MANUAL ON INDUSTRIAL HAZARDOUS WASTE MANAGEMENT FOR AUTHORITIES IN LOW AND MIDDLE INCOME ECONOMIES

- Table of contents, preface, how to use the manual, acronyms, glossary, interesting links, list of figures and tables
# Table of contents

- Table of contents, Preface, How to use the manual, acronyms, glossary, Interesting links, List of figures and tables .............................................................. 1

- Preface .................................................................................................................................................. 12

- How to use this manual ......................................................................................................................... 14

- List of Acronyms and Abbreviations .................................................................................................. 15

- Glossary ................................................................................................................................................ 19

- Definitions as per European Framework Directive on Waste 2008/98/EC ................................. 30

- Some interesting Internet links ............................................................................................................. 32

- List of Figures ....................................................................................................................................... 35

- List of Tables ......................................................................................................................................... 40

- Module 1 ............................................................................................................................................. 43

- Hazardous Waste Generation, a summary ......................................................................................... 43

- Basic Policy Principles of Adequate Waste Management ................................................................. 43

- Waste types and hazardous waste generation - Summary ............................................................... 44

  1.1. Main types of hazardous waste ...................................................................................................... 45

    1.1.1. Healthcare waste (HCW) ....................................................................................................... 45

    1.1.2. Industrial hazardous waste .................................................................................................. 47

  1.2. Hazardous waste generation ....................................................................................................... 50

- Basic Policy Principles with Relevance for Adequate Management of Hazardous Waste 55

  2.1. The Precautionary Principle ........................................................................................................ 55

  2.2. The ‘Duty of Care’ Principle ......................................................................................................... 55

  2.3. The ‘Polluter Pays’ Principle: ....................................................................................................... 56

  2.4. The Cooperative Principle ............................................................................................................ 57

  2.5. The Principle of the ‘Waste Management Hierarchy’: ............................................................... 57
2.5.1. Life Cycle Thinking and Assessment .......................................................... 59

2.6. The Principle of ‘Extended Producer Responsibility’: .................................. 60

2.7. The Principle of ‘Waste Management Self-sufficiency’: ................................ 61

2.8. The Proximity Principle: ............................................................................. 61

2.9. The Principle of ‘Best Available Technique’ (BAT): .................................. 62

2.10. Lessons learnt of German International Cooperation in the Field of Waste Management ........................................................................................................ 63

2.11. Adequate Management of Hazardous Waste .............................................. 67

2.12. Necessary obligations for waste management infrastructure (waste collection and treatment facilities) ................................................................. 68

2.13. Obligations and standards for waste treatment facilities ........................ 69

2.14. Obstacles in relation to the establishment of HWM Systems and approaches for possible solutions ................................................................. 69

2.15. Where is your country in relation to an adequate Hazardous Waste Management System? ................................................................................................. 71

- ........................................................................................................................ 75

- Modules 2 ........................................................................................................... 75

- Legal Frame ....................................................................................................... 75

- International Agreements .................................................................................. 75

- EU waste legislation .......................................................................................... 75

Main international conventions dealing with hazardous chemicals and wastes and their legal repercussions ........................................................................ 76

3.1. Main Actors of International Conventions .................................................... 76

3.2. Multilateral environmental agreements dealing with hazardous chemicals and OECD council decision C (2001)107 on waste .................................................. 77

3.2.1. Basel Convention on the Control of Trans-boundary Movement of HW and their Disposal ................................................................. 78

3.2.2. Rotterdam Convention (PIC Convention) ................................................. 82

3.2.3. Stockholm Convention (POP Convention) ............................................... 83

3.2.4. OECD Decision on the Control of Trans-boundary Movements of Wastes 85

3.3. Legal Assistance from BC secretariat and OECD ........................................ 86

3.3.1. Basic principles of waste legislation to be considered (Basel Convention) 87
3.3.2. Additional aspect to be considered (OECD) in waste legislation, implementation and enforcement

- European Union Legal Framework for Hazardous Waste Management ................. 93

4.1. European Union’s Policy on Hazardous Waste Management ........................................ 93
  4.1.1. Key regulators and enforcing agencies of the European Hazardous Waste System ..... 96
  4.1.2. Systemic prerequisites 96

4.2. Definition of Waste and Classification of Hazardous Waste in the European Union .... 97
  4.2.1. Definitions of Waste 97
  4.2.2. Distinguishing Waste from Non-Waste 98
  4.2.3. Classification of Hazardous Waste 102
  4.2.4. Background and Structure of the European Waste List 104

4.3. Classification of Hazardous Waste according to the European Waste List ............. 108
  4.3.1. How to Find a Waste Code in the EWL 108
  4.3.2. Hazardous characteristics that render wastes hazardous 110
  4.3.3. Hazardous characteristics and Threshold Levels for Dangerous Substances 113
  4.3.4. Establishing the Hazardous – Non-hazardous Nature of a Waste when the Waste Composition is known 115
  4.3.5. Establishing the Hazardous – Non-hazardous Nature of a Waste via Analytical Chemical Investigation 118
  4.3.6. Determination of Hazardous Properties by Direct Testing 122

- ........................................................................................................................................ 125

- Module 3 .................................................................................................................................. 125

- Guidance, training, education, and capacity building for waste generators and waste transporters: ......................................................................................................................................... 125

- On-site Hazardous Waste Management .............................................................................. 125

- Preparation for transport of dangerous goods ...................................................................... 125

- Control of hazardous waste transport ................................................................................. 125

5.1. On-site identification, separation, management, temporary storage and preparation for transportation of Hazardous Waste ........................................................................................................ 128
  5.1.1. Identification and quantification 128
  5.1.2. Principle of On-site Waste Inspections 128
  5.1.2.1. Case Study: Closing the Gap between Declared and Actual Hazardous Waste Generation by On-site Waste Investigations 133
  5.1. 2. Separation 137
5.1.3. Management

5.2. Internal HW Collection and temporary Storage ............................................................... 143

5.2.1. Hazardous waste service providers 144

5.3. Waste Acceptance Procedure ............................................................................................. 148

5.4. Special Transport Vehicles for hazardous waste ................................................................. 148

5.5. Preconditions for Transport to the Hazardous Waste Treatment and disposal facilities 151

5.5.1. Duties of the Hazardous Waste Producer 151

5.5.2. Duties of the Hazardous Waste Transporter – General Personnel 151

5.5.3. Special requirements of Hazardous Waste Transporter regarding driver qualification and Vehicles 153

5.5.4. Transport of dangerous goods (TDG) 154

5.5.5. Labeling system for HW vehicles UN-Number //ADR Numbers 156

5.5.6. Classification of Hazardous Waste according to the Regulations for Dangerous Goods 159

5.5.7. Transport Emergency Card 160

- Control for Hazardous Waste Transport .................................................................................. 162

6.1. Preliminary Remarks ............................................................................................................ 162

6.2. Certificate of Proper Waste Management of Waste in Germany ......................................... 163

6.2.1. The “Record of Proper Waste Management” (RPWM) Procedure 163

- Form “Cover sheet for records of proper waste management” ............................... 170

- Form “Declaration of Responsibility” ...................................................................................... 172

- Form „Declaration Analysis“ (DA) ......................................................................................... 174

- Form „Declaration of Acceptance“ ......................................................................................... 177

6.3. Case Study: The ‘Solid Waste Management Information System’ (SWMIS) of Zhejiang, China ....................................................................................................................... 179

6.3.1. Background 179

6.3.2. Features of the ‘Solid Waste Management Information System’ 180

6.3.3. How does it work? 180

6.3.4. Benefits 185

6.3.5. Status 185

6.3.6. Challenges and Lessons Learned 186

6.4. Monitoring and Control of On-Site Hazardous Waste Management .............................. 186

- Monitoring and Control of On-Site Hazardous Waste Management ...................................... 190

- Module 4 ................................................................................................................................. 191
• Allocation of hazardous waste to treatment and disposal facilities ............... 191

• Generalities about Chemical Physical Biological Treatment (CPT) facilities .... 191

• Allocation of Hazardous Waste to Recovery and Disposal Options ............. 192

7.1. Allocation Criteria .................................................................................. 194

7.1.1. Recycling 194
7.1.2. Other recovery - Energy recovery/use as a fuel 194
7.1.3. Other recovery - back filling 195
7.1.4. Chemical/physical and biological treatment (CPT) 195
7.1.5. Landfill disposal 196
7.1.6. Incineration 196
7.1.7. Underground disposal (High-safety above-ground disposal) 196

7.2. Regulating Hazardous Waste Acceptance in the Licenses of the Facilities .. 197

7.2.1. Application of Positive and Negative Lists for Facility Licensing 197
7.2.2. Prescription of Specific Limit Values for Waste Acceptance 199
7.2.3. Licensing and Ensuring Compliance with License Conditions 201

7.3. Chemical Analysis of Hazardous Waste .................................................. 202

7.3.1. Sampling 202
7.3.2. Objective and Methods of Testing 203

7.4. Recovery and Disposal Codes ................................................................ 207

• Generalities about Chemical / Physical Biological Treatment of HW for Disposal 210

8.1. General Chemical / Physical Biological Treatment of HW for Disposal .......... 210

8.2. Scale of CPT plants – Economy of scale ............................................. 217

• Cost assessment from the Sino – German cooperation project in Zhejiang, China for a CPT plant .................................................................................. 219

8.3. Clarification of terms: Stabilization – Solidification – Chemical-physical treatment .. 223

• ........................................................................................................... 227

• Module 5 ................................................................................................. 227

• Practical aspects of implementation and enforcement .................................. 227

• Permitting and inspection (HW Incinerators and landfills) .......................... 227

• Practical aspects of Implementation and Enforcement ................................ 228
9.1. Basic principles and procedures of implementation and enforcement of legal objectives ................................................................. 228

9.2. Main actors ............................................................................................................................................................................. 231

9.3. Practical aspects: responsibilities and duties of main actors .......................................................................................... 233

9.3.1. Responsibilities and duties of the competent authorities ................................................................. 233
9.3.2. Responsibilities and duties of the waste producer ................................................................................. 239
9.3.3. Responsibilities and duties of the waste collector/transporter ......................................................... 240
9.3.4. Responsibilities and duties of operators of waste treatment facilities ................................................. 240

• Permitting and inspection/control (HW incinerators and landfills) .........................241

Basic principles and questions related to waste management authorization / permitting 243

Register for waste treatment activities ......................................................................................................................... 244

Basic principles and questions to be answered in waste management controlling 245

• Module 6a .................................................................................................................................................................................. 251

• Incinerators and Air Pollution Control......................................................................................................................... 251

• Hazardous Waste Incineration and Air Pollution Control ..........................................................252

Hazardous Waste Incineration 252

• 10.1 Process ........................................................................................................................................................................... 252

• 10.2 Available incineration techniques ................................................................................................. 253

• 10.3 Rotary kiln incineration technique ........................................................................................ 253

•.......................................................................................................................................................................................... 255

10.3.1. Volume measurement and inspection of the input 256
10.3.2. Temporary storage of waste 256
10.3.3. Waste pretreatment 258
10.3.4. Feeding devices 258
10.3.5. Incinerators259
10.3.6. Energy production 262
10.3.7. Chimney and flue gas cleaning 262

• 10.4. Air Pollution Control ........................................................................................................................................... 265

10.4.1 Cyclone filter 266
10.4.2. Electrostatic precipitator 267
10.4.3. Fabric filters 269
11.3.1. Defining acceptance criteria 315
11.3.2. Basic characterization 316
11.3.3. Compliance testing 317
11.3.4. On-site verification 317

11.4. Geological Barrier ................................................................. 319

11.5. Technical Barriers ................................................................. 321

  11.5.1. Design 321
  11.5.2. Liner Systems 323
  11.5.3. Mineral Liners 324
  11.5.4. Geo-membranes 324
  11.5.5. Composite Liners 325
  11.5.6. Asphalt Concrete Liners 329
  11.5.7. Geo-synthetic Clay Liners 330

11.6. Leachate Drainage and Collection ........................................ 331

11.7. Landfill Gas Drainage ............................................................. 333

11.8. Reference Design for Sealing and Leachate Collection System ....... 333

11.9. Quality Assurance (QA) ............................................................ 333

  11.9.1. Suitability testing prior to the beginning of the construction 334
  11.9.2. Quality assurance measures during the construction of the sealing system 336

11.10. Operation .............................................................................. 336

  11.10.1. Leachate Minimization 339
  11.10.2. Leachate Treatment 340

11.11. Monitoring and Control .......................................................... 341

  11.11.1. Elements for control and monitoring procedures 342

11.12. Life Phases of a Landfill Site .................................................. 345

11.13. Economical Aspects .............................................................. 346


  • Underground Disposal of Hazardous Waste .............................. 354

  • ............................................................................................. 361

  • Module 8 ................................................................................. 361

  • Waste Management Planning ................................................. 361

  • Waste Management Plans ....................................................... 362

General aspects of WMP ................................................................. 362
13.1. Planning Principles and Procedures ................................................................. 371

13.2. Assessment of Current Hazardous Waste Generation ........................................ 373

13.2.1. Information collection 374
13.2.2. Estimation of Hazardous Waste Generation from Direct Data 374
13.2.3. Estimation of Hazardous Waste Generation from Secondary Data 376
13.2.4. Estimation of Hazardous Waste Generation by Conducting a Representative Sample Survey of Waste Producers 380

13.3. Forecast of Future Hazardous Waste Generation ............................................... 381

13.3.1. Factors influencing Hazardous Waste Generation 381
13.3.2. Prognosis of Actual and Reported Future Hazardous Waste Generation 382

13.4. Determination of the Future Disposal Capacity ................................................. 383

13.4.1. Estimation of Recovery and Disposal Capacity Required for Primary Wastes 384
13.4.2. Estimation of Secondary Waste Generation 388

13.5. Options for the Future Hazardous Waste Management Infrastructure ............... 390

12.5.1. Considerations with regard to Scale, Capacity and Location of the Disposal Facilities 390
13.5.2. Evaluation of Infrastructure Options 392
13.5.3. Ownership / Operator Models for the Future Hazardous Waste Management System 393

13.6. Advanced Waste Management Planning ......................................................... 394

13.6.1 Decoupling Waste Growth from Economic Growth 394
13.6.2 Curbing Greenhouse Emissions Arising from Waste Management 397

13.7. Case Study, Example from China: Developing a Hazardous Waste Management Infrastructure Plan (HWMIP) for the Province Zhejiang ...................... 400

13.7.1. Taking stock of the present situation 401
13.7.2. Prognosis of Future HW Generation 403
13.7.3 Assessment of Future Treatment and Disposal Capacity Needs 404
13.7.4. Four Alternatives for the Potential Future Infrastructure for HW Treatment & Disposal in Zhejiang Province 407
13.7.5. Results 409
13.7.6 Impact 412

- Module 9 .................................................................................................................. 415

- Factors contributing for a success of a HWM system, a summary .................... 415

- Factors Contributing to the Success of Hazardous Waste Management in a Country .............................................................................................................. 416

14.1 Strategic Area “Regulation and Planning” ............................................................ 417
14.2 Strategic Area “Effective Enforcement, Education and Training” ....................... 420
14.3 Institutional and Organizational Set-up ................................................................. 421
14.4 Strategic Area “Prevention, Recycling and Recovery” ........................................ 425
14.5 Strategic Area “Treatment and Disposal” .............................................................. 427
14.6 Strategic Area “Segregation, Collection, Storage and On-site Treatment” ......... 429
14.7 Strategic Area “Financial Instruments” ................................................................. 430
• Preface

With this manual GIZ addresses primarily competent authorities in low and middle income economies envisaging to establish a hazardous waste (HW) management system or to improve an existing system. It provides basic principles and key information on how to establish and apply a hazardous waste management system in a country or a region.

The manual shall serve as a basic reference document for all departments involved and all levels of authorities to achieve a multiplier effect and overall awareness of the importance of taking proper actions as an administrative body. The countries concerned might have different needs and start at different levels to set up or improve their waste management system.

The manual gives an overview on key issues related to legal requirements and practical procedures pertaining to environmentally sound HW management, taking into account and referring to requirements, recommendation and guidelines provided by Basel Convention and OECD where relevant and providing provisions and procedures from the European Union as model examples in particular.

This manual is a kind of compendium of relevant existing hazardous waste data divided in 9 thematic modules namely:

**Module 1**: Hazardous waste generation- summary and basic policy principles of adequate waste management

**Module 2**: Legal Frame, International agreements and EU waste legislation

**Module 3**: Guidance, training, education, capacity building for waste generators and transporters. On-site HWM, preparation for transport of dangerous goods and control of hazardous waste transport

**Module 4**: Allocation of hazardous waste to treatment and disposal facilities (with two supplements)

**Module 5**: Practical aspects of implementation and enforcement / Permitting and Inspection (HW incinerators and landfills)

**Module 6a**: Incinerators and Air Pollution Control

**Module 6b**: Co-processing: a hazardous waste incineration option

**Module 7**: HW Landfills and underground disposal of HW

**Module 8**: Waste management planning (with one supplement)
Module 9: Factors contributing to the success of a hazardous waste management system in a country, a summary.

But the manual should also serve as ready information tool for the private sector, local consultants, students, journalists and NGOs in low and middle income economies on the salient features of an efficient hazardous waste management system.

Hazardous waste is an unavoidable by-product of industrial processes. Therefore, management of hazardous waste is indispensable. Sound hazardous waste management will prevent harm to the environment and human health by detoxification, safe incineration or safe disposal of dangerous substances. For this purpose, all stakeholders, including small and medium scale enterprises (SMEs) have to get involved with hazardous waste management. However, the integration of SMEs into a sound hazardous waste management system in a specific country remains a big challenge.

Competent authorities should play a key role in supporting actively SMEs to adhere integrally to a waste management system.

With this manual we also want to change the perspective of HWM. The management of hazardous waste should be seen more as a resource efficiency activity (with emphasis in avoidance/substitution, reuse, recycle) in the frame of a circular economy rather than only the management of hazardous and non hazardous wastes. The field of recycling and pretreatment of wastes (secondary raw materials) is developing very fast and is creating new green jobs in countries where this approach is been implemented. In Germany already in 2009 by using secondary raw materials 13% of the needed raw materials by the local industry could be covered with secondary raw materials1.

Examples and technical information illustrate the implementation of hazardous waste management at the example of EU Member States, in particular Germany. Throughout the text some examples of a project carried out by the German International Cooperation in China are given. These case studies show the practical implementation of the information and knowledge laid down in the manual.

Also examples and best practices from different low, middle and high income economies dealing with the management of six major hazardous wastes types (industrial waste, e-waste, hospital waste, PCB waste, asbestos waste and lead batteries waste) are presented in a separate document.

• How to use this manual

Hazardous waste management is a large and complex subject. The manual is meant to provide the fundamental information, but does not claim to be complete. However, the manual provides reference to additional sources if more detailed information is desired.

The glossary contains the definitions of the main terms used, which can be used as a quick guide of these most useful definitions. However, in the majority of the cases the terms used are described and explained in the text or a reference is given.

Where appropriate, the main statements made in the chapters and important definitions are highlighted in boxes. Thus, quick readers may refer to the boxes for a short outline of the main points of the respective chapter.

The structure of the manual permits its use according to the need of the reader. If only a quick overview is needed, the reader can refer to the summary box at the end of each chapter.

In order to facilitate the acquisition of further information references include hyperlinks (the respective text appears in blue and underlined), which can be used to retrieve further information from the World Wide Web.

Both in drafting legislation and in establishing the corresponding enforcement system keep in mind the practicability and efficiency of envisaged measures and the provisions. It is recommendable to take a stepwise approach, starting from more basic requirements to a sophisticated system and from more simple treatment to the higher end of what is technically possible. Nevertheless legislation and enforcement should be organized in a way to ensure and promote constant improvement, expansion and further development of the system.

In addition, please be aware that hazardous waste is only a part of the waste generated by societies and that a comprehensive waste management system also needs to address any other waste streams, namely municipal solid waste, agricultural waste, sewage sludges and construction and demolition waste.

The majority of the recommendations provided in this manual can be applied in principle also for these other waste streams. In addition, the mentioned waste streams are more and more contaminated with hazardous compounds as new products with other materials than just natural ones are increasingly used also in households and commerce or construction.
• **List of Acronyms and Abbreviations**

ADR: accord européen relatif au transport international des marchandises dangereuses par route = European agreement concerning the international carriage of dangerous goods by road

ANC: Acid Neutralization Capacity

AOX: Adsorbable Organic Halogen Compounds

AFR: Alternative fuels and raw materials

APC: Air Pollution Control

BAT: Best Available Technology

BMZ: German Federal Ministry for Economic Cooperation and Development

BOO: Build Own and Operate

BOOT: Build Own Operate and Transfer

BOT: Build Own and Transfer

BREFs: Best Available Techniques Reference Documents

BS EN ISO: British Standards (BS) European Standards (EN) International Organisation for Standards (ISO)

BTEX: Benzene, Toluene, Ethylbenzene, Xylenes

C: Confirmation (Behördliche Bestätigung, BB)

°C: Degree Celsius

C&D wastes: construction and demolition wastes

CEC: North American Commission for Environment Cooperation

CEN: Comité Européen de Normalisation = European Committee for Standardization

CN: Consignment Note (Entsorgungsnachweis)

CPT: Chemical/ physical and biological treatment

CS: Cover Sheet

DAc: Declaration of Acceptance

DAn: Declaration Analysis (Deklarationsanalyse)

DOC: Dissolved Organic Carbon
DMSO: Dimethylsulfoxide
DN: Diameter Nominal, international standard for internal pipe diameters, e.g. DN 300 = (Pipe with an) internal diameter of 300 mm.
DR: Declaration of Responsibility
ECJRC: European Commission Joint Research Center
EECZ: Environmental-oriented Enterprise Consultancy Zhejiang
EIT: Economies in transition
ELV: End of life vehicle (= scrapped cars)
EN: European Norm
EPA: Environmental Protection Agency
EPB: Environmental Protection Bureau, China
ESM: Environmentally Sound Management
EU: European Union
EWL: European Waste List
Fig.: Figure
GDP: Gross Domestic Product
GSB: Sonderabfallentsorgung Bayern GmbH (Bavaria Hazardous Waste Disposal Corporation)
GHS: Globally Harmonized System of Classification and Labelling of Chemicals
H-criteria: Hazardous Criteria, Hazardous properties of waste
HCW: Healthcare waste
HCWM: Healthcare waste management
HIM GmbH: Hessische Industriemüll GmbH (HW Disposal Corporation in the state of Hesse)
H: Gross Calorific Value
HWI: Hazardous Waste Incineration
HWL: Hazardous Waste Landfill
HWM: Hazardous Waste Management
HWMIP: Hazardous Waste Management Infrastructure Plan
IBC: intermediate bulk container
IPPC: Integrated Pollution Prevention and Control
IT: Information technology
kN/m$^2$: kilo Newton per square meter (1 kN/m$^2$ = 1000 Pascal)
KJ/kg: Kilojoule per kilogram
LDC: Less developed countries
LRMC: Long run marginal costs
L/S: Liquid to Solid Ratio
LOI: Loss of Ignition
MEAs: Multilateral environmental agreements
Mg: Megagram = (1000 kg = 1 metric ton)
MJ: mega Joule
µS/cm: micro Siemens per centimeter
MSDS: Material Safety Data Sheet
MSW: Municipal Solid Waste
NACE: Nomenclature of economic activities in the CE
NO$_x$: Nitrogen Oxides
OECD: Organisation for Economical Co-operation and Development
OsWI's: On site waste investigations
PAH: Polycyclic Aromatic Hydrocarbons
PCB: Polychlorinated Biphenyls
PCDD: Polychlorinated Dibeno-p-Dioxin
PCDF: Polychlorinated Dibenzofurans
PCP: Pentachlorphenol
PIC: Prior Informed Consent
PPE: Personal Protective Equipment
POP: Persistent Organic Pollutant
NGO: Non-Governmental Organization
REACH:  Registration, Evaluation, Authorisation and Restriction of Chemicals
RPWM:  Record of Proper Waste Management
SEPA:  State Environmental Protection Agency, China (today Ministry of environment (MEP))
SMEs:  Small and Medium scale Enterprises
SDS:  Safety Data Sheet
SSE:  small size enterprise
SSL:  Software Site License
SWMIS:  Solid Waste Management Information System
TCDD:  Tetra chlor benzodioxin
TCLP:  Toxicity Characteristic Leaching Procedure
TDG:  transport of dangerous Goods
TDS:  Total amount of Dissolved Substances
TFS:  transfrontalier shipment notification document
TOC:  Total Organic Carbon
TSCA:  Toxic substances control act
UGL:  Underground Landfill
UN/ADR:  United Nations/European agreement concerning the international carriage of dangerous goods by road
UNCED:  United Nations Conference on Environment and development
UNECE:  United Nations economic Commission for Europe
US:  United States
VHHC:  Volatile Halogenated Hydrocarbons
VOC:  Volatile Organic Compounds
WBCSD:  World Business Council for Sustainable Development
WEEE:  waste electric electronic equipment
WHO:  World Health Organization
WMO:  Waste management officer
ZSWMSC:  Zhejiang Solid waste Management and Supervision Center
• Glossary

Absolute entries

Absolute entries are entries of waste categories in the European Waste List which are considered as “absolute” hazardous regardless of any threshold concentrations.

