

4.39 Neutralisation of waste acids

Different wastes are stored and mixed for neutralisation with a minimum of chemicals.

The input of the operation is waste acids and bases (e.g. sulphuric, hydrochloric, hydrofluoric, phosphor, nitric acids, calcium hydroxide, soda and ammonia).

Reaction tanks are filled with a charge of alkali and agitated while adding acid wastes (exothermic reaction); in most operations additional alkali is brought in to neutralize the predominating acid mixtures. Flocculants may be added if needed but sometimes there are sufficient iron salts in the incoming acid. The decanted sludge maybe pressed for water reduction [WT-BREF 2003].

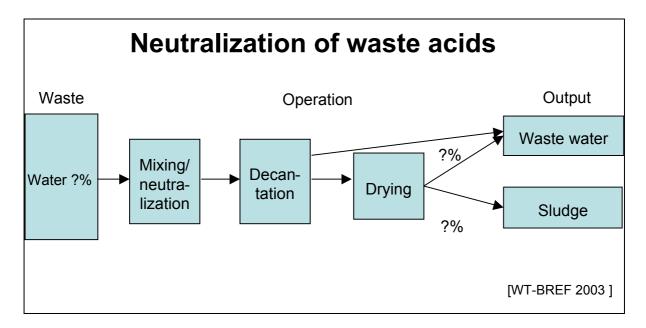


Figure 64: Neutralisation of waste acids



The desired output is typically a slightly alkaline material that encourages the flocculation or precipitation of metals as a disposable sludge. The sludge is disposed; the waste water ends up in a mechanical-biological waste water treatment.

4.40 Landfill of mixed solid waste

Waste is permanently stored on authorised areas (fenced in, geological barrier, gas drainage layer, water drainage layer), compacted and finally covered with a top soil cover (soil or impermeable material).

Critical parameters are inter alia: moisture and the concentration of acids, organic substances, chlorine, bromine, fluorine, sulphur, heavy metals and persistent substances. In several cases the leaching rate is used as a decisive parameter with regard to the necessary equipment of the landfills.

There is no immediate output of the operation (not considering dust or long term output like air and water emissions).



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