BAT

“BAT” stands for Best Available Techniques. In the sense of EU IPPC legislation (namely Directive 2008/1/EC), “Best Available Techniques” means the most effective and advanced stage in the development of activities and their methods of operation which indicate the practical suitability of particular techniques for providing in principle the basis for emission limit values designed to prevent and, where that is not practicable, generally to reduce emissions and the impact on the environment as a whole:

- “techniques” shall include both the technology used and the way in which the installation is designed, built, maintained, operated and decommissioned

- “available” techniques shall mean those developed on a scale which allows implementation in the relevant industrial sector, under economically and technically viable conditions, taking into consideration the costs and advantages, whether or not the techniques are used or produced inside the Member State in question, as long as they are reasonably accessible to the operator

- “best” shall mean most effective in achieving a high general level of protection of the environment as a whole

Biological treatment

Destruction or degradation of a hazardous compound by microbes, e.g. PAH degradation by bacteria, chromium (VI) reduction by bacteria with the help of organic substances (molasses or oils)

BREFs

“BREFs” stand for Best Available Technique Reference Documents. Best Available Techniques Reference Documents (BREFs) are provided by Technical Working Groups for various industrial branches, e.g. for waste treatment industries, waste incineration, surface...
treatment of metals and plastics or tanning of hides and skins\(^2\). The Technical Working Groups include national experts and representatives from industry and environmental organizations. The information provided in the BREFs is focused on applied and emerging processes and techniques of a specific industrial branch and their performance as well as on the techniques to consider in the determination of Best Available Techniques. This information supports the evaluation of what is technically and economically achievable in terms of best environmental performance within waste management facilities. The European IPPC Bureau (see below) is in charge of the drawing up of BREFs.

**Chemical treatment**

Destruction or change of a hazardous compound by a chemical reaction, e.g. reduction of chromium (VI) or oxidation of cyanide

**Chemical Physical and Biological treatment (CPT)**

Chemical/physical and biological treatment (CPT) can lead to a change in waste quality as well as be considered as a treatment and disposal process. As a rule, waste from CPT is assigned to a different waste code, if it is shipped to a subsequent treatment process (e.g. disposal to landfill, incinerator or to a waste oil redistillation plant). Therefore the allocation to a CPT plant is only the first step in a sequence of several treatment-, recovery- or disposal operations.

**Circular economy**

In the sense of avoidance and usage of wastes, also now as closed substance cycle

**Cleaner Production**

Cleaner Production is the Manufacturing in which waste minimization and prevention practices are continuously applied. These practices include (1) conservation of raw materials and energy, (2) elimination of toxic inputs, and (3) reduction in toxic outputs\(^3\)

**Co-incineration**

Often means the same as co-processing, exactly: only the energy potential of a waste is of interest and not the mineral components, e.g. organic chemicals for Portland cement production or light-weight fraction from the shredder in a blast furnace for pig iron production.

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\(^3\) Business Dictionary
Co-processing

Uses industrial by-products or other waste materials that are unable to be recycled, by incorporating the energy potential and mineral components of wastes into the manufacture of an essential product, the wastes are totally destroyed, e.g. during Portland cement production

Design for Environment (DfE)

Design for Environment (DfE) or Ecodesign are methods supporting product developers in reducing the total environmental impact of a product early in the product development process. This includes reducing resource consumption as well as emissions and waste. New EU directives such as WEEE and RoHS introduce the concept of ecodesign. A sound life cycle based Ecodesign can potentially enable to provide reliable decision support at a largely reduced effort for performing the study (Source: ECJRC)

Design for recycling (DfR)

Design for recycling is a method that implies the following requirements of a product: easy to dismantle, easy to obtain 'clean' material-fractions, that can be recycled (e.g. iron and copper should be easy to separate), easy to remove parts/components, that must be treated separately, use as few different materials as possible, mark the materials/polymers in order to sort them correct, avoid surface treatment in order to keep the materials 'clean' (Source: Danish EPA Eco Design Guide)

Eco-efficiency

Joint analysis of the environmental and economic implications of a product or technology, aiming to support choosing the method for production, service, disposal or recovery that makes most ecological and economic sense, ensuring optimum conservation of resources, minimum emissions and waste generation at a low overall cost (Source: ECJRC)

Ecotoxicity potential

Potential environmental toxicity of residues, leachate, or volatile gases to the biocoenosis of plants and animals. Ecotoxic substances alter the composition of the species of ecosystems, destabilizing it thereby and additionally threatening sensitive species in their existence (Source: EC Joint Research Center)

Environmental Risk Assessment (ERA)
Process of identifying and evaluating the adverse effects on the environment caused by a chemical substance. Often implied in the way, that an environmental exposure to the chemical is predicted and compared to a predicted no-effect concentration, supplying risk ratios for different environmental media (Source: ECJRC)

**External costs**

Cost not included in the market price of the goods and services being produced, but caused by e.g. emissions and damages these cause to goods and to the environment, which costs of repair or compensation are borne by the society in general (Source: ECJRC)

**Environmentally sound management (ESM)**

Taking all practicable steps to ensure that hazardous wastes or other wastes are managed in a manner which will protect human health and the environment against the adverse effects which may result from such wastes ESM of Waste” has always been referred to in most OECD Council Acts related to trans-boundary movements of wastes, as well as in other international, regional and/or national regulations, where it is one of the underlying principles of waste management policies. In these earlier OECD Acts, “environmentally sound management of waste” was considered to be a basic condition for allowing or prohibiting an export/import of waste within, as well as outside, the OECD area. However, it was also recognized that the scope and level of ESM varies greatly from one Member country to another. Lack of a clear definition and common understanding of ESM has led to challenges for the practical implementation of ESM instruments. Less stringent environmental controls, safety levels or human health standards (usually implying the lower cost options) in some countries have also created the potential for exporters, importers or waste managers to direct shipments of wastes destined for recovery to OECD countries and/or waste management facilities having lower waste management standards

**Flash point**

Flash point is the lowest temperature at which a liquid can form an ignitable mixture in air near the surface of the liquid. The lower the flash point, the easier it is to ignite the material

**Flue gas**

is the gas exiting to the atmosphere via a **flue**, which is a pipe or channel for conveying exhaust gases from a fireplace, oven, **furnace**, **boiler** or **steam generator**. Quite often, the flue gas refers to the **combustion** exhaust gas produced at **power plants**. Its composition depends on what is being burned, but it will usually consist of mostly **nitrogen** (typically more than two-thirds) derived from the combustion air, **carbon dioxide** (CO₂), and **water vapor** as
well as excess oxygen (also derived from the combustion air). It further contains a small percentage of a number of pollutants, such as particulate matter, carbon monoxide, nitrogen oxides, and sulfur oxides (source: Wikipedia)

**Green Procurement**

A procurement process which takes into account environmental elements when buying products and services. To prevent a mere shifting of burdens of environmental damages among life cycle phases or among environmental problems, an effective Green Procurement should be based on a life cycle thinking or life cycle assessment (Source: ECJRC)

**Green Public Procurement (GPP)**

A procurement process carried out by public purchasers to take into account environmental elements when buying products and services. See also Green Procurement (Source: ECJRC)

**Greenhouse effect**

Warming of the atmosphere due to the reduction in outgoing long wave heat radiation resulting from their absorption by gases such as Carbon dioxide, Methane, etc (Source: ECJRC)

**GHS**

Globally Harmonized System of Classification and Labeling of Chemicals (GHS) “address classification of chemicals by types of hazard and propose harmonized hazard communication elements, including labels and safety data sheets. It aims at ensuring that information on physical hazards and toxicity from chemicals is available in order to enhance the protection of human health and the environment during the management, transport and use of these chemicals. The GHS also provides a basis for harmonization of rules and regulations on chemicals at national, regional and worldwide level, an important factor also for trade facilitation”

The Globally Harmonized System for chemicals will be implemented in the EU in stages between 2009 and 2015. Between these periods the labeling and packaging of dangerous substances and preparations will change significantly. New GHS symbols must be used from specific dates, but may also be used voluntarily from January 2009. Also the material safety data sheet format and content according to GHS will be implemented in stages and will take

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4 UNECE, 2009b
years to be available worldwide. In 2015 the EU chemical Risk Phrases will be replaced by GHS Hazard Statements

**GHS Hazard statements**

The development of the Globally Harmonized System of classification and labeling of chemicals (GHS) has been initiated by the [UNCED Agenda 21](#), Chapter 19, Rio de Janeiro 1992. GHS hazard statements are statements developed as part of the Globally Harmonized System of Classification and Labelling of Chemicals with regard to the hazards, risks and the ability of chemical substances and mixtures to cause harm to the human health and the environment. Each statement is designated a code consisting of the starting letter H and followed by a number of three digits. In addition, the European Legislation provides supplemental hazard statements which are marked with EUH and a three digit number. The GHS hazard statements are supposed to replace the R-Phrases (see below) by 2015. The translation between the classifications is laid down in the [Regulation (EC) No 1272/2008](#).

**GHS Symbol**

The GHS (see above) symbol is part of the pictograms for hazard classes inside a red diamond. Each pictogram is defined by its color, symbol and the general format. Symbols may be exploding bomb, flame, gas cylinder, etc.

**Ground-level landfill**

Disposal/land filling of hazardous waste near the surface, e.g. in a former clay-pit with technical protection layers.

**Hazardous waste**

Wastes that because of their chemical reactivity, toxicity, explosiveness, corrosiveness, radioactivity or other characteristics, constitutes a risk to human health or the environment (Source: ECJRC).

**Human toxicity potential (HTP)**

The degree to which a chemical substance elicits a deleterious or adverse effect upon the biological system of human exposed to the substance over a designated time period (Source: ECJRC).

**H-criteria/ Hazardous characteristics**

5 UNCED, 1992
The Waste Framework Directive provides a framework for the classification of waste. A waste is considered hazardous when one of the fourteen specifically defined parameters in Annex III signifying the hazardous characteristics (e.g. explosive, flammable, toxic, etc.) of a substance or mixture is fulfilled. Each parameter, which is also referred to as H-criteria, is designated a code consisting of the letter H and an index number (e.g. H₁ explosive, H₂ oxidizing etc.)

**Incineration**

Burning of waste, e.g. hazardous waste in a rotary kiln with appropriate and approved emission control

**IPPC**

IPPC is the abbreviation for `Integrated Pollution Prevention and Control´ and refers to the Directive 2008/01/EC of the European Parliament and of the Council of 15 January 2008 concerning integrated pollution prevention and control, also called the `IPPC Directive´. The IPPC Directive, which applies within the EU, sets down the ground rules of the permit procedure for industrial installations of particular environmental relevance. It aims at prevention and reduction of the emissions into the air, water and soil, as well as of the waste during the operation and following closure. To this end the industrial installations are urged to use Best Available Techniques (BAT, see above)

**Integrated product policy (IPP)**

Approach founded on the consideration of the impacts of products throughout their life-cycle to improve the environmental performance of products in a cost-effective way. (Source: ECJRC)

**Internalization of externalities**

Incorporation of an externality into the market decision making process through pricing or regulatory interventions. For example, internalization is achieved by charging polluters with the damage costs of the pollution generated by them, in accordance with the "polluter pays principle" (Source: ECJRC)

**ISO 14000**

A series of standards emitted or being prepared by the International Standards Organization (ISO), covering a number of environmental topics (Source: ECJRC)
ISO 14001

ISO standard on Environmental Management System, EMS that can be adopted by any organization (Source: ECJRC)

ISO 14040

ISO standard on Environmental Management System, EMS, concerning Life Cycle Assessment of products and processes. ISO 14040 is a framework for the standards ISO 14041, ISO 14042, and ISO 14043 that concerns the specific phases of an LCA. (The ISO standards 14041, 14042, and 14043 are integrated, harmonized, and replaced in 2006 by ISO 14044) (Source: ECJRC)

Kyoto Protocol

International treaty that was adopted at the Third Session of the Conference of the Parties (COP) to the UN Framework Convention on Climate Change (UNFCCC) in 1997 in Kyoto, Japan. It contains legally binding commitments, in addition to those included in the UNFCCC. Countries included in Annex B of the Protocol (most OECD countries and EITs) agreed to reduce their anthropogenic emissions of greenhouse gases (CO₂, CH₄, N₂O, HFCs, PFCs, and SF₆) by at least 5 % below 1990 levels in the commitment period 2008 to 2012 (Source: ECJRC)

Life cycle

Consecutive and interlinked stages of a product system, from raw material extraction, through production of materials and intermediates, parts to products, through product use or service operation to recycling and/or final disposal (Source: ECJRC)

Life cycle thinking (LCT)

The concept of Life Cycle Thinking integrates existing consumption and production strategies towards a more coherent policy making and in industry, employing a bundle of life cycle based approaches and tools. By considering the whole life cycle, the shifting of problems from one life cycle stage to another, from one geographic area to another and from one environmental medium or protection target to another is avoided (Source: ECJRC)

Material flow analysis (MFA)

An evaluation method which assesses the efficiency of use of materials using information from material flow accounting. Material flow analysis helps to identify waste of natural
resources and other materials in the economy which would otherwise go unnoticed in conventional economic monitoring systems (Source: Eurostat)

**Material recovery**

Restoration of materials found in the waste stream to a beneficial use which may be for purposes other than the original use (Source: ECJRC)

**Leachate**

Is a complex mixture of organic and inorganic pollutants generated by Infiltration of precipitation water into the waste body; or by settling of waste with high water content (e.g. effluent treatment sludge), thus forming “press water”, or the reaction of water with waste followed by mobilization and uptake of water soluble pollutants. Leachate is internationally considered as “Hazardous Waste”, NOT as wastewater!

**MSDS**

The Material Safety Data Sheet (MSDS) shall enable the employer to determine whether any hazardous chemical agents are present at the workplace. It provides information which helps to assess any risk to the health and safety of workers arising from the use of hazardous chemical substances and to take respective control measures. The MSDS contains physical-chemical and toxicological characteristics detailed in 16 sections, specific effects endangering human health and the environmental condition. In Europe when you buy a chemical substance it is mandatory to deliver its complete MSDS according to the GHS scheme for MSDSs

**Manifest**

Shipping document that travels with hazardous wastes from the point of generation, through transportation, to the final disposal facility, creating a ‘cradle-to-grave’ tracking of the hazardous waste

**Mirror entries**

Mirror entries are entries of waste categories in the European Waste List which are only considered hazardous if dangerous substances are present above the threshold concentrations

**Physical treatment**
Improving the physical property of the waste, e.g. the strength of sludge by adding cement to make it suitable for land filling

**Recovery**

Any operation the principal result of which is waste serving a useful purpose by replacing other materials which would otherwise have been used to fulfill a particular function, or waste being prepared to fulfill that function, in the plant or in the wider economy

**Recycling**

(1) A resource recovery method involving the collection and treatment of a waste product for use as raw material in the manufacture of the same or a similar product. (2) The EU waste strategy distinguishes between: reuse meant as a material reuse without any structural changes in materials; recycling meant as a material recycling, only, and with a reference to structural changes in products; and recovery meant as an energy recovery only (Source: ECJRC)

**R-Phrases (short for Risk Phrases)/Signal Word/ Hazard Statement**

Risk Phrases are phrases formulated on the nature of special risks attributed to dangerous substances and preparations. They concern the chemicals’ ability to cause harm to human health and the environment. Each phrase is designated a code starting with the letter R and followed by a number. The list of R-Phrases has been consolidated in different European languages in the [Commission Directive 2001/59/EC](https://europa.eu/regulation/examining-2001-59-ec_en). In the course of the GHS development the R-Phrases have been replaced by the hazard statements (see above)

**Solidification**

Physical treatment/stabilization (chemical treatment)

**Stakeholder**

An institution, organization, or group that has some interest in a particular sector, product, or system Source (ECJRC)

**Standard (normal)-m³air**

One m³ dry air under defined temperature and pressure conditions

**Sustainable material management**
Sustainable Materials Management is an approach to promote sustainable materials use, integrating actions targeted at reducing negative environmental impacts and preserving natural capital throughout the life-cycle of materials, taking into account economic efficiency and social equity.

**Thermal treatment**

Often means the same as incineration; can also include the melting down of hazardous substances (e.g. asbestos) to destroy the hazardous substances, gasification and pyrolysis as well as plasma processes.

**Underground landfill**

Disposal/land filling of hazardous waste in a salt dome or other geological formation without the penetration of ground water.

**Waste (management) hierarchy**

List of waste management strategies arranged in order of preference, with waste prevention being the most desirable option and disposal the least preferred approach. Departing from such hierarchy may be necessary for specific waste streams when justified for reasons of, inter alia, technical feasibility, economic viability and environmental protection.

**Waste management**

Approach based on three principles (EU):

1) Waste prevention: As a key factor the amount of generated waste should be reduced.
2) Recycling and reuse: If waste cannot be prevented, as many of the materials as possible should be recovered, preferably by recycling.
3) Improving final disposal and monitoring: Where possible, waste that cannot be recycled or reused should be safely incinerated, with landfill only used as a last resort.
• Definitions as per European Framework Directive on Waste 2008/98/EC

1. ‘waste’ means any substance or object which the holder discards or intends or is required to discard;

2. ‘hazardous waste’ means waste which displays one or more of the hazardous properties listed in Annex III of Directive 2008/98/EC

3. ‘waste oils’ means any mineral or synthetic lubrication or industrial oils which have become unfit for the use for which they were originally intended, such as used combustion engine oils and gearbox oils, lubricating oils, oils for turbines and hydraulic oils;

4. ‘bio-waste’ means biodegradable garden and park waste, food and kitchen waste from households, restaurants, caterers and retail premises and comparable waste from food processing plants;

5. ‘waste producer’ means anyone whose activities produce waste (original waste producer) or anyone who carries out pre-processing, mixing or other operations resulting in a change in the nature or composition of this waste;

6. ‘waste holder’ means the waste producer or the natural or legal person who is in possession of the waste;

7. ‘dealer’ means any undertaking which acts in the role of principal to purchase and subsequently sell waste, including such dealers who do not take physical possession of the waste;

8. ‘broker’ means any undertaking arranging the recovery or disposal of waste on behalf of others, including such brokers who do not take physical possession of the waste;

9. ‘waste management’ means the collection, transport, recovery and disposal of waste, including the supervision of such operations and the after-care of disposal sites, and including actions taken as a dealer or broker;

10. ‘collection’ means the gathering of waste, including the preliminary sorting and preliminary storage of waste for the purposes of transport to a waste treatment facility;

11. ‘separate collection’ means the collection where a waste stream is kept separately by type and nature so as to facilitate a specific treatment;

12. ‘prevention’ means measures taken before a substance, material or product has become waste, that reduces:

(a) the quantity of waste, including through the re-use of products or the extension of the life span of products;

(b) the adverse impacts of the generated waste on the environment and human health; or
(c) the content of harmful substances in materials and products;

13. ‘re-use’ means any operation by which products or components that are not waste are used again for the same purpose for which they were conceived;

14. ‘treatment’ means recovery or disposal operations, including preparation prior to recovery or disposal;

15. ‘recovery’ means any operation the principal result of which is waste serving a useful purpose by replacing other materials which would otherwise have been used to fulfill a particular function, or waste being prepared to fulfill that function, in the plant or in the wider economy.;

16. ‘preparing for re-use’ means checking, cleaning or repairing recovery operations, by which products or components of products that have become waste are prepared so that they can be re-used without any other pre-processing;

17. ‘recycling’ means any recovery operation by which waste materials are reprocessed into products, materials or substances whether for the original or other purposes. It includes the reprocessing of organic material but does not include energy recovery and the reprocessing into materials that are to be used as fuels or for backfilling operations;

18. ‘regeneration of waste oils’ means any recycling operation whereby base oils can be produced by refining waste oils, in particular by removing the contaminants, the oxidation products and the additives contained in such oils;

19. ‘disposal’ means any operation which is not recovery even where the operation has as a secondary consequence the reclamation of substances or energy.

20. ‘best available techniques’ means best available techniques as defined in Article 2(11) of Directive 96/61/EC. See also glossary.
Some interesting Internet links

Artisanal mining: http://wwf.panda.org/what_we_do/where_we_work/congo_basin_forests/wwf_solutions/activities/artisanal_mining/

Bifa Environmental Institute, eBegleitschein Portal: www.ebegleitschein.de

Brownfield’s Revitalization Act: http://www.epa.gov/brownfields/


Consist Business Information Technology: www.consist-itu.de


European Agency for Safety and Health at Work: http://osha.europa.eu


European Committee for Standardization: http://www.cen.eu/cenorm/homepage.htm


EU guidance and practical manual on permitting and inspection of waste management operations:
http://ec.europa.eu/environment/waste/framework/inspections.htm

Extended Producer Responsibility: A Guidance Manual for Governments:
http://www.oecd.org/LongAbstract/0,3425,en_2649_34395_2405199_1_1_1_1,00.html


REACH: http://ec.europa.eu/enterprise/sectors/chemicals/reach/index_en.htm

Sewage sludge: http://www.sludgenews.org/about/

The Environment Agency (UK): http://www.environment-agency.gov.uk

TSCA: http://www.ehsol.com/tsca.htm

The story of Stuff: www.storyofstuff.com

Training resource pack for hazardous waste management in developing economies, 2002:
The training resource pack is a set of training materials available as electronic files. The subjects cover the full range of topics in hazardous waste management from prevention to treatment and disposal as well as regulatory aspects, support services and development of national strategies
www.unep.fr/shared/publications/cdrom/3128/index.htm

UNECE. 2009a. European Agreement Concerning the International Carriage of Dangerous Goods by Road (ADR).


UNECE. 2009c. UN Recommendations on the Transport of Dangerous Goods. 16th ed.
http://www.unece.org/trans/danger/publi/unrec/rev16/16files_e.html

http://unstats.un.org/unsd/environment/hazardous.htm


Vital Waste Graphics:
Aims to give policymakers, experts, media professionals, teachers and students a comprehensive overview of relevant waste-related issues, causes, effects, as well as possible solutions. Vital Waste Graphics is based on the most recent data received by the Basel Convention Secretariat.

• List of Figures

Fig. 1 Worldwide generation of hazardous waste - USA and Russia generate the greatest amounts of hazardous waste - (UNSD, 2009) 51
Fig. 2 Total and hazardous waste in Germany, 1999-2007 (Federal Statistical Office, 2009) 51
Fig. 3 Estim. of the total and industrial hazardous waste increase in Vietnam (Based on World Bank, MONRE, SIDA, 2004) 52
Fig. 4: Desirable hierarchy of waste handling options in relation to sustainability as seen from the EU perspective 58
Fig. 5: Phases of waste management development (Source BMZ Resource waste, 2012) 64
Fig. 6: Overview of countries that have ratified the BC as per 2009. Afghanistan, USA, Haiti and other African and Asian countries have not yet ratified the BC. 80
Fig. 7: Overview of the key legal documents in EU Waste Management Policy 98
Fig. 8: Differentiation of “Waste” according to German Waste Law 98
Fig. 9: Decision tree for distinguishing waste from by-products according to criteria laid down in EU Waste Framework Directive 2008/98/EC 100
Fig. 10: Procedure for differentiating hazardous from non-hazardous waste in general 103
Fig. 11: The structure of the EWL coding system 105
Fig. 12: Procedure for differentiating between hazardous and non-hazardous waste during EWL classification 110
Fig. 13: Discrepancy between no’s of hazardous waste streams reported and found (On-site waste investigation campaign Zhejiang, 17 enterprises investigated, 2007) 135
Fig. 14: HWM Methods applied by the enterprises (On-site waste investigation campaign Zhejiang, 17 enterprises investigated, 2007) 136
Fig. 15: right: Sample of a hazardous waste label and left: TDG pictogram indicating flammability 139
Fig. 16: Samples of containers, 60-litre polyethylene canisters 140
Fig. 17: Samples of containers, 200-litre steel drums 140
Fig. 18: Separation of incompatible wastes/materials 141
Fig. 19: Sample of IBCs, containers for liquids of 600 up to about 1000 liters volume 142
Fig. 20: Sample of skip, 5 to 10 m^3 steel skips for solids 142
Fig. 21: HW Storage facilities 142
Fig. 22 left: IBC for acids and caustic liquids waste. Right: IBC for solid and pasty waste 144
Fig. 23 left: IBC for liquid organic waste. Right: IBC for waste oil 145
Fig. 24 Left: Management of IBC. Right: IBC containers can be stacked. 145
Fig. 25: Containers are equipped with a collision protection guard 145
Fig. 26: Example of filled and closed polyethylene drums 146
Fig. 27: Example of filled and closed steel drums 147
Fig. 28: Preparing HW for transport
Fig. 29: Suction tanker trucks (Source of pictures: Assmann GmbH, Im Brühl 90, D-74348 Lauffen/Neckar, Germany, www.assmann-sonderfahrzeuge.de)
Fig. 30: Suction tanker truck (Source of picture: E. Schultes, HIM GmbH)
Fig. 31: Suction tanker truck (Source of picture: E. Schultes, HIM GmbH)
Fig. 32: Dump truck with tipping container for bulk solid waste (5 - 8 m³)
Fig. 33: Dump truck with flat tipping container for bulk solid waste (approx. 15 m³), suitable e.g. for filter cake; container can be placed under a chamber filter press.
Fig. 34: Labeling of vehicles transporting hazardous wastes
Fig. 35: Example of an orange plate with ADR and UN numbers
Fig. 36: Examples of hazard diamonds used for transport of dangerous goods
Fig. 37: Left: Safe transport of HW; Right: Unsafe transport of HW
Fig. 38: Traffic accidents with hazardous waste (or dangerous goods) can have severe environmental impacts and cause high remediation costs
Fig. 39: Information Flow of the ‘Record of Proper Waste Management’ application procedure
Fig. 40: The ‘Collective Record of Proper Waste Management’
Fig. 41: Proof of completed waste management operations in the form of sextuplicate consignment note
Fig. 42: Zhejiang Province in China and its eleven city districts
Fig. 43: Information flow between stakeholders during transfer plan application in Zhejiang, China. Paper based communication can be abandoned once the electronic signature has gained legal recognition.
Fig. 44: Electronic format of the Transfer Plan: Excerpt of the page for waste-specific data from the waste producer's “Declaration of Responsibility” (English demo-version)
Fig. 45: Poorly managed hazardous waste landfill site belonging to a refinery in Asia. Backing-up of leachate causes hydraulic pressure on the liner and enhances risks of groundwater pollution. See problems associated with pit design in section 11.5
Fig. 46: Recovery and Disposal options for (hazardous) waste according to EU five-step waste hierarchy
Fig. 47: Examples for preparation of the eluate (overhead room shaker; gentle overhead movement for waste analysis)
Fig. 48: Percolation test; water is pumped upstream through waste material (black) in a column, and collected and analyzed at a certain L/S-ratio (e.g. 0.1 or 2.0)
Fig. 49: Process scheme of a chemical-physical treatment plant with two treatment sections (organic and inorganic)
Fig. 50: Chemical / Physical Treatment Plant of HIM GmbH at Kassel, Germany (Total capacity = 31,000 t/a; thereof 25,000 t/a capacity for oil emulsion treatment)
Fig. 51: Different types of residues from physico-chemical treatment containing dangerous substances, disposed on an above-ground hazardous waste landfill 224

Fig. 52: Organization of waste management by allocation of responsibilities 230

Fig. 53: Involved authorities and services for waste management planning and related tasks 232

Fig. 54 Major priorities (?) and potential deficits (-) in waste management permitting 243

Fig. 55: Major priorities (?) and potential deficits (-) in waste management control 246

Fig. 56: Planning measures to assure effective control [inspired by: Doing the Right Things II_2008]247

Fig. 57: Rotary kiln of the hazardous waste incineration plant in Schwabach (Germany) 254

Fig. 58: Scheme of a rotary kiln incinerator (source: INDAVER at http://www.indaver.be/Rotary-kiln.1728.0.html?&L=0 ) 255

Fig. 59: Cross section through a rotary kiln for the incineration of hazardous waste, 258

Fig. 60: section through a rotary kiln 260

Fig. 61: Scheme of a rotary kiln combined with a secondary combustion chamber and feeding systems. (1100 °C and 2 sec are needed if hazardous wastes with a content of more than 1 % of halogenated organic substances, expressed as chlorine, are incinerated) 261

Fig. 62: Air flow profile of a cyclone filter (left taken from , and right taken from) 267

Fig. 63: Operating principle of an electrostatic precipitator, taken from: 268

Fig. 64: Structure of an electrostatic precipitator, taken from 268

Fig. 65: Schematic view of a fabric filter, taken from: 270

Fig. 66: Schematic view of a semi-dry flue gas cleaning, taken from 273

Fig. 67: Comparison of different methods for dust deposition in mg per standard-m ^3. Numbers in brackets from reference 274

Fig. 68: Schematic view of the entrained-phase absorption process before the dust deposition; HOK = (abbreviation from the German word Herdolčenkoks) 275

Fig. 69: Schematic structure of a SCR-reactor, taken from: 278

Fig. 70: Combination of several modules for the purification of exhaust gases for a HWI plant in Germany , ZWS = Circulating fluidized bed reactor, “Sorbalit” is a sorbent (lime as reagent and carbon as surface-active substance). 281

Fig. 71: Ashes and slags produced from hazardous waste incineration 286

Fig. 72: Hazardous Waste Incinerator of HIM GmbH at Biebesheim, Germany (Capacity: 2x 50,000 t/a)292

Fig. 73: Scheme of the hazardous waste incineration plant of AVG, Hamburg (Capacity: 2x 44,000 t/a)295

Fig. 74: Example of a scheme of an air pollution control system Source: K.H.Decker 296

Fig. 75: Discharge of acid resins into a sludge "lagoon" in Germany, 1968 308

Fig. 76: Leachate from a landfill containing only mineral wastes (left) and leachate from a landfill containing a high amount of organic wastes 309

Fig. 77: Barriers for pollution retention from landfill sites 311
Fig. 78: Testing probe for measuring the vane shear strength of sludge
Fig. 79: Waste sampling for on-site verification at the delivery station of a hazardous waste landfill in Germany
Fig. 80: Reference samples of hazardous waste consignments accepted for disposal at a hazardous waste landfill site
Fig. 81: Principal design types of landfills
Fig. 82: CAD (Computer-aided design) drawing of longitudinal – and cross sections of a “slope design” landfill
Fig. 83: Composite sealing system: Base- and cover liner, Germany
Fig. 84: Cross section: Base and cover liner
Fig. 85: Placement of a mineral base liner on a slope during extension works at a hazardous waste landfill site in Germany
Fig. 86: Placement of a geo-membrane liner on a slope during extension works at a hazardous waste landfill site in Germany
Fig. 87: Placement of the sealing layer of an asphalt concrete liner during extension works on a hazardous waste landfill in Switzerland: Small picture: Cylindrical core sample drawn from an asphalt concrete liner for quality testing (diameter approx. 12 cm). The foundation- and sealing layers are clearly visible
Fig. 88: Leachate drainage and collection system: Cross section and perspective view; leachate collection pipe, cross section
Fig. 90: Longitudinal cross section and lay-out views of cell development during landfill disposal [199] (The first cell to be developeds the red-shaded cell, the second cell the brown-shaded-cell, and so on)
Fig. 91: Intermediate cover and temporary surface liner at hazardous waste landfill site Billigheim in Germany
Fig. 92: Roofing constructions at hazardous waste landfill site Rondershagen, Germany. Total capacity: 960,000 m$^3$; roofed area = 45,000 m$^2$ (2010)
Fig. 93: Leachate collection tanks with two-stage reverse osmosis treatment plant
Fig. 94: Life phases of a landfill site
Fig. 95: Hazardous Waste Landfill Site Billigheim in Germany (Total capacity: 930,000 m$^3$, delivery: 20-40,000 t/a, tentative end of disposal phase: 2025)
Fig. 96: Hazardous waste landfill site in Ningbo. Since landfill disposal is more expensive than incineration, the landfill does not receive much hazardous waste for disposal
Fig. 97: Hazardous waste landfill site in Taizhou. Initial development of the entire site area requires higher investment and increases disposal costs, compared to progressive site development
Fig. 98: Geological barrier of an underground disposal facility in Germany
Fig. 99: Disposal of hazardous waste packed in big bags (IBC) in underground disposal site Herfa-Neurode in Germany
Fig. 100: Steps of escalation

Fig. 101: Steps during elaboration of a hazardous waste management plan

Fig. 102: Hazardous waste generation in Europe in kg per capita

Fig. 103: Generation and material flow of secondary wastes

Fig. 104: Categorization and allocation of forecasted HW from primary sources to recovery and disposal options

Fig. 105: Recycling, incineration and landfilling of MSW in EU Member States and other European countries, 2007

Fig. 106: Sankey diagram showing quantities and flow of primary and secondary hazardous wastes of a hazardous waste management scenario (secondary wastes shaded red)

Fig. 107 left: Hazardous waste transfer station (capacity = 20,000 t/a), right: HW transfer station combined with chemical/physical treatment plant (capacity = 30,000 t/a), both in Bavaria, Germany

Fig. 108: Views of the hazardous waste treatment plant of the GSB in Ebenhausen (Germany), where around 85% of the stockholders are public, while around 15% are private

Fig. 109: Decoupling waste growth and economic growth, Germany, 2002-2008 (Source: German Federal Statistical Office, 2009)

Fig. 110: Recovery rates of main waste fractions, Germany, 2000-2007 (Source: German Federal Statistical Office, 2009)

Fig. 111: Gas engine modules fuelled by landfill gas at a landfill site in Busan, South Korea (Commissioned 2003, electrical output: 6,348 kW)

Fig. 112: Share of Zhejiang’s 11 Cities in industrial hazardous waste generation in 2004 according to official data (total HW generation: 378,000 t/a)

Fig. 113: Prognosis of future HW Declaration in Zhejiang Province

Fig. 114: Shares of hazardous waste recycling/recovery in percent of total primary hazardous waste generation (left figure) and in absolute numbers (right figure) for 2004 (baseline scenario) and for 2010 and 2020 (anticipated)

Fig. 115: Alternative 1 (Decentralized infrastructure: All 11 cities equipped with one CPT plant, incinerator and landfill site) Alternative 4 (Centralized infrastructure: All 11 cities grouped into 3 clusters and each cluster equipped with one centralized landfill site and incinerator, while every city has yet one CPT plant)

Fig. 116: Successful implementation of a hazardous waste management plan requires simultaneous action of the stakeholders in different strategic areas
List of Tables

Table 1: Waste management development phases. The chronological sequence and the temporal length of each phase may vary from region to region depending on the environmental policy and the economic conditions of the respective area

Table 2: Compilation of criteria used in OECD countries for distinguishing waste from non-waste

Table 3: The 20 Chapters of the EWL

Table 4: Four-step procedure for assigning waste to a EWL entry

Table 5: Fifteen characteristics that render wastes hazardous according to WFD 2008/98/EC

Table 6: Categories of Danger, Risk-Phrases, and hazard threshold limits of dangerous substances with respect to hazardous properties of waste

Table 7: Methodology for allocating a waste to the hazardous or non-hazardous part of a mirror entry

Table 8: Derived orientation values to distinguish between hazardous and non-hazardous wastes

Table 9: Derived orientation values for distinguishing between hazardous and non-hazardous waste acc. to H15

Table 10: UN classes for dangerous goods. Clicking in each pictogram will enlarge it. Source: UN Transport regulations Chapter 2.0.1 Classes, divisions, packing groups

Table 11: Key players and their role during the ‘Record of Proper Waste Management’ procedure

Table 12: Overview of forms included in the ‘Record of Proper Waste Management’ dossier

Table 13: User groups and their access to system functions of the ‘Solid Waste Management Information System’

Table 14: Excerpt of a positive list (waste acceptance catalogue) of a HW disposal facility (chemical/physical treatment (first raw:CPT) and HW incineration (second raw:HWI), x = permitted for acceptance)

Table 15: Unit level operations for chemical-physical treatment and their effect on pollutants

Table 16: “Economy of Scale” effect for chemical-physical treatment plants of different capacities (based on estimated local costs, China, 2007. 1RMB = 0.1€)

Table 17: Responsibilities of competent authorities

Table 18: Main private sector actors* and specification of responsibilities for each actor involved in (hazardous and non-hazardous) waste management which has to be reflected in relevant legal framework

Table 19: Examples for the determination of a conditioning framework for delivered hazardous waste

Table 20: Selection of typical pollutant concentrations in the raw gas from hazardous waste incinerators in Europe (EU) and Germany (G) and their clean gas emission threshold

Table 21: Comparison of three different dust filter systems. Source:

Table 22: Comparison of different procedural principles for dioxin removal in waste incineration plants (supplemented by); Mg refers to a ton of waste, Mg / h = Mg per hour, burning waste gases for 1 Mg household waste in 7,000 standard-m³ (norm-m³)
Table 23: Investment costs of several system components for the purification of exhaust gases for two lines and 200,000 Mg waste per year (1999)

Table 24: Procedural comparison and economic efficiency analysis for the four different options of the purification of exhaust gases of waste incineration plants. In the table the following abbreviations have been used: RG-condensing = condensation of flue gas; NH3 Stripper = Step that strips surplus ammonia; DaGaVo = prewarming of raw gases with low pressure vapor; Slip = Loss because of the breakthrough into the clean gas

Table 25: “Economy of Scale” effect for hazardous waste incinerators of different capacities (based on estimated local costs, China, 2007. 1RMB ≈ 0.1€)

Table 26: Staff costs as part of the fixed operating costs of incinerators

Table 27: Fuel consumption as part of the fixed operating costs of incinerators

Table 28: Limit emission values in different permits and regulations in Austria, Switzerland and Germany for wastes used for co-processing in cement plants.

Table 29: Limit emission values according to the Directive 2000/76/EC incineration of waste (Daily average 10% O2, all values in mg/m3 dioxins and furans in ng/m3) that have to be observed for waste combustion in cement plants

Table 30: Allocation criteria for municipal and hazardous waste landfill disposal, Germany

Table 31: Cost items for landfill development

Table 32: Estimation of “Economy of Scale” effect for hazardous waste landfill disposal (based on actual local costs, China, 2007. 1RMB ≈ 0.1€)

Table 33: Acceptance criteria for hazardous waste in an underground disposal facility

Table 34: Waste generation coefficients in selected manufacturing industry sectors (kg / employee / year)

Table 35: EUROSTAT data explorer for compilation of sector specific hazardous waste generation coefficients

Table 36: Effects that influence future hazardous waste generation

Table 37: Generation, recycling/recovery, disposal, discharge and storage of HW in Zhejiang’s 11 Cities according to HW declaration data 2004

Table 38: Influencing factors affecting hazardous waste declaration in Zhejiang

Table 39: Estimated capacities for chemical/physical treatment, incineration and landfill of primary and secondary hazardous waste required in Zhejiang in 2010 and 2020 (Assumption: 50% and 45% of primary hazardous waste generated will be absorbed by recycling & recovery in 2010 and 2020 respectively)

Table 40: Investment requirements for the four alternatives

Table 41: Total annual operation costs for the four alternatives including capital-, variable & fixed operating- and additional transport costs in 2010 and 2020
The Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH was formed on 1 January 2011. It has brought together under one roof the capacities and long-standing experience of three organisations: the Deutscher Entwicklungsdienst (DED) gGmbH (German Development Service), the Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ) GmbH (German technical cooperation) and Inwent – Capacity Building International, Germany. For further information go to www.giz.de.
• Module 1

• Hazardous Waste Generation, a summary

• Basic Policy Principles of Adequate Waste Management
• Waste types and hazardous waste generation - Summary

The following types of waste can be distinguished, depending on the source of the generated waste:

1. Municipal solid waste
2. Construction and demolition waste
3. Industrial waste (industrial non-hazardous waste, industrial hazardous waste)
4. Healthcare waste (from clinics and hospitals)
5. Sewage sludge (from Waste Water Treatment Plants)
6. Agricultural waste

In general, construction and demolition waste constitutes the largest part (up to 60% of all generated waste), but the disposal thereof is less dangerous compared to municipal or industrial waste.

The volume of municipal solid waste generation varies in industrial countries (Poland approx. 300 kg per capita per year, Germany about 500 kg per capita per year, U.S. approx. 800 kg per capita per year). The generation in developing countries is much lower (100 – 300 kg per capita per year) but increases in rapidly growing mega cities.6

Agricultural waste mainly hazardous pesticides as well as their containers originate from agricultural activities. Obsolete pesticides and their disposal7 already present a great challenge to many countries.

Industrial waste is waste generated by factories and industrial plants. The larger part of industrial waste is not dangerous but a certain fraction of waste generated by industry may fulfill all criteria for hazardous waste (e.g. the properties defined as hazardous by legislation) and is subject of concern. However, the parameters for classifying waste as hazardous or non-hazardous vary throughout the world. The special properties of hazardous waste make it more difficult to deal with than with non-hazardous waste.

Industrial hazardous waste is only a part of the waste generated by societies and a comprehensive waste management system also needs to address any other waste streams, namely municipal solid waste\textsuperscript{8}, agricultural waste, sewage sludge and construction and demolition waste.

Sewage sludge is relevant in countries with functional wastewater treatment infrastructures\textsuperscript{9}. Still there are big challenges to solve regarding the safe disposal of hazardous sludges from sewage.

Especially industrial hazardous waste has a high risk and danger to human health and the environment and if not managed in a sound manner, it can become a problem to future generations. This manual will mainly deal with industrial hazardous waste management.

1.1. Main types of hazardous waste

In general, hazardous waste is any waste or combination of waste which may cause detrimental effects to environment or human health because of its specific nature.

Hazardous waste can be found in different waste fractions defined by their origin e.g. the household waste, the commercial and industrial waste, waste from hospitals, waste from agricultural activities, etc. Artisanal mining activities produce important amounts of hazardous wastes. In the next sections we will discuss hazardous waste from health care facilities and from industry.

1.1.1. Healthcare waste (HCW)

Waste from hospitals can be extremely hazardous. Therefore, focus has to be laid on their disposal, especially under the aspect of hygiene (to prevent spreading of infectious diseases). Furthermore, healthcare waste management incorporates observing basic principles of occupational health and safety as well as ethical concerns.

According to the European Waste List (EWL), wastes stemming from hospitals and similar institutions can be very diverse and can have up to 40 individual waste constituents in some cases.

\textsuperscript{8} See Solid Waste Management - A key to public health and environmental protection \url{http://www.gtz.de/de/themen/umwelt-infrastruktur/abfall/27769.htm}

\textsuperscript{9} \url{http://ec.europa.eu/environment/waste/sludge/index.htm}
The following table from the EWL lists wastes that form part of the spectrum of health care wastes, the particularly hazardous waste types being marked with an asterisk (*).

<table>
<thead>
<tr>
<th>EWL code</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>18 01</td>
<td>Wastes from natal care, diagnosis, treatment or prevention of disease in humans</td>
</tr>
<tr>
<td>18 01 01</td>
<td>Sharps (except 18 01 03*)</td>
</tr>
<tr>
<td>18 01 02</td>
<td>Body parts and organs including blood bags and blood preserves (except 18 01 03*)</td>
</tr>
<tr>
<td>18 01 03*</td>
<td>Wastes whose collection and disposal is subject to special requirements in order to prevent infection</td>
</tr>
<tr>
<td>18 01 04</td>
<td>Wastes whose collection and disposal is not subject to special requirements in order to prevent infection (for example dressings, plaster casts, linen, disposable clothing, diapers)</td>
</tr>
<tr>
<td>18 01 06*</td>
<td>Chemicals consisting of or containing dangerous substances</td>
</tr>
<tr>
<td>18 01 07</td>
<td>Chemicals other than those mentioned in 18 01 06</td>
</tr>
<tr>
<td>18 01 08*</td>
<td>Cytotoxic and cytostatic medicines</td>
</tr>
<tr>
<td>18 01 09</td>
<td>Medicines other than those mentioned in 18 01 08</td>
</tr>
<tr>
<td>18 01 10*</td>
<td>Amalgam waste from dental care</td>
</tr>
</tbody>
</table>

The different types of wastes mentioned here are to be kept separately as far as possible by being discarded in separate receptacles adequate for the characteristic qualities of the waste. The sorting of the wastes should be carried out at the original place of formation, e. g. in the operating theatre, the treatment room or the sickroom.

Pointy or sharp items like knives, syringes, so-called “sharps” (scalpels, hollow needles / cannulae of syringes and infusion systems) etc. are to be placed in containers that cannot be pierced. For the other types of hazardous health care waste, special type-examination tested receptacles have to be provided additionally, in which the different types of waste can be safely stored and sealed. These containers have to be labelled accordingly. Specialised staff has to carry out the further transport of these containers. Infectious wastes (or the containers), in particular, strictly have to be prevented from being opened, decanted or otherwise handled inappropriately in the course of transportation. Safety directions / procedures have to be observed and followed for the transportation to the disposal facility. This may imply, in the case of infectious wastes, that they may only be transported in specific, type-examination tested containers, which in turn have to be labelled accordingly.

Healthcare wastes must be disposed of in a safe and sound manner. Notably, thermal treatment in special facilities (incineration plants for hazardous wastes) has to be envisaged for infectious wastes. In this context, the waste has to be burnt in its respective receptacles or collecting containers. Any disposal together with normal domestic waste should be avoided wherever possible. Specifically, healthcare waste should never be dumped in landfills, deposited in garbage disposal sites, nor be treated manually or mechanically. For

1.1.2. Industrial hazardous waste

Hazardous waste mainly emanates from industrial activities, although it may differ from production process to production process. Hazardous waste generated in diverse industrial production processes can pose severe health and environmental threats. Many components of such industrial hazardous waste types have been identified as occupational carcinogens, e.g. benzene and chromium VI. In addition, other substances -like lead in metal sludges- can cause neurological dysfunction in humans or malfunction of the kidneys and the nervous system. Adverse health impacts of selected industrial hazardous waste\textsuperscript{10} are listed here below:

<table>
<thead>
<tr>
<th>Hazardous waste</th>
<th>Health/ impact</th>
<th>Generating industrial sector</th>
</tr>
</thead>
<tbody>
<tr>
<td>Waste xylene</td>
<td>Eye and mucous membrane irritation</td>
<td>Pulp and paper, textile, paints</td>
</tr>
<tr>
<td></td>
<td>Disturbances of liver and kidney function</td>
<td></td>
</tr>
<tr>
<td>Waste benzene</td>
<td>Cancer</td>
<td>Paints, paper, leather</td>
</tr>
<tr>
<td></td>
<td>Blood disorder</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Skin irritation</td>
<td></td>
</tr>
<tr>
<td>Peroxides waste</td>
<td>Eye and skin irritation</td>
<td>Pulp and paper, textile</td>
</tr>
<tr>
<td></td>
<td>Lung irritation</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Irritation and inflammation of nose, throat, respiratory tract</td>
<td></td>
</tr>
<tr>
<td>Waste containing lead</td>
<td>Neurological dysfunction in humans</td>
<td>Lead smelting, inorganic chemical industry, iron and steel, pigments, paint</td>
</tr>
<tr>
<td></td>
<td>High blood pressure in adults</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Affects blood chemistry, kidney and nervous system</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Accumulates in some shellfish such as mussels</td>
<td></td>
</tr>
<tr>
<td>Waste containing cadmium</td>
<td>Cancer</td>
<td>Textile, leather, inorganic chemical industry, iron and steel, wood preserving, dyes and pigments</td>
</tr>
<tr>
<td></td>
<td>Kidney damage</td>
<td></td>
</tr>
<tr>
<td></td>
<td>De-calcification of bone tissues</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Toxic to human</td>
<td></td>
</tr>
<tr>
<td>Waste containing</td>
<td>Cancer</td>
<td>Metal finishing, leather/fur, paper</td>
</tr>
</tbody>
</table>

\textsuperscript{10} Source: Ministry of State for Environmental Affairs, Egyptian Environmental Affairs Agency and Egyptian Pollution Abatement Project: Hazardous Waste Management – Inspection Manual, 2002
| Hazardous waste          | Health/ impact                                                                 | Generating industrial sector                                                                 |
|--------------------------|--------------------------------------------------------------------------------|
| chromium VI              | Chronic irritation of the respiratory system                                  | printing, tanning, steel, chemicals manufacturing                                              |
| Waste containing arsenic | Can cause cancer                                                              | Pigments, paints, wood preserving, inorganic chemicals, leady metallurgy                      |
| Waste containing cyanide | Toxic, can cause prompt death due to respiratory arrest                       | Dyes and pigments, metal treatment and coating                                                |
| Waste sulphuric acid     | Irritating to skin, eyes and mucous membrane                                  | Textile, inorganic chemicals, printing inks, secondary lead smelting, metal treatment         |
| Waste sodium hydroxide   | Irritating to the upper respiratory system                                    | Textile, metal treatment                                                                      |
| Waste halogenated solvents | Probable human carcinogen                                                        | Organic chemical industry, textile, pesticide, dyes and pigments, paint, inks                |
|                          | Affects central nervous system, liver, kidney or respiratory system             |                                                                                               |

Industrial hazardous wastes may also pollute soil, air, surface water, or underground water. Underground pollutants can be carried by underground water flow. Especially dangerous are halogenated solvents that may have leaked from underground storage tanks or may have been carelessly poured on the ground.

The production of industrial hazardous wastes is mainly correlated with the use of very different hazardous chemicals. The world production of chemicals has tremendously increased in the past decades. Although 80% of chemicals are produced in only 16 countries there is almost no country which does not use chemicals or place them into circulation. Further increase in chemical production is expected in the near future.

Although, it is assumed that the production of chemicals will be the highest in the OECD countries, disproportional extension of production and use of chemicals is expected in the developing countries. China is expected to be the biggest consumer and producer of chemicals by 2015.

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Chemicals are essential in meeting the social and economic goals of the world. With total output of over $3 trillion in 2008, the chemical industry provides employment for 7 million people and supports 20 million additional jobs.\(^{13}\)

The Strategic Approach to International Chemicals Management SAICM\(^{14}\) was developed by a multi-stakeholder and multi-sectoral Preparatory Committee and supports the achievement of the goal agreed at the 2002 Johannesburg World Summit on Sustainable Development\(^{15}\) of ensuring that, by the year 2020, chemicals are produced and used in ways that minimize significant adverse impacts on the environment and human health.

However until now, the implementation of the commitments has been uneven and insufficient globally. With the increase of the production and use of chemicals growing amounts of wastes containing hazardous waste are expected. Industrial hazardous waste management will therefore become even more important in the future.

“The chemicals industry is one of the largest sectors of the world economy, and nearly every man-made material contains one or more of the thousands of chemicals produced by the industry. While OECD countries have seen a reduction in releases from the production of chemicals, policies are needed to address releases from the use and disposal of products, which include hazardous chemicals. Adopting a science-based risk assessment approach is among the policies reviewed as a means to ensure that adverse impacts are avoided in the most cost effective manner. With the rapid increase of chemicals production in non-OECD countries, greater attention is needed to international co-operation with these governments to build capacity, share information and promote effective chemicals management globally”.\(^{16}\)

The decision whether waste (or a certain waste stream) is hazardous or not is to be made by legislators and/or public authorities. A common concept used is to define properties which render a waste hazardous (such as being flammable, corrosive, toxic, carcinogenic, infectious, eco-toxic, etc; however, waste produced in certain industrial practices or exhibiting certain properties may be outside the scope of a waste management regime. Some industrial discharges may also be out of scope of waste management but regulated by other regimes (waste waters by waste water legislation, industrial gas emissions by emission control legislation, radioactive waste by radioactive legislation …), whereas industrial hazardous


\(^{16}\) [OECD Environmental Outlook to 2030](http://www.oecd.org/environment/outlookto2030)
wastes may basically be submitted to hazardous waste legislation as is the case in the EU irrespective whether it occurs in solid, sludge or liquid form.

As a first broad definition, industrial hazardous waste can be understood in this manual as all waste generated by / within industry having hazardous properties. Industrial hazardous waste in this sense may be generated in different ways and may include very different types of waste: from discharges from production processes, from used chemicals… The hazardous waste can affect negatively our waters and soils if not properly managed.

1.2. Hazardous waste generation

The United Nations Statistic Division has compiled the currently available data on the worldwide generation of hazardous waste as shown in Fig. 1. The figure demonstrates that most of the Latin American, African, Middle East and Central Asian countries have no or insufficient data available on hazardous waste.

The German Federal Statistical Office\textsuperscript{17} publishes annually data on waste generation (Fig. 2). The decrease of waste generation observed in the period between 1999 and 2005 could be achieved by the introduction of the circular economy which facilitates the recycling of end-of-life products. The increase of total waste generation in Germany was mainly due to an increase of construction and demolition waste. Hazardous waste generation remained almost constant throughout the years.

\textsuperscript{17} \url{http://www.statistikportal.de/statistik-portal/en/en_inhalt10.asp}
Although most of hazardous waste is generated in industrialized countries hazardous waste generation in low and middle income economies constitutes a higher danger to health and environment due to inadequate management of hazardous waste. Additionally, it is expected that in future the ratio of hazardous waste generated in industrialized and low and middle income economies will change in favor of the latter.
The Vietnamese Environmental Agency has estimated that the total amount of waste will double by the year 2010 in comparison to 2001 (see Fig. 3).

The amount of hazardous waste is estimated to double as well. These changes are due to high growth of the Vietnamese industrial sector. The basic industry for example, including mechanical, metallurgy, electronic and information technology and chemical industries, increased by 16.5% from 2001 to 2005.

![Fig. 3 Estim. of the total and industrial hazardous waste increase in Vietnam](Based on World Bank, MONRE, SIDA, 2004)

The development of waste and hazardous waste generation in Vietnam is a representative example for many low and middle income economies. It is alarming to see that in view of increasing waste and hazardous waste amounts the structures and institutions for adequately dealing with them are insufficient in many low and middle income economies.

**Industrial hazardous wastes in the USA**

Four types of industry account for about 90% of industrial hazardous wastes generated in the United States: (1) chemical manufacturing, (2) primary metal production, (3) metal fabrication, and (4) petroleum processing.

Large chemical plants and petroleum refineries, and other "large quantity generators" that produce more than 1000 kg of hazardous wastes per month, are the most visible and heavily regulated facilities in the United States. However, businesses of all sizes generate dangerous chemicals; the EPA currently lists more than 250000 facilities as "small-quantity generators" (SQGs) of hazardous waste. These diverse, smaller producers account for about 10% of the potentially harmful substances produced each year.

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19 Duong Thai Cong (year not specified)
Though large industry produces the majority of hazardous waste in the United States, the small quantity generators (SQGs) that produce between 100–1000 kg of hazardous waste per month present particular regulatory challenges: (1) The chemicals used by auto garages, dry cleaners, construction companies, scientific labs, photo developers, printers, large offices, and farmers are often toxic. (2) Hazardous wastes generated by SQGs are much more varied than those produced by large companies. Each chemical, be it a month's supply of dry cleaning fluid or a house-worth of residential insulation, requires its own handling and disposal strategy. (3) SQGs, who do not have the legal and administrative support common at large companies, often have difficulty deciphering hazardous waste regulations. Noncompliance can result from simple ignorance of a small business's responsibility to follow environmental laws.

Other sources of hazardous waste in the US are associated with military bases, mines and residential communities.

United States military bases have some of the most serious hazardous waste problems in the nation, an issue only recently addressed by government and private environmental agencies. About 19000 sites at 1800 military installations show some degree of soil or groundwater pollution. More than 90 military bases have been on the EPA's Superfund list of high-priority, hazardous waste cleanup sites. Moreover, a law passed in 1992 allows federal and state regulatory agencies to levy fines against the military if their hazardous wastes are not properly managed. Prior to this, the armed forces were not subject to state or federal environmental laws. Consequently, the military now has a range of programs to clean up hazardous waste problems at its bases.

Mining waste, a type of industrial waste, often includes hazardous substances. Mining operations commonly use hazardous chemicals, and sometimes naturally toxic substances are released into the environment during mining and the disposal of its waste materials. For example, gold mining in the Amazon Basin of South America results in the release of 90–120 tons of mercury into rivers every year. This has resulted in elevated levels of mercury in fish and humans in the region. Chemical separation of ore minerals like lead, iron, and zinc from their host rocks creates so-called acid-mine drainage that contains both the toxic chemicals used in the separation process like arsenic and sulfuric acid, and poisonous heavy metals like lead and mercury. Acid-mine drainage from metal mining in the American West has contaminated drinking water and caused serious ecological damage since the mid-1800s.

Household hazardous wastes are discarded products used in the home, which contain dangerous substances. Examples include paint, motor oil and antifreeze, drain cleaner, and pesticides. In the 1980s, many local governments in the USA and Canada began to set up regular collection programs for household hazardous wastes, to ensure that they are properly
disposed or recycled. Local or state/provincial governments usually pay the costs of such programs. However, a system used in British Columbia, Canada, requires consumers to pay an "eco-fee" on paint they buy. This, along with funds provided by the paint industry, helps pay for a collection program for waste paint from households.

**Waste in the European Union**

Around 3 billion tons of waste is generated in the EU each year - over 6 tons for every European citizen²¹- including 40 million tons of hazardous waste (over 10 kg per person per year).

This has a huge impact on the environment, causing pollution and greenhouse gas emissions that contribute to climate change. Good waste management can significantly reduce these impacts, and Life Cycle Thinking and Assessment (see chapter 2.5.1.) can help policy makers choose the best environmental options.

A key aim of EU policies on resources and waste is to move to a more resource-efficient and sustainable future. EU policies and legislation on waste highlight the need for good waste management.

The amount of waste is expected to increase over the coming years, because of the population growth and the progressive industrial development. For this reason an adequate waste management system has to be in place in each country to cope with these increasing waste challenges.

As example, the European Union has taken profound measures to tackle the problems of inadequate waste management and has achieved model results which can guide other countries in successful development of their waste and hazardous waste management systems.

Waste management in the EU can be understood as an approach based on three principles:

1) Waste prevention: As a key factor the amount of generated waste should be reduced
2) Recycling and reuse: If waste cannot be prevented, as many of the materials as possible should be recovered, preferably by recycling.
3) Improving final disposal and monitoring: Where possible, waste that cannot be recycled or reused should be safely incinerated, with landfill only used as a last resort.

(Source: [http://ec.europa.eu/environment/waste/index.htm](http://ec.europa.eu/environment/waste/index.htm))

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• Basic Policy Principles with Relevance for Adequate Management of Hazardous Waste

The following section outlines some guiding principles with relevance for waste management that should be reflected on legal acts.

2.1. The Precautionary Principle

“Where there are threats of serious or irreversible damage, lack of full scientific certainty shall not be used as a reason for postponing cost-effective measures to prevent environmental degradation.”

UN Conference on Environment and Development 1992, Rio Declaration

The purpose of the Precautionary Principle is to create an impetus to take a decision notwithstanding scientific uncertainty about the nature and extent of the risk, i.e. to avoid ‘paralysis by analysis’ by removing excuses for inaction on the grounds of scientific uncertainty.

The principle involves taking precautions now to avoid possible environmental damage or harm to human health in the future. Application of this principle to hazardous waste management has concrete repercussions. For example, in case of wastes which are deemed to be potentially hazardous, such wastes should be classified, managed and disposed as hazardous waste as long as the confirmation of their hazardous or non-hazardous nature is pending or unclear. Regulators have to consider this aspect when developing hazardous waste classification systems.

2.2. The ‘Duty of Care’ Principle

To comply with the ‘Duty of Care’ reasonable steps have to be taken:

1) To prevent the escape of waste whilst it is in the possession of the holder, and while it is being held by others after being transferred,

2) To provide written information which describes the waste when it is being

transferred to another person, sufficiently well to allow them to comply with their duties,

3) To ensure that waste is only transferred to a person authorized to receive it,
4) To prevent waste causing pollution or harm, both when it is under the holder’s control and subsequently under the control of those to whom the waste is transferred.

The “Duty of Care” with respect to waste management is implemented in the United Kingdom where it is being enacted under the Environmental Protection Act 1990. It enhances the scope of the ‘Polluter pays’ principle by addressing additional stakeholders and by formulating duties specific to waste management. The “Duty of Care” enshrines in law the requirements for all producers, carriers, importers, exporters, brokers, dealers and processors of hazardous waste to manage the waste correctly by storing it properly, only transferring it to the appropriate people and ensuring that when it is transferred it is sufficiently well described to enable its safe recovery or disposal without harming the environment.

The fourth point mentioned above is of particular importance as it reminds waste generators that they remain responsible for wastes generated by them even after transfer to another party.

2.3. The ‘Polluter Pays’ Principle:

The costs of waste management shall be borne by the original waste producer or by the current or previous waste holders.

EU Directive 2008/98/EC, Article 14 (1)

The ‘Polluter Pays Principle’ is a guiding ethical principle that is enacted in legislations at European, international and national levels and that applies to all types of pollution. It means that polluters should bear the full costs of the consequences of their actions. With respect to waste management the ‘Polluter Pays’ principle seeks to shift the responsibility dealing with waste from governments (and thus, taxpayers and society at large) to the

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entities generating it. In effect, it internalizes the cost of waste disposal into the cost of the product, theoretically meaning that the producers will improve the waste profile of their products, thus decreasing waste and increasing possibilities for reuse and recycling.

2.4. The Cooperative Principle

The Cooperative Principle is intended to integrate all participating actors in the process of environmental decisions. This principle is indispensable for sustainable development, seeing that its holistic approach affects the complexity of production and consumption of goods as well as treatment of wasted materials and products.

The Cooperative Principle is political and governs procedures, aiming for agreements in reaching environmental goals. Industry, citizens, environmental organizations, and science have to take responsibility. Sustainable success in environmental protection can only be achieved if everyone does their bit in their field.

2.5. The Principle of the ‘Waste Management Hierarchy’:

The waste hierarchy is a concept at European level that provides a preferred order of priorities for selecting and deciding upon waste management options with the aim to conserve resources and to minimize environmental damages.

The desirable hierarchy of waste handling options is related also to sustainability. Consult the DEFRA “Guidance on applying the waste hierarchy to hazardous waste” for learning more how to apply the hierarchy principle, especially reduction, reuse and recycling.

The key options of the waste management hierarchy are explained here below:

- **Waste avoidance and reduction**
  Waste avoidance and reduction seek to minimize the use of resources as well as the quantities and/or hazard levels of the wastes generated at the source. Measures for achieving waste avoidance and reduction are
  - Input substitution, for reducing quantity as well as hazard level of waste
  - Increased efficiency in the use of raw materials, energy, water or land
  - Process and product design
  - Improved maintenance and operation of equipment

- **Re-use**
  Re-use means any operation by which products or components that are not waste are used again for the same purpose for which they were conceived

- **Waste Recycling/Material and or Energy Recovery:**
  - Recovery: means any operation the principal result of which is waste serving a useful purpose by replacing other materials which would otherwise have been used to fulfill a particular function, or waste being prepared to fulfill that function, in the plant or in the wider economy. Note that incineration of waste
(see below) with high energy output and backfilling operations (use of material to fill mines or for landscaping purpose) can fulfill this definition

- Recycling: means any recovery operation by which waste materials are reprocessed into products, materials or substances whether for the original or other purposes. It includes the reprocessing of organic material but does not include energy recovery and the reprocessing into materials that are to be used as fuels or for backfilling operations.

It has to be noted that recovery can generate secondary wastes which again require treatment and disposal. The common approach to utilization should be to encourage the recycling business to adopt Best Available Technology (BAT) and to authorities to provide licenses to such installations only that fulfill minimum standards with regard to environment, health and safety.

- Waste Incineration, waste treatment:
  In case there is no other appropriate solution, incineration or treatment followed by landfill disposal is required in a way that causes the least harm to the environment.

  - Incineration is applied to wastes with a high content of organic pollutants. Incineration generates secondary wastes such as ash, slag, filter dusts and spent scrubber liquids.
  - Chemical/physical treatment (for example evaporation, drying, calcinations, neutralization, precipitation, dewatering or encapsulation) is applied to liquid or slurry wastes for obtaining stabilized materials with defined contents and mobility of pollutants.

- Waste Landfill disposal
  Final disposal is effected by disposing secondary wastes generated from incineration or treatment on secured landfill sites. Only such residues are permitted for landfill disposal that have achieved a defined level of inertness during the preceding treatment. Secured landfill sites have to meet the criteria of the ‘Multi barrier Principle’ which requires several barriers to be set up one independent from another to avoid release of pollutants.

2.5.1. Life Cycle Thinking and Assessment

Over their life-time, products (goods and services) can contribute to various environmental impacts. Life Cycle Thinking considers the range of impacts throughout the life of a product.

Life Cycle Assessment quantifies this by assessing the emissions, resources consumed and pressures on health and the environment that can be attributed to a product. It takes the entire life cycle into account – from the extraction of natural resources through to material processing, manufacturing, distribution and use; and finally the re-use, recycling, energy recovery and the disposal of remaining waste.

The fundamental aim of Life Cycle Thinking is to reduce overall environmental impacts. This can involve trade-offs between impacts at different stages of the life cycle. However, care needs to be taken to avoid shifting problems from one stage to another. Reducing the environmental impact of a product at the production stage may lead to a greater environmental impact further down the line. An apparent benefit of a waste management option can therefore be cancelled out if not thoroughly evaluated.

Following the waste hierarchy will generally lead to the most resource efficient and environmentally sound choice. However, in some cases refining decisions within the hierarchy or departing from it can lead to better environmental outcomes. The “best” choice is often influenced by specific local conditions and care needs to be taken not to simply shift environmental problems from one area to another. Decision-makers need to base their choices on firm factual evidence. Life Cycle Thinking and Assessment provides a scientifically sound approach to ensure that the best outcome for the environment can be identified and put in place.

The European Commission is developing a series of technical and strategic guidance documents based on life cycle thinking to complement the waste hierarchy. These guidance documents help quantify the environmental and health benefits, as well as the trade-offs, that are associated with options for waste prevention, recycling, re-use, and energy recovery (waste hierarchy).

2.6. The Principle of ‘Extended Producer Responsibility’:

The Member States may take legislative or non legislative measures to ensure extended producer responsibility. EPR is expressed among others by actions as for example:

- Acceptance of returned products
- Design of products reducing environmental impacts and generation of waste

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26 [http://lct.jrc.ec.europa.eu/assessment/publications](http://lct.jrc.ec.europa.eu/assessment/publications) and [http://www.oecd.org/document/19/0,3746,en_2649_34281_35158227_1_1_1_1,00.html](http://www.oecd.org/document/19/0,3746,en_2649_34281_35158227_1_1_1_1,00.html)
during the production process and subsequent use of the product
- Provision of publically available information as to the extent to which the product is reusable and recyclable

The principle of ‘Extended Producer Responsibility’ implies that designers, manufacturers, importers, distributors and retailers of products that give rise to the generation of wastes, should take (collective) responsibility for those wastes, rather than expecting the community to bear the burden. Responsibility should be taken for:

- Minimizing waste generated by them
- Designing and developing goods that are inherently re-usable or recyclable and do not contain materials that pose an unnecessary risk or burden for the environment
- Developing markets for the re-use and recycling of the goods they produce.

There are two key features to an EPR policy: on the one hand, the responsibility for a product in its post consumption phase is shifted upstream in the production consumption chain, to the producer, and secondly, providing incentives to producers to incorporate environmental considerations into the design of their products.

By putting the responsibility and economic burden of waste management on the producer, EPR can constitute a key element to set incentives for waste prevention for the appropriate actors.

2.7. The Principle of ‘Waste Management Self-sufficiency’:

Waste management self-sufficiency should be achieved on a regional or national level and in particular, if possible, on the Member State’s level of a political or economic union. To this end, Member States will have to establish, possibly in co-operation with other Member states, an integrated and adequate network of waste utilization and disposal facilities.

This principle aims at stopping the misuse of economical gaps between different regions for exporting waste from high income to low- and middle income countries.

2.8. The Proximity Principle:

Wastes should be treated or disposed of as close to their source of generation as possible
The proximity principle means that waste should be treated and/or disposed of as near as possible to the point where it arises. This principle aims to avoid the adverse environmental impacts of unnecessary waste transport. However, the environmental impacts of transporting wastes very much depend on local conditions and circumstances.

The application of the principle will therefore vary according to the type of waste concerned, the quantity, the potential hazard and the potential environmental impact of the method of waste treatment/disposal and the mode of transport. There also has to be a balance between the proximity principle and economy of scale\textsuperscript{27}. In certain cases, economy of scale means that some specialist treatment, recovery or disposal operations may be located far from the point where the waste is generated.

2.9. The Principle of ‘Best Available Technique’ (BAT):

According to the European Integrated Pollution Prevention and Control (IPPC) Directive (http://ec.europa.eu/environment/air/pollutants/stationary/ippc/index.htm) emissions from installations to the environment should be reduced to the most possible extent and economically in the most efficient manner. The European IPPC Bureau (located in Seville, Spain) provides Best Available Techniques Reference Documents (BREFs)\textsuperscript{28} compiled for various industrial branches, e.g. for “Surface treatment of metals, or “Tanning of hides and skins”. Although primarily elaborated for purposes at EU level, BREF are a useful tool to assess the state-of-the-art of environmental sound technology. The information contained in the BREFs can help to evaluate what is technically and economically achievable in terms of best environmental performance within waste management facilities.

List of 33 BREF documents published at http://eippcb.jrc.es/reference

\begin{figure}
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\begin{tabular}{|l|}
\hline
\textbf{Waste policy is based on:} \\
\begin{itemize}
\item Precautionary principle \\
\item Polluter pays principle
\end{itemize} \\
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\end{tabular}
\end{figure}

\textsuperscript{27} \textit{Economy of scale}, in microeconomics is the cost advantages that a business obtains due to expansion. They are factors that cause a producer’s average cost per unit to fall as scale is increased. Economy of scale is a long run concept and refers to reductions in unit cost as the size of a facility, or scale, increases.

\textsuperscript{28} http://eippcb.jrc.es/reference
- Duty of care principle
- Cooperative principle
- Waste management hierarchy principle
- Extended Producer Responsibility principle
- Waste management self-sufficiency principle
- Proximity principle
- Standards for best available techniques

These fundamental principles may serve as a good starting point for low and middle income economies interested in developing and/or improving their own HWM systems. Whereas industry largely has impacts on waste generation and waste management, the responsibility and costs of appropriate waste management are primarily on the shoulders of the competent authorities and the general public, because there are no other incentives for the producing industry to change to less impacting products.

In order to change this situation and to foster sustainable innovation in industrial production, the introduction of the polluters pay principle is paramount. The most ambitious approach in this field is to establish and extended producer responsibility (EPR). This constitutes a political approach in which the producer’s financial and/or physical responsibility for a product is extended to the post consumer stage of the product’s life cycle. It specifically focuses on reducing the environmental impacts of a product in the post consumer phase.

2.10. Lessons learnt of German International Cooperation in the Field of Waste Management

The German Federal Ministry for Economic Cooperation and Development (BMZ) is in charge of financing and providing orientation for the cooperation with partner countries. This is achieved in part through its financial and technical instruments, supporting peaceful solutions for crises and conflicts, helping to improve in a fairer way the distribution of resources and to preserve the resources for future generations. The overall aim is to increase the amount of people having a share in the prosperity. This cooperation focuses on selected thematic fields related e.g. to poverty alleviation, good governance, sustainable development, and among others waste management, including hazardous waste.

29 *BMZ Strategiepapier 3, Ressource Abfall 2012*

30 Afghanistan, Albania, Algeria, Angola, Armenia, Azerbaijan, Bangladesh, Benin, Bolivia, Bosnia and Herzegovina, Brazil, Burkina Faso, Burundi, Cambodia, Cameroon, China, Colombia, Costa Rica, Côte d'Ivoire, Cuba, Democratic Republic of the Congo, Dominical Republic, Ecuador, Egypt, El Salvador, Ethiopia, Ghana, Georgian Republic, Guatemala, Guinea, Haiti, Honduras, India, Indonesia, Jordan, Kenya, Kosovo, Kyrgyzstan Laos, Lebanon, Liberia, Madagascar, Mali, Malawi, Mauritania, Mexico, Moldova, Mongolia, Montenegro, Morocco, Mozambique, Namibia, Nepal, Nicaragua, Niger, Nigeria, Palestinian Territories, Pakistan, Paraguay, Peru, the Philippines, Rwanda, Zambia, Senegal, Serbia, Sierra Leone, South Africa, Sri Lanka, Sudan, Syria, Tajikistan, Tanzania, Tunisia, Uganda, Ukraine, Uzbekistan, Vietnam, Yemen
Development of waste management systems contributes to the preservation of human health and environment, especially of the climate, the biodiversity and the water. It helps to establish a proper functioning urban infrastructure, facilitates good governance, improves economic conditions, and boosts secondary raw material and alternative energy supply. The main principles of the German assistance in waste management is to efficiently use raw materials and to minimize waste generation where possible, to use waste as a resource where appropriate, and to diminish the negative impacts on the human health and the environment of the waste handling processes.

BMZ supports the activities of waste management in partner countries and thus focuses on advisory and strengthening strategic planning, establishment of legal basis, creation of relevant institutions, selection of appropriate waste handling techniques, instruments of finance and cost recovery, diffusion of the circular economy, participation of and cooperation with the private and the informal sectors as well as with all other stakeholders.

Experience from both industrial and developing countries has shown that the way to manage waste as a resource is the result of a process involving five phases and cannot be achieved in only one step. These five phases show the different levels of the development of the appropriate waste management system, as is shown in Fig. 5.

![Fig. 5: Phases of waste management development (Source BMZ Resource waste, 2012)](image)

Adequate handling of hazardous waste is an integrated part of the waste management system. It therefore cannot be considered separately but must be treated as an issue which
is connected to other fields and aspects of waste management, including both technical and non-technical matters.

Table 1 describes the fields of waste management activities characteristic of each of the five phases. However, the chronological sequence and the temporal length of each phase may vary from region to region depending on the environmental policy and the economic conditions of the respective area.
Table 1: Waste management development phases. The chronological sequence and the temporal length of each phase may vary from region to region depending on the environmental policy and the economic conditions of the respective area.

<table>
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<tr>
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<tbody>
<tr>
<td>Collection</td>
<td>Collection of waste for the purpose securing the sanitation</td>
<td>Increase of collection rates</td>
<td>Beginning of separate collection of valuable material and hazardous waste</td>
<td>Efficiency optimization of the collection systems and further differentiation of waste collection</td>
<td>Alignment of the collection systems with the requirements of the circular economy</td>
</tr>
<tr>
<td>Recovery</td>
<td>Recovery carried out by the informal sector and private companies (without public funding)</td>
<td>Recovery carried out by the informal sector (waste picking) and private companies (without public funding)</td>
<td>Introduction of instruments for enhancement of recovery and recycling (deposit systems, subsidies, regulations on recyclable products)</td>
<td>Systematic identification of recovery potentials</td>
<td>Total recovery of waste</td>
</tr>
<tr>
<td>Treatment</td>
<td>Non</td>
<td>Non</td>
<td>Simple systems of recovery (shredding, sieving, composting), separate treatment of hazardous waste</td>
<td>Complex systems of waste treatment (bio-mechanical treatment, thermal treatment), no land filling without pretreatment</td>
<td>Total recovery of valuable material and reintroduction into the production cycle</td>
</tr>
<tr>
<td>Land filling</td>
<td>Open uncontrolled dumping sites</td>
<td>Dumping at appropriate sites with precautionary measures during the landfill operation</td>
<td>Land filling with treatment of leakage water, gas collection and use of gas, recultivation and renaturation</td>
<td>Restriction of land filling to inert waste</td>
<td>No land filling</td>
</tr>
</tbody>
</table>
2.11. Adequate Management of Hazardous Waste

The management of hazardous waste in a country, a region or worldwide is a complex, multidisciplinary process. Bad waste management entails serious health and environmental risks; for this reason management activities must be properly planned.

Although most hazardous waste is generated today in industrialized countries, hazardous waste generation in Low and Middle income economies constitutes a higher danger to health and environment due to often inadequate management of hazardous waste. Additionally, it is expected that in the future Low and Middle income economies will produce more hazardous wastes than the industrialized countries; therefore waste management infrastructure and an appropriate administrative system need to be improved in these countries.

Waste generation is determined by a number of factors such as levels of economic activity, production procedures and product design. Any product produced will become waste at the end of its life cycle. Therefore the composition and amount of products and product packaging is a crucial factor for the quantity and environmental risks of the generated waste and determines/limits the possibilities for recycling and recovery of material and energy from waste. To be successful, waste policy hence needs to be closely linked with product policy in terms of a so-called integrated product policy taking into consideration during the production phase already the full life cycle and the impacts and implications on waste generation and treatment.

Definition of waste management

In principle “Waste management” comprises any step of handling waste from the moment of its generation up to the moment of its final disposal or its re-entering into the product status by means of recycling or recovery. Accordingly, the EU Waste Framework Directive defines waste management as “the collection, transport, recovery and disposal of waste, including the supervision of such operations and the after-care of disposal sites, and including actions taken as a dealer or broker”.

Links between waste management and waste prevention and sustainable material management:

Management of hazardous waste is not an isolated task, but has to be seen in the context of the legislator’s general approach towards waste management and, moreover, with the general policy on integrated product management. Preventing the generation of waste in the first place, e.g. through the improvement of industrial processes aiming to decrease the amount of waste generated or the hazardousness of waste and its negative impacts or by facilitating the re-use of materials before they actually become...
waste, should be emphasized in preference to any means of waste treatment. Waste prevention or minimization can produce environmental benefits throughout the product life cycles. Most directly, preventing the generation of waste reduces the need for further investments and energy use to collect, store, process and dispose of what would have been waste. This translates into fewer waste collection vehicles with less air pollution and into a reduced need for waste storage space, waste processing and waste disposal.

Waste potentially contains also an increasing amount of valuable material and/or energy which is lost for the economic cycle if disposed of. In the light of increasing shortness of available resources and restrictions on the use of energy and raw material, waste management therefore should focus on resources, the best possible efficiency in recycling and recovery of substances and energy contained in the waste. Waste management should hence be closely linked with and can contribute considerably to sustainable material management.

2.12. Necessary obligations for waste management infrastructure (waste collection and treatment facilities)

Successful waste management requires certain infrastructural features such as an adequate regulatory framework and enforcement infrastructure (see recommendations in OECD Guidance Manual from 2007\(^{31}\), in chapter 2.3), and the establishment of an appropriate waste separation, collection and treatment infrastructure.

This includes (apart from the definition of matter and scope), provisions and schemes for authorizations/licenses/permits, performance standards (e.g. emission limit values, construction and site standards, operational standards), monitoring and reporting obligations, environmental liability and penalties. Besides national provisions, international waste movement needs to be taken into consideration and has to be covered as well.

The enforcement mechanisms should comprise verification of compliance with legal instruments and standards, co-ordination between several government levels, information exchange, training, and incentive programs.

Establishment of the appropriate waste management infrastructure comprises planning and awareness of targeted policies in order to encourage the development of a varied and tailor-made system of environmentally sound management encouraging recycling and recovery.

2.13. Obligations and standards for waste treatment facilities

In addition to provisions and obligations for waste management and control infrastructure related to competent authorities, successful waste management requires obligations and standards for treatment facilities. For this purpose the OECD recommends integrating so-called Core Performance Elements (CPEs) into national policies and/or programs to be applied at the level of individual facilities as minimum standard without discouraging recycling, in particular increasing the rates of environmentally sound recovery of low risk waste.

The OECD Guidance Manual from 2007\(^{32}\) lists the following six obligatory CPEs to be complied with by waste management facilities:

1. Environmental Management System (EMS)\(^{33}\)
2. Adequate measures to safeguard occupational and environmental Health and Safety
3. Adequate monitoring, recording and reporting programs
4. Appropriate and Adequate Training Program for Personnel
5. Adequate Emergency Plan

2.14. Obstacles in relation to the establishment of HWM Systems and approaches for possible solutions

The development of legislation on waste management might be difficult with regard to elaborating a concise and clear legal framework on such a complex issue like waste management. However, Basel Convention and OECD provisions as well as EU legislation provide good starting points to adopt provisions on a national scale (see more details in Module 2).

Obstacles in most cases are financial or related to lack of awareness and expertise. They hence affect mainly the practical enforcement of those legal provisions for environmentally sound waste management.

Further the lack of expertise, the lack of legal framework, the lack of documentation among other factors represents mayor obstacles in the establishment of a HWM system.

According to a recent survey performed on behalf of the Basel Convention\(^{34}\) it was noticed that:


\(^{33}\) [http://www.quality.co.uk/ecoadvic.htm](http://www.quality.co.uk/ecoadvic.htm)
- Waste prevention and minimization, recycling, recovery and disposal, the use of cleaner technologies and production, the improvement of institutional and technical capacity-building, and the development and transfer of environmentally sound technologies are not fully implemented.

- Treatment of hazardous waste and establishment of an appropriate enforcement infrastructure is costly. According to the survey, the main obstacles in the implementation of appropriate waste management are a lack of adequate and sustainable financial mechanism (associated with difficulties in resource mobilization). This leads to an absence of proper facilities to dispose of hazardous waste as well as a lack of inadequate technology for effective hazardous waste treatment and a lack of training and awareness raising.

Cost recovery mechanisms that could be used (by companies, regional and local authorities) for investment in hazardous waste management could be one step towards solving this problem. Other approaches are product stewardships (producer responsibility schemes), and a stepwise approach starting with major hazards before expanding to the entire sector.

This manual should support competent authorities in overcoming part of these obstacles. Most of these obstacles may be tackled with the help of information and close cooperation as will be discussed in this manual on topics referring to the description of main responsibilities of the different stakeholders involved in HWM (see chapter 5.2), to the waste management planning (see module 6), to permitting and control (see module 4 and 5), and to awareness raising and support of waste producers (see module 3).

Regular information exchange, nomination of a task force and expert rounds to discuss observed problems and deficits in the field of waste management can be a successful approach. Training and awareness raising then need to be expanded to the industry and the general population.

Guidance, training, incentives and penalties are the major instruments to convince the industry to deal with the additional bureaucratic provisions and to fulfill all requirements in order to comply with legal provisions.

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34 Report on the review of the implementation of the current strategic plan, 2009
http://www.google.de/url?q=http://archive.basel.int/stratplan/report/report.pdf&sa=U&ei=3ySMT_iHGsWZhQfWxKm8CQ&ved=0CBQQFjAA&usg=AFQjCNQGQvKs7cKAgFEN-hV9CSXqG3-dQ
In regard to waste recycling there are various market barriers and reasons for failures. Although recycling is less a matter of hazardous waste management general principles and problems do also relate to closed loop production approaches.

Nevertheless, recycling of hazardous waste especially, and hazardous metals, will play an important role in the future due to the scarcity of raw materials and the negative environmental impact during their extraction. These aspects should be considered in future raw material strategies for different countries. As an example see the German raw materials strategy under the following link: http://www.bmwi.de/English/Navigation/Service/publications,did=376156.html

Last but not least, the OECD document on recycling markets “Improving Recycling Markets” which deals with common obstacles for waste oils, waste plastics, and used rubber tires, and the use of “industrial” policies complementary to more traditional environmental policies in terms of social welfare costs, is recommended as additional information source.

2.15. Where is your country in relation to an adequate Hazardous Waste Management System?

To evaluate the situation in your country you can invite key representatives from the public, private and NGO waste sector to discuss the subject and to make suggestions for improvement. This can be done during a moderated stakeholder dialogue, where it should be evaluated where your country is in relation to an adequate HWM and which steps should be taken to improve the implementation of an adequate hazardous waste management system considering also recovery, reuse and recycling policies. For discussion and documentation purposes you can use the points referred in the following box (next page) during the stakeholder dialogue as indicators for this evaluation and so described more precisely which obstacles still exist in preventing the establishment of an appropriate HWM system in your country.

Possible discussion points during a stakeholder dialogue:

- Lack of adequate and up to date legislation including sublegal acts for ESM (reduction, reuse, recycling, incineration, landfill) and enforcement mechanisms (e.g. Strategic Plan and infrastructure including inter ministerial coordination and the role of regional and local authorities)

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- Lack of an effective monitoring system and implementation mechanisms to effect changes
- Lack of waste facilities for collection, treatment and disposal
- Lack of understanding and acceptance of roles and responsibilities by stakeholders (including behavior and cultural resistance to change waste management practices)
- Limited collaboration among agencies in the management of hazardous wastes
- Weak mechanism for information sharing among important stakeholders to facilitate decision making
- Lack of record-keeping on hazardous waste generation at the source (hazardous waste generation, quantity, physico-chemical properties, and producers of wastes)
- Lack of necessary data concerning waste production and management (hazardous waste list, inventory and identification of new hazardous waste)
- Lack of a chemicals legislation in the country similar to REACH or TSCA
- Under-utilization and improper use of practical and theoretical expertise where it may be available
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Module 2

Legal Frame

International Agreements

EU waste legislation
Main international conventions dealing with hazardous chemicals and wastes and their legal repercussions

The establishment of an appropriate legal framework is the first step in establishing a systematic waste management system aiming at environmentally sound waste management.

Such a legal framework should be concise with clear definitions and with clear allocation of responsibilities for the different actors. It is crucial for successfully dealing with the challenges of waste management. All actors in the waste management area, authorities as well as industry, SMEs and other stakeholders, have to be aware of what their legal obligations are and what consequences exist in case of violations. International agreements have an influence on national legislation.

3.1. Main Actors of International Conventions

Sovereign States are the main actors in the area of international law. They may conclude international agreements, in the form of multi-lateral agreements (MEAs) also known as conventions. Most of MEAs are implemented via national legislation and regulatory measures.

'Multilateral environmental agreements’ (MEAs) 36 are agreements between states which may set out non-legally binding principles which parties will respect when considering actions which affect a particular environmental issue or which specify legally-binding actions to be taken to work toward an environmental objective. The institutional elements of MEAs include: Conference of Parties37, a Secretariat, executive and subsidiary bodies, a clearinghouse mechanism, and a financial mechanism. The Secretariat of the Conventions can develop guidelines and can assist signatory States. These conventions have repercussion on the national legislation if ratified by the corresponding country.

The graph38 here below shows how international agreements and other demands from society and customs have a direct influence on production companies included SMEs in a country:

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37 Conference of the Parties (COP) is the ultimate decision-making body on the overall implementation and development of their respective MEAs, including the work programme, budget, and adoption of protocols and annexes

38 Source Dr Jürgen Hannák, 2011
3.2. Multilateral environmental agreements dealing with hazardous chemicals and OECD council decision C (2001)107 on waste

The relevant MEAs dealing with hazardous chemicals are: Basel Convention on Trans-boundary Movement of Hazardous wastes, Rotterdam Convention (PIC), Stockholm Convention on POPs and the OECD Decision on the Control of Trans-boundary Movements of Wastes C(2001)107/Final.

This last one is an international convention in the sense of article 11 paragraph 2 of the Basel convention. The difference between the Basel Convention and the 2001 OECD decision is that the decision regulates only the cross-border movement of waste for recovery, not of wastes shipped for disposal. The decision further regulates all wastes and not only hazardous ones.

There are other MEAs related to chemicals that have been established and ratified in the last 35 years. The graphic here below shows some selected conventions dealing with chemicals:

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39 Source: Dr Jürgen Hannak, 2011
Around 1970-1975 there were many scandals related with transport of hazardous wastes from industrialized countries to developing countries. This was due mainly to the insufficient infrastructure for disposal of hazardous waste and the high prices for disposal in the “developed” countries. As a consequence of this aberrant situation two important international systems of rules for the trans-boundary movement of hazardous waste were developed to regulate the movements of HW: The Basel Convention and the OECD Decision on the Control of Trans-boundary Movements of Wastes.

The Basel Convention (BC) seeks to protect human health and the environment from dangers posed by the trans-boundary movement of hazardous wastes and other wastes applying the Prior Informed Consent (PIC) procedure. The Convention had 172 Parties as of November 2009.40

The Convention furthermore obliges its Parties to ensure that hazardous and other wastes are managed and disposed of in an environmentally sound manner. Technical assistance, technical guidelines on the Environmentally Sound Management of specific hazardous waste streams and further guidance material are provided by the BC Secretariat.41

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40 [www.basel.int](http://www.basel.int)

41 The Basel Convention has also established independent Regional Centers for Training and Technology Transfer in the following countries: Argentina, China, Egypt, El Salvador, Indonesia, Nigeria, Senegal, Slovak Republic, Russian Federation, South Africa, Trinidad & Tobago and Uruguay. The description of the core functions of the Centers is as follows: Training; Technology transfer; Information; Consulting; and, Awareness-raising. Their core functions are to:

- Provide guidance on technical, technological and legal issues, as well as advice on enforcement aspects of
In Germany and all other EU member states transfrontier shipments of waste are regulated by Regulation (EC) No 1013/2006 on shipments of waste, which is based on the Basel Convention on the Control of Trans-boundary Movements of Hazardous Wastes and Their Disposal and on the Decision of the OECD-Council on the Control of Tran boundary Movements of Wastes Destined for Recovery Operations.

The cross-border movement/shipment of waste has to be accompanied by a notification document (TFS) and a movement document indicating the intended disposal method; the country of destination and the classification of the waste

**Trans-boundary shipment (TFS) notification and movement documents** at [http://www.basel.int/Procedures/NotificationMovementDocuments/tabid/1327/Default.aspx](http://www.basel.int/Procedures/NotificationMovementDocuments/tabid/1327/Default.aspx) under other publications: Revised versions of the forms for the notification document and the movement document and related instructions adopted at COP8

The Basel Convention prohibits the trans-frontier shipment of wastes to or from non-Parties (Article 4 Para 5). However, Article 11 of the Basel Convention allows Parties to enter into bilateral agreements on trans-frontier waste shipments with non-Party states, on the condition that environmentally sound waste management as required by the Basel Convention is carried out.

As an example from Germany that has concluded bilateral agreements pursuant to Art. 11 of the Basel Convention with Afghanistan (import of military waste into Germany) and with UN/KFOR – UN administration in Kosovo (import of waste from KFOR military activities into Germany). These waste transports are subject both to the provisions of the EC Waste Shipment Regulation and to the national laws of the individual state.

- the Basel Convention and related Conventions
- Encourage the introduction of Cleaner Production-technologies
- Encourage the use of environmentally sound management practices
- Enhancement of information exchange, education and awareness-raising

The Convention’s current work focuses on management of POPs as waste, end of- life mobile phones, wastes from the surface treatment of metals and plastics; dioxins and furans; disposal of PVCs; and household wastes. Carelessly discarded electronic and electrical equipment can leak dangerous chemicals into the environment, including PCBs. For example, there are millions of discarded mobile phones deteriorating in landfills around the world or burning in municipal waste incinerators, releasing the cadmium and nickel in their batteries, lead in their solder and gallium and arsenic in their transistors. Cadmium is a particularly toxic pollutant of waterways.
Fig. 6: Overview of countries that have ratified the BC as per 2009. Afghanistan, USA, Haiti and other African and Asian countries have not yet ratified the BC.

For shipment data and statistics you can consult e.g. the German focal point of the Basel convention at: [http://www.umweltbundesamt.de/abfallwirtschaft/gav/index.htm](http://www.umweltbundesamt.de/abfallwirtschaft/gav/index.htm)

There are two major amendments that have been added to the Basel Convention after its adoption. One is the “Basel Ban”, prohibiting any export of hazardous waste from developed countries to developing countries. No binding international agreement has yet been reached as the ratification is not (yet) complete. (See also annex 1e, Bamako Convention).

The lists A and B (Annex VIII and IX) were developed to facilitate the implementation of the Convention in general and the Ban amendment in particular. The hazardous wastes list A (Annex VIII) would ban the export of wastes containing arsenic, lead, mercury, asbestos and many other chemical substances. The non-hazardous wastes list B would exempt from the Ban those wastes that can be safely recycled or re-used, including scrap iron, steel or copper, certain electronic assemblies, non-hazardous chemical catalysts, solid plastic wastes, paper and textile wastes.
The other amendment is the Basel Protocol on liability and compensation for damage resulting from trans-boundary movements of hazardous waste also referred to as the “Liability Protocol. The Liability protocol states that countries that suffer damage (health, environment etc) from hazardous waste that has been received, without the proper procedures under the Basel Convention, are entitled to compensation from the exporting country.

A protocol is linked to an existing convention, but it is a separate and additional agreement that must be signed and ratified by the Parties to the convention. Protocols typically strengthen a convention by adding new, more detailed commitments.

Core rules/activities the Basel Convention deal with:

Import, export and transit controls of HW and they are only allowed if all involved parties/countries have been prior informed and the transport, shipment and disposal have been authorized. Shipment / Transport / Disposal to Non members to the BC are not allowed. The exporter of the HW is responsible that all rules of the BC are fulfilled especially in case of illegal movements. The BC and its effort to minimize international movement of HW are very helpful to reduce the dangers posed by HW on a world wide scale. The main aim is to minimize the trans boundary movement of HW. The BC is considered the most comprehensive global treaty dealing with hazardous waste materials through their lifecycles, from production and transport to final use and disposal.
Bamako Convention\textsuperscript{42} 

After the Basel Convention entered into force, several LDCs and NGOs argued that the Convention based actions were not strong enough and demanded a total ban on shipment of all hazardous waste to LDCs. The main reason for this demand was the fact that many developed countries were exporting hazardous wastes to Africa. Additionally, traders exported hazardous waste purporting a movement of waste for recycling. These arguments led to the introduction of several regional hazardous waste trade bans. Among them was the Bamako Convention.

The Bamako Convention on the ban on the import into Africa and the Control of Trans-boundary Movement and Management of Hazardous Wastes within Africa was signed by twelve nations of the Organization of African Unity in Bamako, Mali in January 1991 and entered into force in 1998.

3.2.2. Rotterdam Convention (PIC Convention)\textsuperscript{43}

The Rotterdam Convention on the Prior Informed Consent (PIC) Procedure for Certain Hazardous Chemicals and Pesticides\textsuperscript{44} provides Parties with a first line of defense against hazardous chemicals (pesticides and some industrial chemicals). It promotes international efforts to protect human health and the environment as well as enabling countries to decide if they want to import hazardous chemicals and pesticides listed in the Convention. The Convention builds on the voluntary PIC procedure. The Rotterdam Convention had 130 Parties as of November 2009.

If a chemical is to be exported from a country where this chemical is banned or restricted the exporting Party must provide an export notification to the importing country including certain information before the first shipment and frequently thereafter; the export of chemicals is to be accompanied by an up-to-date safety data sheet and chemicals must be labeled in an appropriate way.

\begin{flushleft}
\textbf{The Rotterdam Convention addresses pesticides and industrial chemicals that have been banned or severely restricted for health or environmental reason by Parties to the convention and that}
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\begin{flushright}
\textsuperscript{42} In the contrary to the Basel Convention which makes exceptions on certain hazardous waste imports, the Bamako Convention prohibits the import of any hazardous waste (e.g. including radioactive wastes) to the signatory nations. In 1995 key European countries and environmental NGOs demanded the inclusion of a Ban Amendment to the Basel Convention. However, several countries strongly opposed the amendment. The ban amendment prohibits the export of hazardous waste from a number of developed countries to developing countries independently from its purpose, including recycling. The ratification of three fourth of the signatories is required for the amendment to enter into force. As of mid-2009 65 countries have ratified the amendment. As The European Union fully integrated the Ban Amendment of the Basel Convention into the Regulation on Shipments of Waste (1013/2006) and thus made the amendment legally binding in all EU member states.
\textsuperscript{43} \textsuperscript{www.pic.int}
\textsuperscript{44} The PIC procedure, along with information exchange, is one of the key provisions of the Rotterdam Convention. For each chemical listed in Annex III of the Convention a decision guidance document (DGD) is prepared and sent to all Parties with a request that they take a decision as to whether they will allow future import of the chemical. The resulting decisions on future import of these chemicals (import responses) are published by the Secretariat and made available to all Parties every six months through the PIC Circular.
\end{flushright}
have been notified by Parties for inclusion in the Prior informed Consent (PIC) procedure.

Two main objectives of the PIC convention are:

1. To promote shared responsibility and cooperative efforts among Parties in the international trade of certain hazardous chemicals in order to protect human health and the environment from potential harm
2. To contribute to the environmentally sound use of those hazardous chemicals by facilitating information exchange and by providing for a national decision-making process on the import and export of those hazardous chemicals

Rotterdam Convention and list of chemicals subject to the Prior informed Consent procedure (PIC) (Annex III) to download at: [http://www.pic.int/home.php?type=t&id=29&sid=30](http://www.pic.int/home.php?type=t&id=29&sid=30)


3.2.3. Stockholm Convention (POP Convention)\(^{45}\)

The Stockholm Convention on Persistent Organic Pollutants (POPs) requires the Parties to the Convention to eliminate or reduce the release of specific POPs into the environment.

POPs are chemicals that are persistent, bio accumulative, subject to long-range environmental transport and that are toxic to humans and the environment. The Stockholm Convention entered into force in 2004 and had 168 Parties as of November 2009.

POPs are chemicals that remain intact in the environment for long periods. Through the food change they become widely distributed geographically and accumulate in the fatty tissue of living organisms.

The Stockholm Convention includes the prohibition of production of chemicals listed in Annex A, the restriction of production and use of chemicals listed in Annex B. The Annex C of the Convention concerns the POPs formed and released unintentionally.

The Stockholm Convention on POPs is a global treaty to protect human health and the environment from highly dangerous, long lasting chemicals by restricting and ultimately eliminating their production, use, trade, release and storage.

\(^{45}\) [http://chm.pops.int/default.aspx](http://chm.pops.int/default.aspx)
Governments have to take measures to eliminate or reduce the release of POPs into the environment.

At its adoption, the Convention targeted 12 particularly toxic POPs for reduction and eventual elimination. Nine further POPs (new POPs) have been added to the Convention based on a consensus decision by the Parties in 2009.

The Convention also provides support to developing countries and countries with economies in transition to phase out and clean up stockpiles of certain chemicals.

Stockholm Convention, including lists of the chemicals subject to the Annexes A, B and C as well as the 9 new POPs

Further information:

How toxic chemicals reach the Arctic and other hazardous chemicals’ videos at:


The Commission on Sustainable Development (CSD), established by the United Nations General Assembly in 1992 to ensure effective follow-up to the 1992 United Nations Conference on Environment and Development (Earth Summit), is responsible for reviewing the progress in the implementation of Agenda 21 and the Rio Declaration on the Environment and Development as well as providing policy guidance to follow up the Johannesburg Plan of Implementation (JPOI) at the local, national, regional and international levels.

The publication "Practices in the Sound Management of Chemicals", 2010, outlines current trends, emerging issues and priority areas in the field of chemicals management and allows for a better understanding on how the sound management of chemicals is central to sustainable development and the achievement of the United Nations Millennium Development Goals.

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48 The publication, which was developed by the Division for Sustainable Development of the United Nations Department of Economic and Social Affairs (UNDESA), the Secretariat of the Stockholm Convention on POPs, and UNEP Chemicals, is available at: http://chm.pops.int/Convention/Meetings/18hCSDsession/tabid/753/language/en-US/Default.aspx
49 http://www.undp.org/content/undp/en/home/mdgoverview.html
3.2.4. OECD Decision on the Control of Trans-boundary Movements of Wastes

Since March 1992, trans-boundary movements of wastes destined for recovery operations between member countries of the Organization for Economic Co-operation and Development (OECD) have been supervised and controlled under a specific intra-OECD Control System.

The Council of the OECD has passed several decisions on the “Control of Trans-boundary Movements of Wastes Destined for Recovery Operations”, the most recent one being the “Decision of the Council concerning the Control of Trans-boundary Movements of Wastes Destined for Recovery Operations” (C(2001)107/FINAL)\(^50\) (see guidance manual also\(^51\)

This Control System aims at facilitating trade of recyclables in an environmentally sound and economically efficient manner by using a simplified procedure as well as a risk-based approach to assess the necessary level of control for materials. Wastes exported outside the OECD area, whether for recovery or final disposal, do not benefit from this simplified control procedure.

The OECD Control System is based on two types of control procedures:

1. Green Control Procedure: for wastes that present low risk for human health and the environment and, therefore, are not subject to any other controls than those normally applied in commercial transactions;

2. Amber Control Procedure: for wastes presenting sufficient risk to justify their control.

Wastes subject to these control procedures are listed in Appendices 3 and 4 to Decision: the so-called Green and Amber lists of wastes.

The controls of waste shipments are carried out by national competent authorities and Customs Offices as appropriate, through the use of notification and movement documents.

The Guidance Manual for the Control of Trans-boundary Movements of Recoverable Wastes explains the functioning of the OECD control system in detail. It assists national governments and competent authorities to implement the OECD control system and also helps private companies to import and export of recoverable wastes in an environmentally sound and economically efficient manner.

OECD lists of wastes subject to the green and the amber control procedure at www.oecd.org/dataoecd/57/1/42262259.pdf pages 81-98


\(^{51}\) www.oecd.org/dataoecd/57/1/42262259.pdf
Purpose of Notification and Movement Documents
The Notification Document is intended to provide the Competent Authorities of countries concerned with the information they need to assess the acceptability of the proposed waste movement. The Document includes space for acknowledging receipt of the notification by the relevant Competent Authority (ies) and, when required, consenting in writing to the movement.

The Movement Document is intended to travel with the consignment at all times from leaving the waste generator to its arrival at the disposal/recovery facility in another country. Space is provided on the Document for completing detailed information on the first and any subsequent carriers of the consignment.

Also, there are spaces to record passage of the consignment through Customs offices of all countries concerned. (While not strictly required by the International Agreements, some countries may by national legislation require such procedures and information to ensure proper control). Finally, the Document is to be used by the disposal/recovery facility to certify that the waste has been received and that the recovery/disposal operation is completed.

Although the 25 OECD members are mainly developed countries, a great influence on hazardous waste policy on a world-wide level is given.
OECD Waste List is also mainly material (substance) oriented and to be used mainly towards trans-boundary movement of wastes.
The Basel Y code Waste List is based on the OECD waste Lists of C(92/39), whereas the new OECD decision C(2001)107 list is based on Annexes VIII and IX of the BC

3.3. Legal Assistance from BC secretariat and OECD
The Basel Secretariat, through its legal unit, advises and assists Parties regarding the adoption, and implementation of national legislation, through direct contacts with countries and the elaboration of technical guidance documents.

The Organization for Economic Co-operation and Development (OECD), besides various other activities, aims at improving waste management and resource efficiency by encouraging and providing guidance concerning Sustainable Materials Management (SMM); environmentally sound management of waste, trans-boundary movements of waste, waste prevention and minimization, and radioactive waste management. It puts a focus on policies and instruments which ensure cost-effective management of materials throughout their life-cycle. In addition, the negative impacts resulting from material use and consumption are not relegated to the end of the material’s chain.
3.3.1. Basic principles of waste legislation to be considered (Basel Convention)

Waste legislation should address the various aspects that are relevant in waste management and must be adequate, coherent and enforceable within any legal system. Basic principles and topics that should be covered at the very least are the following:

(a) The aim and the scope of the law
(b) The responsible authority that is issuing the legislation
(c) Definition of waste, hazardous waste and any related issues (classification systems, management, storage, collection, transport, recovery, disposal, approved/authorized facilities, after-care of disposal sites)
(d) Definition of treatment methods, any waste management hierarchy and parties involved
(e) Allocation of responsibilities and obligations to involved parties, authorization, control system
(f) Enforcement infrastructure
(g) Technical standards and procedural requirements for treatment methods (disposal and recovery)
(h) Prevention, reduction and/or elimination measures
(i) Monitoring, reporting and documentation, evaluation and review mechanisms
(j) Training, information, awareness raising
(k) Offenses, penalties and sanctions
(l) Procedural aspects and restrictions on trans-boundary movement of wastes (import, export, transit, illegal shipments, penalties).

A Basel Convention Model National Legislation on the Management of Hazardous Wastes\(^2\)

A checklist also provided by the Basel Convention is available online at [http://www.google.de/url?q=http://archive.basel.int/legalmatters/natleg/chklst210706%2520.doc&sa=U&ei=KCqMT-yOosGXhQfBqq2xCQ&ved=0CBUQFjAA&usg=AFQjCNGz-ZZp6EodiAa8zR7X8Ujp4hLZ4Q](http://www.google.de/url?q=http://archive.basel.int/legalmatters/natleg/chklst210706%2520.doc&sa=U&ei=KCqMT-yOosGXhQfBqq2xCQ&ved=0CBUQFjAA&usg=AFQjCNGz-ZZp6EodiAa8zR7X8Ujp4hLZ4Q)

The Basel Convention stresses the fact that waste management and related legislation and enforcement need to be linked with product policy. “Waste minimization policies that focus on end-of-life products and materials are not effective in reducing the increasing amounts of waste associated with production and consumption. Therefore, it is necessary to focus on long-term solutions, based on a life-cycle approach”.

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\(^2\) The document is available at: [http://www.google.de/url?q=http://archive.basel.int/pub/modlegis.pdf&sa=U&ei=ISmMT9HeNYLChAfkJMm3CQ&ved=0CBUQFjAA&usg=AFQjCNG6jdvIMh6w9z75778V43FcJJiH5q](http://www.google.de/url?q=http://archive.basel.int/pub/modlegis.pdf&sa=U&ei=ISmMT9HeNYLChAfkJMm3CQ&ved=0CBUQFjAA&usg=AFQjCNG6jdvIMh6w9z75778V43FcJJiH5q)
It is considered crucial to reduce and control trans-boundary movements of hazardous waste while promoting the reuse, recycling and recovery of hazardous waste which may require export to appropriate facilities and controlling illegal traffic (caused by the uneven distribution of supply and demand of recyclable resources) in order to prevent environmental risks and to save resources.

3.3.2. Additional aspect to be considered (OECD) in waste legislation, implementation and enforcement

A list of the 34 OECD countries and the OECD work on each particular country can be seen at: http://www.oecd.org/document/58/0,3746,en_2649_201185_1889402_1_1_1_1,00.html

In regard to waste management, the OECD forum focuses on developing recommendations/guidance for:

Environmentally sound management (ESM) of waste; the OECD Council Recommendation on ESM of Waste comprises waste collection, storage, recovery and disposal, including policy recommendations for governments and practical recommendations for waste treatment facilities (e.g. implementation of an environmental management system, auditing in terms of environment, health and safety measures, monitoring and recording of emissions and waste generation, ensuring of a safe and healthy occupational environment, etc.).

The OECD Guidance Manual published in 2007\(^{53}\) lists the following 11 recommendations for waste legislation and enforcement:

1. Have an adequate regulatory framework and enforcement infrastructure and mechanisms at an appropriate governmental level. Legal requirements should comprise authorizations/licenses/permits, or standards (such as emission limit values, environmental performance standards, technology standards or other regulations applicable to waste management activities). The enforcement mechanisms could consist of the verification, by government officers or appropriate bodies, of compliance with legal instruments and standards. In some instances, issuing authorizations/licenses or permits may be appropriate. Co-ordination between several government levels (whether national/federal or sub-national) in order to ensure effective enforcement

2. Develop and implement practices and instruments that facilitate the efforts of competent authorities to monitor the implementation of six core performance elements (CPEs)\(^{54}\), and

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\(^{54}\) See chapter 2.13
control compliance of waste management activities with applicable national and international rules and regulations. Take prompt, adequate and effective actions in case of non-compliance with existing rules. Establish simple means or procedures facilitating control, such as registers of licensed facilities and recognized inspectors/auditors. With regard to sanctions adopt quick, dissuasive and well targeted approaches, in order to enhance their effectiveness.

3. Ensure that waste management facilities are operating according to best available techniques (BAT) also called “State-of-the-Art Technology” and work towards continually improving environmental performance.

4. Take appropriate measures to encourage information exchange between producers, waste generators, waste management service providers (collection, transport, treatment) and authorities, including participation in sectoral trade or industry association activities, in order to foster waste prevention, optimize recovery operations and minimize quantities as well as potential risk of waste destined for disposal or recovery.

5. Integrate into national policies and/or programs the six Core Performance Elements (CPEs) to be applied at the level of individual facilities as a minimum standard.

6. Consider incentives and/or relief measures for facilities that fulfill the CPEs.

7. Implement the technical guidance for Environmental Sound Management (ESM55) of waste developed by OECD and Basel Convention.

8. Move towards internalization (waste and related costs should be known and considered by companies) of environmental and human health costs in waste management, taking into account the differences between hazardous and nonhazardous waste.56

9. Support existing recycling schemes/policies and encourage the development of new environmentally sound ones, by providing incentives to take part in environmentally sound recycling schemes.

10. Encourage the development and implementation of an environmental liability regime57 (see more details below) for facilities that carry out risky or potentially risky activities to ensure adequate measures upon definite cessation of activities and to prevent environmental damage.

11. Ensure that the implementation of the CPEs does not discourage recycling, in particular increasing the rates of environmentally sound recovery of low risk waste.

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55 See glossary
56 The rationale behind this idea is that economically, often the total social costs including environmental and human health costs from waste management practices are not fully reflected in the financial costs of waste management, with the difference being borne by other economic agents. As long as this is the case, waste generators and managers may not have sufficient incentive to adopt an appropriate level of waste management within their facilities. In the same way, any environmental benefits of production from waste should be internalized into waste management decisions at the facility level. For example, the recovery and production of metals from wastes may require less energy, use of chemicals and disturbance of land in comparison to the production of the same metals from ore. While metals produced from waste must compete in open markets, the added environmental benefits they bring should be fully recognized, and their production should be encouraged in an appropriate manner. See OECD Guidance Document, p. 35.
57 The OECD stresses the fact that bankruptcies of industrial companies tend to result in orphan Brownfield/contaminated sites, and that public authorities have to pay large sums of money for clean-up and remediation. Therefore, it is deemed crucial to include in national legislation provision for environmental liability (including liability for clean-up costs) for waste management activities which pose environmental and human health risks. In addition operators of risky waste management activities should be obliged by the legislation to insure their potential liabilities (e.g. via financial guarantees, deposits, etc.) (As model see e.g. CERCLA, Brownfield’s Law, RCRA (USA); EC Directive 2004/35/EC (EU). In addition to these recommendations related to organization and the standard requirements for waste management to take into consideration in waste management the OECD provides additional recommendations for transboundary movement of waste (valuable waste for recovery) and radioactive waste.
In addition to these recommendations on implementation and enforcement, the OECD provides additional recommendations with respect to international (trans-boundary) movement of waste (valuable waste for recovery) and radioactive waste.

Trans-boundary movements of waste

Imports and exports of waste destined for recovery within the OECD countries are to be controlled by a system developed by the OECD on the way (basis of the legally binding Decision of the Council concerning the Control of Trans-boundary Movements of Wastes Destined for Recovery Operations). The control system allows to trade recyclable materials (wastes) in an environmentally safe way (standards) by defining certain minimum treatment standards. An interactive OECD database provides information for authorities and exporters/importers for the notification and movement documents for trans-boundary waste shipments. A Guidance Manual for the Control of Trans-boundary Movements of Recoverable Wastes in 2009 explains the functioning of the OECD control system. (see document under reference)

Radioactive waste management

The OECD Nuclear Energy Agency (NEA) provides guidance on sustainable solutions for the management of radioactive waste covering policy and governance issues, safety evaluation and regulation, as well as scientific technical developments.

Furthermore, the OECD has developed recommendations with respect to embedding waste management policy in sustainable development policies.

The following 4 main sustainable development policies are briefly outlined.

1. Sustainable materials management (SMM)

The OECD emphasizes the need for governments to look for integrated management solutions which link resource use and prevention of waste into a coherent policy approach. In this framework, the following working definition for the Sustainable Materials Management (SMM) paradigm has been elaborated: “Sustainable Materials Management is an approach to promote sustainable materials use, integrating actions targeted at

59 Database on Transboundary Movement of Wastes destined for Recovery Operations: http://www2.oecd.org/waste/
60 For details see www.nea.fr/rwm.
reducing negative environmental impacts and preserving natural capital throughout the life-cycle of materials, taking into account economic efficiency and social equity”.

The document “Recommendation of the Council on Resource Productivity” includes recommendations from the OECD Council with regard to the analysis of material flows and their environmental impacts as well as in relation to policies of Member countries concerning the improvement of resource productivity. In addition, specific instructions for the Environmental Policy Committee are given.

2. Waste prevention and minimization

Waste prevention is a key element of a policy aiming for sustainable economic development and resource management. Waste prevention is a long-term objective of all OECD countries as announced in respective OECD Recommendations and should be established by encouraging legislative measures and incentives in the framework of EPR.

Relevant OECD documents provide comprehensive information on strategic and scientific approaches on waste prevention (see e.g. “Reference Manual on Strategic Waste Prevention” and “Towards Waste Prevention Performance Indicators”).

3. Extended producer responsibility (EPR)

This guidance manual “Extended Producer Responsibility: A Guidance Manual for Governments” represents one means to inform national governments about the potential benefits and costs associated with EPR. The other reference document “EPR Policies and Product Design: Economic Theory and Selected Case Studies” explains the principle and mechanisms of extended producer responsibility and provides information on practical application by governments. Within given case studies the main benefits of this policy approach are illustrated.

Extended producer responsibility is a policy approach implying that producers accept significant financial and/or physical responsibility for the environmentally safe treatment or disposal of products at the post-consumer stage (waste). Assigning such responsibility might provide incentives for waste prevention at the source, to promote eco-efficient product design and to support the realization of better recycling and materials management. Within the OECD, the trend goes strongly towards the extension of EPR to new products, product groups and waste streams such as electrical appliances and electronics.


63 Towards Waste Prevention Performance Indicators (OECD, 2004)


4. **Green Public Procurement (GPP)**

GPP can be an important instrument to privilege industry that is innovative and ambitious in reducing environmental hazards from production and waste management. The OECD has recommended to its Member Countries to take account of environmental considerations in public procurement of products and services (including, but not limited to, consumables, capital goods, infrastructure, construction and public works), in order to improve the environmental performance of public procurement, and to thereby promote continuous improvement in the environmental performance of products and services.

In recent years, a considerable number of OECD Member countries introduced initiatives such as "greener public purchasing" policies in order to reduce the environmentally damaging effects of public procurement. Such policies aim at increasing the amount of recycled material content of products or achieve specified levels of energy efficiency in capital equipment. The OECD document “The Environmental Performance of Public Procurement: Issues of Policy Coherence” examines these issues in detail.

Due to the fact that the Commission of the European Communities and many EU Member States take part in the work of the OECD, legal requirements and standards recommended by the OECD are reflected in EU legislation.

Therefore, the legal framework of the European Union (EU) will be presented in the following chapter as a model example for waste management legislation. Because of the experience made and the lessons learned in the last 40 years with the management of waste and hazardous waste and because of the variety of economic, ecological and geographical conditions in the EU Member States, the EU approach represents a good example of how to set up waste management legislation.

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• European Union Legal Framework for Hazardous Waste Management

This chapter is dedicated to explain main features of the EU waste legislation on hazardous waste management that may be roughly divided into three categories:

1. The **framework legislation**, containing the scope of EU waste management legislation, strategic aims, basic principles, overall definitions (e.g. on the definition of hazardousness) and overall obligations for MS. The main legal document in this field is the **Waste Framework Directive 2008/98/EC (WFD)** applicable by the MS as of December 2010.

2. The Regulation on **shipments of waste**. This regulation implements the Basel Convention and sets strict additional requirements for transports of all kinds of wastes between MS, outside and inside the EU – hazardous wastes, even between EU MS and even if destined for recovery operations, are submitted to a procedure of notification and consent of authorities of the involved countries prior to shipment.

3. Legal acts with respect to **treatment operations**; namely Directives on land filling and on waste incineration; in case the waste treatment facility exceeds a defined size, it additionally has to comply with the strict **Integrated Pollution Prevention and Control Directive (IPPC)**. These acts set up obligations for permitting, operation requirements (including emission limit values for pollutants), and provisions for monitoring and control.

A number of Directives are dedicated to single waste streams deemed to be of concern. The main measures used in these Directives are obligations for producers to organize separate collection schemes and targets for MS (reduction/collection/recovery/efficiency). Figure 7 gives an overview of key legal documents.

### 4.1. European Union’s Policy on Hazardous Waste Management

Legal acts issued by the European Union often have to be transposed into national legislation by the Member States. The advantage of this procedure is that there is a common legal basis for all Member States. With regard to hazardous waste management a common Europe-wide legal basis allows the introduction of comparable waste management systems throughout the European Union and a smooth handling of hazardous waste beyond the national borders of the respective member states. The European legal acts themselves are formulated and issued on the basis of and in line with international regulations.

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66 It should be noted that for the purpose of this chapter, a focus is laid on waste management legislation whereas other regulations which might also be relevant when dealing with hazardous waste (such as regulation on Occupational Health & Safety or Rules for Transport of Dangerous Goods) will be addressed in the text where deemed relevant, but not explained in further detail.
The following legal documents constitute the backbone of the European Community waste management policy:

  
  It contains basic definitions and lays down basic principles of EU waste management as well as prescriptions and obligations for waste management in the EU.

  a. A key element of the WFD is notably the obligation for MS to establish and to publish Waste Management Plans and Waste Prevention Programs to define priorities, problems and solutions for a given time framework and a defined geographical area.
  
  b. With respect to hazardous waste management, the WFD defines the categories which render a waste hazardous (such as flammable, toxic, ecotoxic,) and which distinguishes hazardous from non-hazardous wastes.
  
  c. The WFD is complemented by the EU List of Wastes (EWL)\(^ {67}\) which introduces a classification system for waste categories, applying a source-oriented approach.

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d. Key elements of the EU approach specifically with respect to hazardous waste management are stricter rules on control and record keeping as well as a ban of mixing.

- Regulation (EC) No 1013/2006 on shipments of waste

It sets out stringent requirements to the control of waste shipments (import/export/transit), taking into account the principles of self-sufficiency and proximity for waste for disposal.

Based on the general legal framework, the Community waste management policy is supplemented by a number of more specific Directives:

Directives and regulations on specific waste streams covering the measures of prevention and common rules for separate collection and treatment:

- Directive on Packaging Waste (94/62/EC)
- Directive on batteries and accumulators (2006/66/EC)
- Directive on Sewage Sludge in Agriculture (86/278/EEC)
- Directive on the disposal of PCBs/PCTs (96/59/EC)
- Regulation (EC) No 850/2004 on POPs
- Regulation (EC) No 1102/2008 on the banning of exports of metallic mercury and certain mercury compounds and mixtures and the safe storage of metallic mercury

Directives aimed at reducing the impact of treatment and disposal by setting up common technical standards for:

- Directive on the incineration of waste (2000/76/EC)
- Directive on the landfill of waste
4.1. Key regulators and enforcing agencies of the European Hazardous Waste System

The enforcement of EU waste legislation is characterized by the fact that both the EU and the MS are competent. Simplified, the regulatory framework as regards aims and objectives is set at EU level and complemented by detailed MS regulations which are free to choose the way they want to pursue the aims. MS must not fall short of environmental requirements set at EU level; on the other hand, they may go beyond and adopt additional protective measures.

The enforcement of EU environmental law is to a large extent left to Member States which execute the EU legislation with their own authorities applying national procedural framework (the EU itself does not obtain a lot of enforcement resources, and currently, there is no agency at EU level for the enforcement of waste related issues). The enforcement system differs from MS to MS and depends to a large extent on the structure of the MS (e.g., whether it is a federal or a centralized state). For the authorization (permitting/licensing), inspection and control of hazardous waste, a number of authorities may be competent including general law enforcers such as police. To facilitate co-operation and exchange of information between these authorities (and for many constellations, namely cross-border waste shipments, between authorities of different MS) is an important task for the MS.

4.1.2. Systemic prerequisites

The better and the more clear the legal framework is, the higher is the probability that the law is enforced appropriately. A sound legal framework is a precondition for successful enforcement. The administrative enforcement structure should be adjusted following an assessment of the needs of the legislation to ensure that enforcement mechanisms are co-operative and smooth running.

A good qualification of concerned staff (e.g. experienced, well-trained engineers and lawyers) is crucial for enforcement. Without sufficient knowledge and expertise the officers on the field will not be in the position to detect violation of legislative rules and requirements.

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Such expertise needs to comprise detailed knowledge about legal requirements, expert knowledge on characteristics and appearance of (hazardous waste), expert knowledge about related risks, inspection planning, execution and prosecution. Such expertise requests continuous training and guidance and other support from the central level for involved authorities but also for involved and concerned industry.

Compliance with legal requirements for environmentally sound waste management entails considerable administrative burden and costs for waste producers, waste management services.

Compliance hence cannot be expected automatically and needs to be supported.

Such support can be twofold and complementary:

On the one side there is need for incentives such as economic benefits for certain behavior (funding or reimbursement systems, environmental funds that are used to support industry, etc), certification or award schemes that may support and honor correct behavior.

On the other hand every legal and enforcement system is to be flanked by a sanction system which is dissuasive (though not exceeding the idea of proportionality) and which introduces clear and foreseeable penalization of violations of legislation to set incentives for compliant behavior.

Environmental taxes or waste management taxes can be considered an additional instrument to direct waste to the intended treatment.

4.2. Definition of Waste and Classification of Hazardous Waste in the European Union

4.2.1. Definitions of Waste

According to the European Directive on Waste 2008/98/EC (often referred to as “Waste Framework Directive”), ‘waste’ means any substance or object which the holder discards or intends or is required to discard’. As a legal term, the word ‘discard’ is not limited to the usual meaning of ‘throw away’. It indicates that recycling and recovery of material or energy may follow. The Waste Framework Directive 2008/98/EC additionally defines prerequisites for an exclusion of substances or objects from the waste legislation under special conditions.

More detailed waste definitions have been left to the discretion of the Member States. German waste legislation for example requires additionally the waste holder to “discard waste when such property is no longer used in keeping with its original purpose, and when, due to its specific state, it could endanger, either in the present or the future, the public interest, especially the environment; and when its potential danger can be ruled out only through proper and safe recovery, or disposal that is compatible with the public interest”.

97
Waste holders are obliged to either recover or dispose their waste. This definition of “waste” has readjusted the traditional understanding of “recovery” in Germany and is a cornerstone of Germany’s circular (recycling) economy that was notified in the “Closed Substance Cycle and Waste Management Act” in 1994 and revised in 2012.

![Diagram of waste classification](image)

**Fig. 8: Differentiation of “Waste” according to German Waste Law**

The Basel Convention states that ‘wastes’ are substances or objects which are disposed of, or intended to be disposed of, or required to be disposed of, by the provisions of national law. It should be noted that the terms “disposal” and “dispose” used in the Basel Convention cover both, disposal and recovery operations, as laid down in Annex IV of the BC.

According to the EU legislation and the Basdel Convention wastes are substances or objects for which the owner, holder or producer has no further use, and which consequently must be discarded. This broad definition is rendered more precisely in the EU Waste Framework Directive 2008/98/EC and the end-of-waste status is defined.

German legislation differentiates between “waste for recovery” and “waste for disposal” and requires waste holders to either recover or dispose their wastes in order to avoid harm to the public welfare.

**4.2.2. Distinguishing Waste from Non-Waste**

A crucial issue with regard to waste definitions is the distinction of waste from non-waste such as by-products or commercial goods.

Many waste generators consider residues from manufacturing, formulation, supply and use as by-products or “commercial goods” rather than waste if such materials have yet a commercial value and can be sold (e.g. spent solvents, distillation residues, etc.). This interpretation becomes particularly critical in case of materials containing hazardous...
substances. When the nature and concentration of the hazardous substances contained is unknown, sale, use and processing these materials in downstream applications bears uncontrollable risks to the public welfare, in particular to the environment and to occupational health and safety. Downstream processing of such materials is therefore usually permitted only in those facilities that have been approved by the competent authorities for recycling or recovering waste or for using waste as an alternative raw material or fuel. Labeling such materials as “by-product”, “residue” or “commercial good” undermines this concept by disengaging them from the waste regime. Whereas waste holders may be doing so without intent to deceive, the competent authorities have to scrutinize those cases carefully if the materials under consideration exhibit risks to public health and safety.

Another challenge that calls for attention in this context is “sham recovery”. When enforcement of hazardous waste related regulation started to accelerate in Europe in the 1970-1980ies, hazardous waste generating entities found ways to avoid high disposal costs by labeling their hazardous wastes as “by-products” or “commercial goods” and by assigning them to recovery operations. In many cases however “recovery” turned out to be “sham recovery”, and frequently fraudulent intent of the waste holders became evident. In this case labeling of hazardous waste as by-product was deliberately used for bypassing waste regulation.

To a large extent the problems mentioned above can be resolved by a comprehensive definition of the term “waste” encompassed by a detailed waste classification system. For example, the waste definition introduced in Germany as part of the “Closed Substance Cycle Waste Management Act” in 1994 (“waste for recovery” - “waste for disposal”) clarified respective ambiguities of the previous German waste definition that had enabled waste generators to claim their wastes to be “commercial goods”. The problem has stopped since.

However the basic question how to distinguish waste from by-products remains. Though a universally valid discrimination of waste from by-products is impossible due to the complexity of the issue, regulators and other involved bodies and organizations have developed criteria for providing guidance in order to arrive at conclusions on a case by case basis. EU Waste Framework Directive 2008/98/EC specifies in Article 5 four criteria for distinction that have been illustrated in Fig. 9.
Fig. 9: Decision tree for distinguishing waste from by-products according to criteria laid down in EU Waste Framework Directive 2008/98/EC

Moreover, the ‘Organization for Economic Co-operation and Development’ (OECD) has compiled criteria used by the OECD member countries for distinguishing waste from non-waste. See table 2 here below.

Table 2: Compilation of criteria used in OECD countries for distinguishing waste from non-waste

---

1) General Considerations
   a) Is the material produced intentionally?
   b) Is the material made in response to market demand?
   c) Is the overall economic value of the material negative?
   d) Is the material no longer part of the normal commercial cycle or chain of utility?

2) Characteristics and Specification
   a) Is the production of the material subject to quality control?
   b) Does the material meet well developed nationally and internationally recognized specifications/standards?

3) Environmental Impact
   a) Do these standards include environmental considerations, in addition to technical or economic considerations?
   b) Is the use of the material as environmentally sound as that of a primary product?
   c) Does the use of the material in a production process cause any increased risks to human health or the environment greater than the use of the corresponding raw material?

4) Use and Destination of the Material
   a) Is further processing required before the material can be directly used in a manufacturing/commercial application?
   b) Is this processing limited to minor repair?
   c) Is the material still suitable for its originally intended purpose?
   d) Can the material be used for another purpose as a substitute material?
   e) Will the material actually be used in a production process?
   f) Does the material have an identified use?
   g) Can the material be used in its present form or in the same way as a raw material without being subjected to a recovery operation?
   h) Can the material be used only after it has been subjected to a recovery operation?

Regulators, enforcing agencies dealing with hazardous waste as well as other relevant government departments should find common ground for differentiating waste from non-waste and educate the regulated community accordingly. Transfer and processing of critical materials generated by the manufacturing- or the service sector should be carefully observed and adequate action taken if required.
4.2.3. Classification of Hazardous Waste

For differentiating hazardous from non-hazardous waste regulators of most countries have adopted generic hazardous waste lists comprising common hazardous waste types that are known to exceed minimum hazardous characteristics thresholds. Waste types specified in these lists are defined as hazardous. Whereas US-EPA uses four different hazardous waste lists arranged by different criteria, the EU has notified one comprehensive catalogue that lists hazardous as well as non-hazardous waste types. Complementary to these catalogues regulators have defined series of hazardous characteristics that render wastes hazardous when they exhibit such characteristics. US-EPA defines four hazard characteristics (flammability, corrosivity, reactivity and toxicity), whereas the EU, using a more detailed approach, defines 15 hazard characteristics (H1-H15). The general procedure for differentiating between hazardous and non-hazardous waste is shown in Fig. 10. When the waste type under consideration cannot be found in the hazardous waste list, it has to be checked if the waste meets at least one of the hazard characteristics. This can be done by finding indicative evidence from the waste generation history or by testing a sample of the waste in order to confirm the hazard characteristics by analysis. Testing of a complex waste sample without any information about its origin may require extensive investigation efforts. A good waste list should enable therefore as far as possible unambiguous classification and differentiation between hazardous and non-hazardous waste in the first place, thus minimizing the need for expensive sampling and analytics.

In general, there are two approaches for building a waste list or for structuring a waste classification system:

- Source based classification
- Substance based classification

Both approaches can be also mixed.

Source based classification refers to the waste generation history, i.e. to the industrial activity from where the waste is generated; substance based classification refers to the key pollutants or to the hazardous substances that the waste contains. For example, the Y-Code list of the Basel Convention incorporates both classification approaches: Y-Codes 1-18 are source based, Y-Codes 19-45 are substance based (see also textbox below). In general source based classification is considered advantageous over substance based classification because it requires less effort for testing. See more about testing in chapter 8.3.
Fig. 10: Procedure for differentiating hazardous from non-hazardous waste in general

Waste lists designate waste types via waste codes. A waste code is a descriptive waste name combined with a multiple digit identifier. Once a waste has been assigned to a waste code, the waste type under consideration has received a proof of identity, comparable to a passport number. Wastes classified under the same waste code have similar characteristics, provided the waste list is well structured and enables unambiguous classification.

The Y-Code List of the Basel Convention

The Basel Convention includes several hazardous waste lists out of which the so called Y-code list is the one best known. The Y-Code list comprises 47 relatively broad hazardous waste categories that partially refer to the source of waste generation and partially to the hazardous substances contained thus creating a considerable overlap between the categories.

It is the responsibility of the exporter — or of the competent authority of the exporting country — to assign a Y-Code to the waste intended for export. Due to the overlap it is not uncommon that exporters assign more than one Y-Code to a waste. Whereas the unspecific nature of the Y-Code list does not pose a problem with regard to hazardous waste export declaration, it becomes a challenge when the Y-Code list is being used for National hazardous waste classification which requires more detailed and unambiguous waste codes. Some low- and middle income countries who had introduced the Y-Code list for their National hazardous...
waste classification after having ratified the Basel Convention experienced difficulties in setting up their hazardous waste management system due to the unspecific nature of this waste list.

4.2.4. Background and Structure of the European Waste List

Background

As a step towards a clear waste classification, European and European Member State regulatory authorities developed a waste list in 1994 and have improved it periodically since then. The first European waste lists were published as separate documents: (1) the European Waste Catalogue in Commission Decision 94/3/EC for non-hazardous waste, and (2) the Hazardous Waste List in Council Decision 94/904/EC for hazardous waste. In 2000 both lists have been combined into one list, the European Waste List (EWL) which was subsequently amended until 2002 three times. A consolidated version of the EWL as it is implemented today (2010) can be found in Commission Decision 2000/532/EC, Consolidated Version. The EWL contains a provision to periodically review the list in light of new knowledge and research results and, if necessary, to revise the list in accordance with Article 38 of EU Waste Framework Directive 2008/98/EC.

The EWL has been adopted by all 27 EU Member States. It is well established and serves as a practicable basis for a common enforcement of waste legislation inside the European Union. Because of its successful application, the EWL has been introduced also in the EU candidate countries and – beyond the EU – in other parts of the world as well (e. g. New Zealand, Switzerland Morocco, Vietnam, China)

The EWL caters effectively to the needs of:

- Public administration and law enforcement, e. g. planning of waste management infrastructure, statistics, enforcement of waste regulation, licensing and supervision of waste recovery and disposal facilities, application- and approval procedures
- Waste generating industries, e. g. categorization/classification of waste types and allocation to appropriate waste management methods
- Waste treatment and disposal sector, e. g. categorization/classification of waste types and assignment of waste to specific treatment technologies.

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70 Now in Article 7(1) WFD; see recent study Oekopol: “Review of the European List of Waste”, 2008
72 http://www.gd-maroc.info/index.php?id=118
**Structure of the EWL**

The EWL takes a pragmatic approach with regard to waste classification. It refers as far as possible to the source of waste generation (e.g. wastes from the textile industry) and resorts to substance based classification only in those cases where wastes contain materials that are applied across many industrial activities (e.g. solvents, oil, package material etc.). This is to keep the number of entries within a manageable level.

The European Waste List (EWL) comprises 839 waste codes which are divided into 20 chapters. Each of the 20 chapters represents either an industrial or commercial activity (chapters 1 to 12 and 17 to 19) or an industrial process (chapters 6 and 7) or a specific substance (chapters 13 to 15). Chapter 20 contains municipal waste. Chapter 16 is miscellaneous waste which has not been allocated to other chapters.

The chapters are further divided into sub-chapters. The sub-divisions vary: chapter 9, for example, contains only one sub-chapter, chapter 10 on the other hand is further divided into 14 sub-chapters. In total there are 111 subchapters. The systematic of the enumeration of the sub-chapters has historical reasons.

A six-digit decimal classification system, XX YY ZZ, is used in the EWL for coding (see Fig. 11):

- **XX** stands for the chapters 1 to 20
- **YY** stand for the sub-chapters, with YY = 01 to maximal 14
- **ZZ** stands for the waste types. A waste-key XX YY 99 (last two digits = 99), stands for “wastes not otherwise classified” and allows the assignment of a waste to a six digit code if a more specific classification is not possible.

From the 839 waste codes, 434 codes refer to non-hazardous waste codes and 405 to hazardous waste codes.

![Fig. 11: The structure of the EWL coding system](image-url)
The following Table shows the 20 main chapters of the EWL. Chapters in which source- and substance-based classification are applied are differentiated by color.

**Table 3: The 20 Chapters of the EWL**

<table>
<thead>
<tr>
<th>Nr.</th>
<th>Chapter title</th>
</tr>
</thead>
<tbody>
<tr>
<td>01</td>
<td>Wastes resulting from exploration, mining, dressing and further treatment of minerals and quarry</td>
</tr>
<tr>
<td>02</td>
<td>Wastes from agricultural, horticultural, hunting, fishing and aquaculture primary production, food preparation and processing</td>
</tr>
<tr>
<td>03</td>
<td>Wastes from wood processing and the production of paper, cardboard, pulp, panels and furniture</td>
</tr>
<tr>
<td>04</td>
<td>Wastes from the leather, fur and textile industries</td>
</tr>
<tr>
<td>05</td>
<td>Wastes from petroleum refining, natural gas purification and pyrolytic treatment of coal</td>
</tr>
<tr>
<td>06</td>
<td>Wastes from inorganic chemical processes</td>
</tr>
<tr>
<td>07</td>
<td>Wastes from organic chemical processes</td>
</tr>
<tr>
<td>08</td>
<td>Wastes from the manufacture, formulation, supply and use (MFSU) of coatings (paints, varnishes and vitreous enamels), adhesives, sealants and printing inks</td>
</tr>
<tr>
<td>09</td>
<td>Wastes from the photographic industry</td>
</tr>
<tr>
<td>10</td>
<td>Inorganic wastes from thermal processes</td>
</tr>
<tr>
<td>11</td>
<td>Inorganic metal-containing wastes from metal treatment and the coating of metals, and non-ferrous hydrometallurgy</td>
</tr>
<tr>
<td>12</td>
<td>Wastes from shaping and surface treatment of metals and plastics</td>
</tr>
<tr>
<td>13</td>
<td>Oil wastes (except edible oils, and those in chapters 05, 12 and 19)</td>
</tr>
<tr>
<td>14</td>
<td>Wastes from organic substances used as solvents (except 07 and 08)</td>
</tr>
<tr>
<td>15</td>
<td>Waste packaging; absorbents, wiping cloths, filter materials and protective clothing not otherwise specified</td>
</tr>
<tr>
<td>16</td>
<td>Wastes not otherwise specified in the list</td>
</tr>
<tr>
<td>17</td>
<td>Construction and demolition wastes (including road construction)</td>
</tr>
<tr>
<td>18</td>
<td>Wastes from human or animal health care and/or related research (except kitchen and restaurant wastes not arising from immediate health care)</td>
</tr>
<tr>
<td>19</td>
<td>Wastes from waste treatment facilities, off-site waste water treatment plants and the water industry</td>
</tr>
<tr>
<td>20</td>
<td>Municipal wastes and similar commercial, industrial and institutional wastes including separately collected fractions</td>
</tr>
</tbody>
</table>

- Chapters 1 to 12 and 17 to 20 refer to specific industrial activities or sectors (i.e. **source-oriented classification**)
- Chapters 13, 14, and 15 refer to substances contained in the waste (i.e. **substance-oriented classification**)
- Chapter 16 serves as a pool for waste types of not mentioned elsewhere.
**Type of Entries in the EWL**

The waste codes of the EWL consist of three types of entries:

**Absolute Hazardous Entries:**
Absolute hazardous entries are automatically considered hazardous. There is no requirement to assess the composition of these wastes to determine whether they are hazardous or not; the European Commission has determined that these wastes possess one of more hazardous properties. Absolute hazardous entries are marked with an asterisk (*), e.g.:

<table>
<thead>
<tr>
<th>Code</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>07 07 03*</td>
<td>Organic halogenated solvents, washing liquids and mother liquors</td>
</tr>
</tbody>
</table>

**Non-hazardous Entries:**
Where a waste is not marked in the EWL with an asterisk, then it is not hazardous. e.g.:

<table>
<thead>
<tr>
<th>Code</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>01 04 09</td>
<td>Waste sand and clays</td>
</tr>
</tbody>
</table>

**Mirror Entries:**
Some wastes have the potential to be either hazardous or not, depending on whether they contain “dangerous substances” at or above certain thresholds. These wastes which constitute about 33% of all entries are covered by linked (usually paired) entries, collectively called 'mirror entries' that comprise a hazardous waste entry marked with an asterisk (*) and a non-hazardous waste entry not marked with an asterisk, e.g.

<table>
<thead>
<tr>
<th>Code</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>17 05 05*</td>
<td>Dredging spoil containing dangerous substances</td>
</tr>
<tr>
<td>17 05 06</td>
<td>Dredging spoil other than those mentioned in 17 05 05*</td>
</tr>
</tbody>
</table>

To make the definition of waste more specific and to reduce uncertainty, the EU has drawn up the list of wastes which currently contains 839 types of hazardous and non-hazardous wastes. The EU waste list contains 20 chapters with several subchapters. Individual waste types are assigned a six-digit code comprising two digits for the chapter, two for the subchapter and two specific to the waste type. Types of waste that are considered hazardous are marked with an asterisk. Example: 04 02 14* = waste from finishing, containing organic solvents.

Summary of the three entry types in the EWL:

- **Absolute Entries** refer to wastes that are considered hazardous regardless of any threshold concentrations.
- **Mirror Entries** refer to wastes that are considered hazardous only if dangerous
substances are present above threshold concentrations.

- Non hazardous Entries refer to wastes that are considered non hazardous

Wastes and Potential Hazards for Absolute and Mirror Entries in the EWL.

“Absolute entries” are shown in red, “and mirror entries” are shown in blue color.

Download at:

Hazardous waste lists are an important link in the Hazardous Waste Management Chain. It would be desirable to have a worldwide harmonization of these hazardous waste lists as a very powerful basic instrument for management of hazardous wastes worldwide. An interesting aspect of lack of harmonization of these lists from different countries is the liability aspect and its consequences.

A basic aspect for adequate management of HW is the availability of a legal binding waste list in the country. This list should be user friendly, comprehensive and easy to update, thus permitting an unambiguous classification of each produced waste ideally with a specific code number.

One of the main constraints for an adequate management of hazardous waste is the difficulty to exactly determine the amount of hazardous waste generated in a country or region. Most often this is the case in low and middle income economies due to lack of a consistent classification system, inadequate legal regulation and insufficient control, lack of testing equipment and knowledge for determining if a waste is hazardous or not, incomplete or wrong labeling of chemicals in use and absence/gap in legislation regarding the obligation to deliver a Safety Data Sheet which each chemical.

4.3. Classification of Hazardous Waste according to the European Waste List

4.3.1. How to Find a Waste Code in the EWL

Before attempting to classify a waste under the EWL, sufficient information concerning the waste and the waste producing process must be obtained. This will include the waste producer’s activity, details of the process from which the waste is derived and any other relevant information such as analytical reports or material safety data sheets.

73 Some hazardous wastes are listed in some countries as hazardous and in others as non hazardous (wastes examples from the USA and the EU classified as hazardous in the EU but not mentioned or differently addressed on the US lists (http://www.epa.gov/osw/hazard/wastetypes/index.htm) are e.g.: various residues from copper, other non-ferrous metal production, hydrometallurgical processes, glass wastes, bricks and tiles, crematoria, power stations, and incineration facilities, physico-chemical treatment plants, waste oils and brake fluids, refrigerant, packaging material, ELVs, health care waste, waste wood, cables, oxidizing substances, C&D wastes, asbestos, spent catalysts, acids and bases, MSW fractions).
Assigning waste to a EWL entry is a four-step procedure, as described in paragraph 3 of the annex to Commission Decision 2001/118/EC (See Table 4). As a result of the four-step procedure you will obtain an absolute entry, a non-hazardous entry or a mirror entry.

Table 4: Four-step procedure for assigning waste to a EWL entry

1. Identify the source generating the waste in Chapters 01 to 12 or 17 to 20 and identify the appropriate six-digit code of the waste (excluding codes ending with 99 of these chapters). Note that a specific production unit may need to search several chapters for finding its activities.

2. If no appropriate waste code can be found in Chapters 01 to 12 or 17 to 20, check Chapters 13, 14 and 15.

3. If neither of these waste codes applies, check Chapter 16.

4. If the waste is not in Chapter 16 either, the 99 code (wastes not otherwise specified) must be used in the chapter and respective sub-chapter identified in step one corresponding to the most appropriate source generating the waste.

Users of the EWL may refer to an electronic interactive EWL version that facilitates the identification of the correct waste code.\textsuperscript{74}

Fig. 12 shows the schematic procedure how to differentiate between hazardous and non-hazardous waste when a waste is classified according to the EWL. When the appropriate waste code resulting from the application of the four-step procedure as described in is an ‘absolute entry’ or a non-hazardous waste, classification has been completed. However where the most appropriate EWL entry proves to be a ‘mirror entry’, it will be necessary to review the waste to determine whether it exhibits any hazardous properties. The additional information gathered at the beginning of this process will prove particularly useful at this stage.

\textsuperscript{74} interactive electronic version of the EWL
The European Waste List contains 405 waste codes for hazardous waste and 434 waste codes for non-hazardous waste. Hazardous waste codes include 222 “absolute hazardous entries” for wastes that are known by their origin to be always hazardous and 183 so-called “mirror entries”, which have the potential to be either hazardous or not. Waste is hazardous if it possesses one or more of fifteen specifically defined hazardous characteristics / criteria (H1-H15). Assessment methods and threshold limits are stipulated for most of the H-criteria. Threshold limits are often defined by risk phrases (R-phrases) relating to the classification of dangerous substances.

This classification system is instrumental during the decision process on the further management of the waste (separation, storage, collection, transport, recovery, recycle, treatment options, disposal, licensing and planning)

4.3.2. Hazardous characteristics that render wastes hazardous

Table 4 lists the hazardous characteristics that render wastes hazardous according to EU legislation. Hazardous characteristics are designated by H-Codes H1-H15. A waste is deemed hazardous if it exhibits at least one of these properties.
It should be noted that the definition of the hazardous characteristics in the EU is more elaborate compared to the four hazardous characteristics defined by US-EPA (See Annex 5).
It is also different from the hazardous properties (H criteria H1-H13) laid down in the Basel Convention (Annex 1c) that focuses on the transport of dangerous goods, due to its reference to the hazard classification system included in the United Nations Recommendations on the Transport of Dangerous Goods.⁷⁵

⁷⁵ UNECE, 2009c
Table 5: Fifteen characteristics that render wastes hazardous according to WFD 2008/98/EC

<table>
<thead>
<tr>
<th>Code</th>
<th>Designation</th>
<th>Note</th>
</tr>
</thead>
<tbody>
<tr>
<td>H 1</td>
<td>Explosive</td>
<td>Substances and preparations which may explode under the effect of flame or which are more sensitive to shocks or friction than dinitrobenzene.</td>
</tr>
<tr>
<td>H 2</td>
<td>Oxidizing</td>
<td>Substances and preparations which exhibit highly exothermic reactions when in contact with other substances, particularly flammable substances.</td>
</tr>
<tr>
<td>H 3A</td>
<td>Highly Flammable</td>
<td>- Liquid substances and preparations having a flashpoint of below 21°C (including extremely flammable liquids), or</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Substances and preparations which may become hot and finally catch fire in contact with air at ambient temperature without any application of energy, or</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Solid substances and preparations which may readily catch fire after brief contact with a source of ignition and which continue to burn or to be consumed after removal of the source of ignition, or</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Gaseous substances and preparations which are flammable in air at normal pressure, or</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Substances and preparations which, in contact with water or damp air, evolve highly flammable gases in dangerous quantities.</td>
</tr>
<tr>
<td>H 3B</td>
<td>Flammable</td>
<td>Liquid substances and preparations having a flashpoint equal to or greater than 21°C and less than or equal to 55°C.</td>
</tr>
<tr>
<td>H 4</td>
<td>Irritant</td>
<td>Non-corrosive substances and preparations which, through immediate, prolonged or repeated contact with the skin or mucous membrane, can cause inflammation.</td>
</tr>
<tr>
<td>H 5</td>
<td>Harmful</td>
<td>Substances and preparations which, if they are inhaled or ingested or if they penetrate the skin, may involve limited health risks.</td>
</tr>
<tr>
<td>H 6</td>
<td>Toxic</td>
<td>Substances and preparations (including very toxic substances and preparations) which, if they are inhaled or ingested or if they penetrate the skin, may involve serious, acute or chronic health risks and even death.</td>
</tr>
<tr>
<td>H 7</td>
<td>Carcinogenic</td>
<td>Substances and preparations which, if they are inhaled or ingested or if they penetrate the skin, may induce cancer or increase its incidence.</td>
</tr>
<tr>
<td>H 8</td>
<td>Corrosive</td>
<td>Substances and preparations which may destroy living tissue on contact.</td>
</tr>
<tr>
<td>H 9</td>
<td>Infectious</td>
<td>Substances containing viable micro-organisms or their toxins which are known or reliably believed to cause disease in man or other living organisms.</td>
</tr>
<tr>
<td>H 10</td>
<td>Toxic for reproduction</td>
<td>Substances and preparations which, if they are inhaled or ingested or if they penetrate the skin, may produce or increase the incidence of non-heritable adverse effects in the progeny and/or of male or female reproductive functions or capacity.</td>
</tr>
<tr>
<td>H 11</td>
<td>Mutagenic</td>
<td>Substances and preparations which, if they are inhaled or ingested or if they penetrate the skin, may induce hereditary genetic defects or increase their incidence.</td>
</tr>
<tr>
<td>H 12</td>
<td>-</td>
<td>Substances and preparations which release toxic or very toxic gases in contact with water, air or an acid.</td>
</tr>
<tr>
<td>H 13</td>
<td>Sensitizing</td>
<td>Substances and preparations which, if they are inhaled or if they penetrate the skin, are capable of eliciting a reaction of hyper-sensitization such that on further exposure to the substance or preparation, characteristic adverse effects are produced.</td>
</tr>
<tr>
<td>H 14</td>
<td>Ecotoxic</td>
<td>Substances and preparations which present or may present immediate or delayed risks for one or more sectors of the environment.</td>
</tr>
<tr>
<td>H 15</td>
<td>-</td>
<td>Substances and preparations capable by any means, after disposal, of yielding another substance, e.g. a leachate, which possesses any of the characteristics listed above.</td>
</tr>
</tbody>
</table>

*) As far as testing methods are available. See also review of Hazardous Properties at http://ec.europa.eu/environment/waste/framework/list.htm

76 H 13 was added 2008 when Directive 2008/98/EC was notified. Earlier H 15 was coded as H 13
4.3.3. Hazardous characteristics and Threshold Levels for Dangerous Substances

A waste that proves to be a mirror entry during EWL classification has to be reviewed if it exhibits at least one of the hazard characteristics listed in Table 4.

The EWL defines the hazardous characteristics by referencing the “Categories of Danger” and “Risk-Phrases” for dangerous substances laid down in the respective European laws and regulations on chemical safety, namely Directive 67/548/EEC (which will stepwise be replaced by Regulation (EC) No 1272/2008 (CLP) until June 2015). With regard to hazardous characteristic H3, a distinction need not be made between H3-A and H3-B. Waste shall be classified as flammable if the flash point is \(< 55\, ^\circ\text{C}\) (Table 6). The EWL further substantiates the important hazard characteristics H4 to H8, H10 and H11 by providing concentration based threshold values for dangerous substances. Whereas the EWL does not specify threshold values for H14, some EU Member States (e.g. UK, Germany) have derived concentration based threshold values for H14. With regard to H13, it should be noted that there are no concentration thresholds yet as this property was recently introduced (See [76]). With regard to H1, H2, H3, H9, H12 and H15 it is not sensible or impossible to specify concentration based thresholds. Wastes that are suspected to exhibit these properties need to be tested (see section 4.3.5.).

The information compiled in Table 6 provides guidance for identifying the hazardous or non-hazardous nature of a waste by referring to dangerous substance classification and hazard threshold values with respect to hazards H3-H8, H10, H11 and H14. With the exception of H3, all threshold values are concentration based. Concentrations are given in weight percent and refer to the sample original. If the dangerous components of the waste and their concentrations are known, in most cases allocation of the waste to the correct mirror entry is possible by referring to the categories of danger, risk phrases and hazard thresholds. It has to be noted that concentrations of substances classified as ‘Toxic’ ‘Very Toxic’, ‘Harmful’, ‘Corrosive’, ‘Irritant’ and ‘Dangerous for the Environment’ are additive, whereas concentrations of substances classified as ‘Carcinogenic’, ‘Toxic for Reproduction’ and ‘Mutagenic’ are not. A similar table with more details and arranged by risk-phrases in an ascending order has been published by the Environment Agency of UK. This table is recommended for practice-oriented use.


The association of dangerous substance concentrations with the hazardous characteristics of a waste is an important and unique feature of European hazardous waste classification. It provides a logical approach for differentiating between hazardous and non-hazardous waste based on the waste generation history.

It should be noted that “Categories of Danger” and “Risk-Phrases” are being replaced by “Hazard Classes” and “Hazard Statements” during a transition period in the course of implementing GHS regulation. Accordingly, the concentration based threshold values for the hazardous properties will need to be reviewed.

Table 6: Categories of Danger, Risk-Phrases, and hazard threshold limits of dangerous substances with respect to hazardous properties of waste

<table>
<thead>
<tr>
<th>A waste is hazardous whenever one of the following applies:</th>
<th>Cat. of Danger, R-Phrase</th>
<th>Hazard Threshold</th>
<th>H-Code</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Flash point of the waste less than or equal to 55 °C. (Wastes suspected to be flammable and/or containing substances labeled flammable / extremely flammable according to R10, R11, R12, R15, R17, R18, require testing.)</td>
<td>F, F+, R10, R11, R12, R15, R17, R18</td>
<td>≤ 55 °C</td>
<td>H3 Flammable</td>
</tr>
<tr>
<td>• Total concentration ≥ 10 % of one or more substances classified as irritant according to R 41 (risk of serious damage to eyes)</td>
<td>Xi, R41</td>
<td>≥ 10 %</td>
<td>H4 Irritant</td>
</tr>
<tr>
<td>• Total concentration ≥ 20 % of one or more substances classified as irritant according to R36 (irritating to eyes), R37 (irritating to respiratory system), R38 (irritating to skin)</td>
<td>Xi, R36, R37, R38</td>
<td>≥ 20 %</td>
<td>H4 Irritant</td>
</tr>
<tr>
<td>• Total concentration ≥ 25 % of one or more substances classified as harmful with reference to resp. R-Phrases</td>
<td>Xn, R20, R21, R22, R48/<em>, R68/</em> R65</td>
<td>≥ 25 %</td>
<td>H5 Harmful</td>
</tr>
<tr>
<td>• Total concentration ≥ 3 % of one or more substances classified as toxic with reference to resp. R-Phrases</td>
<td>T, R23, R24, R25, R39/<em>, R48/</em></td>
<td>≥ 3 %</td>
<td>H6 Toxic</td>
</tr>
<tr>
<td>• Total concentration ≥ 0.1 % of one or more substances classified as very toxic with reference to resp. R-Phrases</td>
<td>T+, R26, R27, R28, R39/*</td>
<td>≥ 0.1 %</td>
<td>H6 Toxic</td>
</tr>
<tr>
<td>• Concentration ≥ 0.1 % of one substance known to be carcinogenic of category 1 or 2 with reference to R45 (may cause cancer) and R49 (May cause cancer by inhalation)</td>
<td>Carc.Cat.1, Carc.Cat.2, R45, R49</td>
<td>≥ 0.1 %</td>
<td>H7 Carcinogenic</td>
</tr>
<tr>
<td>• Concentration ≥ 1 % of one substance known to be carcinogenic of category 3 with reference to R40 (Limited evidence of a carcinogenic effect)</td>
<td>Carc.Cat. 3, R40</td>
<td>≥ 1 %</td>
<td>H7 Carcinogenic</td>
</tr>
<tr>
<td>• Total concentration ≥ 1 % of one or more substances classified as corrosive according to R 35 (causes severe burns)</td>
<td>C, R35</td>
<td>≥ 1 %</td>
<td>H8 Corrosive</td>
</tr>
<tr>
<td>• Total concentration ≥ 5 % of one or more substances classified as corrosive according to R 34 (causes burns)</td>
<td>C, R34</td>
<td>≥ 5 %</td>
<td>H8 Corrosive</td>
</tr>
<tr>
<td>• Concentration ≥ 0.5 % of one substance classified as toxic for reproduction of category 1 or 2 with reference to R60 (may impair fertility) or R61 (may cause harm to the unborn child)</td>
<td>Repr.Cat.1, Repr.Cat.2, R60, R61</td>
<td>≥ 0.5 %</td>
<td>H10 Toxic f. reprod.</td>
</tr>
<tr>
<td>• Concentration ≥ 5 % of one substance classified as toxic for</td>
<td>Repr.Cat.3,</td>
<td>≥ 5 %</td>
<td>H10</td>
</tr>
</tbody>
</table>

A waste is hazardous whenever one of the following applies:  

<table>
<thead>
<tr>
<th>Cat. of Danger, R-Phrase</th>
<th>Hazard Threshold</th>
<th>H-Code</th>
</tr>
</thead>
<tbody>
<tr>
<td>reproduction of category 3 with reference to R62 (possible risk of impaired fertility), R63 (possible risk of harm to the unborn child)</td>
<td>R 62, R 63</td>
<td>Toxic f. reproduct.</td>
</tr>
<tr>
<td>Concentration ≥ 0.1 % of one substance classified as mutagenic of category 1 or 2 with reference to R46 (may cause heritable genetic damage)</td>
<td>Muta.Cat.1, Muta.Cat.2, R46</td>
<td>≥ 0.1 %</td>
</tr>
<tr>
<td>Concentration ≥ 1 % of one substance classified as mutagenic of category 3 with reference to R68 (possible risk of irreversible effects)</td>
<td>Muta.Cat.3, R68</td>
<td>≥ 1 %</td>
</tr>
<tr>
<td>Total concentration ≥ 0.25 % of one or more substances classified as dangerous for the environment with reference to R 50/53 (Very toxic to aquatic organisms and may cause long-term effects in the aquatic environment)</td>
<td>N, R 50/53</td>
<td>≥ 0.25 %</td>
</tr>
<tr>
<td>Total concentration ≥ 2.5 % of one or more substances classified as dangerous for the environment with reference to R 51/53 (Toxic to aquatic organisms and may cause long-term effects in the aquatic environment)</td>
<td>N, R 51/53</td>
<td>≥ 2.5 %</td>
</tr>
<tr>
<td>Total concentration ≥ 25 % of one or more substances classified dangerous for the environment with reference to R 52/53 (Harmful to aquatic organisms and may cause long-term effects in the aquatic environment)</td>
<td>N, R 52/53</td>
<td>≥ 25 %</td>
</tr>
<tr>
<td>Total concentration ≥ 0.1 % of one or more substances classified as very toxic with reference to resp. R-Phrases</td>
<td>T+, R26, R27, R28, R39/+</td>
<td>≥ 0.1 %</td>
</tr>
<tr>
<td>Total concentration ≥ 0.1 % of one or more substances classified as dangerous for the environment with reference to R 59 (dangerous for the ozone layer)</td>
<td>N, R59</td>
<td>≥ 0.1 %</td>
</tr>
</tbody>
</table>

* R39/, R48/, R68/ = combinations of phrases

4.3.4. Establishing the Hazardous – Non-hazardous Nature of a Waste when the Waste Composition is known

For assigning a waste to the hazardous or non-hazardous part of a mirror entry, the waste has to be checked if it contains dangerous substances and if respective concentrations exceed the threshold limits of the related hazardous properties.

To this end, the waste generation history has to be reviewed. Knowledge of production processes enable statements to be made regarding the input-materials. Approximate material balances of the processes provide information on newly formed intermediate products or the products themselves. Documented waste analyses may also be used. This information and, if appropriate, details of hazardous and non-hazardous constituents from ‘Material Safety Data Sheets’ (MSDS) can be used to check the substances in the waste and their reaction properties with regard to hazards. If this does not lead to a result, an analysis specific to the waste must be performed on the components relevant to the classification (See chapter 4.3.7.). In many cases, information relating to the origin allows the scope of the analysis to be limited.
There are also National Guidance Documents that provide assistance with regard to the identification of potential hazards of mirror entries, based on the source of generation and application of characteristic dangerous substances in the respective processes:


After identification, the key hazardous components have to be classified according to the categories of danger and respective risk-phrases. Most convenient sources for dangerous substance classification data are the following:

- **(Material) Safety Data Sheets**
  
  (M) SDS in many countries refers to EU dangerous substance classification and specifies categories of danger and risk-phrases on the substances they are related to. Attention should be paid if the data refer to pure substances or to their percentage in preparations. Since the quality of MSDS may greatly vary, information provided by MSDS has to be read with care.

- **EU legislation, such as**
  
  - Regulation (EC) No 1272/2008 (CLP), Annex VI, Table 3.2. [http://ec.europa.eu/enterprise/sectors/chemicals/documents/classification/](http://ec.europa.eu/enterprise/sectors/chemicals/documents/classification/). This table contains more than 4000 entries on dangerous substances. Classification data can be sourced from the 6th column of this table. It should be noted that data in the column “Concentration Limits” cannot be applied for waste classification since they refer to pure substances rather than waste. This table is available presently only in English.\(^8\)

- **“International Chemical Safety Cards” (ICSC)** [http://www.dguv.de/ifg/en/gestis/icsc/index.jsp](http://www.dguv.de/ifg/en/gestis/icsc/index.jsp), published jointly by the International Labor Office (ILO), the United Nations Environment Program (UNEP) and the World Health Organization (WHO)

  The European classification system of dangerous substances has been adopted also by international organizations such as ILO, UNEP and WHO. ICSC are comparable with MSDS, however they set out peer-reviewed information about substances in a more concise and simple manner. They are originally prepared in English and placed

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\(^8\) It may be noted that, for a transition period in the course of GHS implementation and with effect of 2009, Regulation (EC) No 1272/2008 (CLP), Annex VI, Table 3.2 has replaced Annex I of the Substance Directive 67/548/EEC where these data have been laid down initially.
on the Web. Subsequently, national institutions translated the Cards from English into different languages. The international English version has approx. 1,300 entries.

- [http://www.inchem.org/pages/pds.html](http://www.inchem.org/pages/pds.html) for Pesticide Data Sheets: PDS) gives information on pesticides

Table 7 summarizes the steps to be taken for allocating a waste to the hazardous or non-hazardous part of a mirror entry. According to EU legislation waste generators or holders are responsible for classifying their wastes. If the presence of hazardous properties cannot be ruled out, the waste shall be classified as hazardous, in compliance with the precautionary principle.

Table 7: Methodology for allocating a waste to the hazardous or non-hazardous part of a mirror entry

1. Identify the composition of the waste.
2. Identify the risk phrases that apply to each component in the waste. Safety Data Sheets, data from EU sources or International Chemical Safety Cards can be used to give all the risk phrases for the waste.
3. Record the hazards and threshold concentrations for each component.
4. Use Table 6 or [78] which show categories of danger and risk phrases with the associated hazardous property, to identify the relevant hazards and threshold concentrations that apply to each component.
5. If any of the threshold concentrations recorded are exceeded, the whole consignment will be hazardous. For some hazards concentrations of components in the waste must be added to calculate the total concentration of the substances with that hazard.

It should be noted that the procedure described above can be used also beyond the scope of the EWL for differentiating between hazardous and non-hazardous waste. The textbox below shows an example how to apply the methodology.
Example of Hazardous Waste Assessment Methodology

A chemical industry in Europe has produced an aqueous residue that contains 15 g/l Phenol. Is this material wastewater or liquid hazardous waste?

Step 1: The composition of the residue is known. It is assumed that phenol is the only hazardous component.

Step 2: Phenol is a dangerous substance and is classified: T, R23/24/25; C, R34; Xn, R48/20/21/22; Mut.Cat. 3, R68

Steps 3 & 4: With the correlations from Table 6 a waste containing phenol exhibits hazardous properties above certain concentration limits:

<table>
<thead>
<tr>
<th>Danger Category</th>
<th>R-Phrase</th>
<th>Description of Risk</th>
<th>Conc. Limit</th>
<th>Haz. Property</th>
</tr>
</thead>
<tbody>
<tr>
<td>Toxic (T)</td>
<td>R 23/24/25</td>
<td>Toxic by inhalation, in contact with skin and if swallowed</td>
<td>&gt; 3%</td>
<td>H 6</td>
</tr>
<tr>
<td>Corrosive (C)</td>
<td>R 34</td>
<td>Causes burns</td>
<td>&gt; 5%</td>
<td>H 8</td>
</tr>
<tr>
<td>Harmful (Xn)</td>
<td>R 48/20/21/22</td>
<td>Danger of serious damage to health by prolonged exposure through inhalation, in contact with skin and if swallowed.</td>
<td>≥ 25%</td>
<td>H 5</td>
</tr>
<tr>
<td>Mutag. Cat. 3</td>
<td>R 68</td>
<td>Possible risks of irreversible effects</td>
<td>≥ 1%</td>
<td>H 11</td>
</tr>
</tbody>
</table>

Step 5: The highest danger category of phenol is “Mutagenic Category 3” which has accordingly the lowest concentration limit of 1% weight, corresponding to 10 g/kg, or in this case 10 g/l.

Since the phenol concentration is 15 g/l, the residue is liquid hazardous waste by H11, “Mutagenic”.

4.3.5. Establishing the Hazardous – Non-hazardous Nature of a Waste via Analytical Chemical Investigation

In case the information on the waste generation history and the dangerous substances contained is insufficient to enable identification of the hazardous properties, the waste has to be sampled and analyzed. The threshold values for distinguishing between hazardous and non hazardous in Table 8 and Table 9 may provide guidance for this purpose. It should be noted however that the choice of parameters in these tables is not exhaustive. If there are reasons to believe that a waste – due to its origin and type - does contain hazardous
materials other than those mentioned, the specific contamination must then be taken into account in judging the hazardous level of the waste.

Most of the orientation values presented in Table 8 are derived from concentration based hazard thresholds of Table 6. E.g. the compounds of Sb, Pb, Cu, Ni and Se are in category N, R50/53, accordingly the limit value is 0.25 % w/w or 2,500 mg/kg. Cr (VI) and Tl are in categories T+ or canc. cat 2 and the limit value is accordingly 0.1 % w/w or 1,000 mg/kg. Orientation values lower than 1000 mg/kg are taken from other European chemical safety regulations. E.g. the values for substances No’s 16-18 stem from the European adoption of the Stockholm (POP’s) Convention

Whereas Table 8 provides orientation values for organic sum parameters such as BTEX, there is no orientation value for mineral oil. The reason is that, according to EWL classification, oil containing waste types are covered by absolute hazardous entries regardless of their composition. In Directive 67/548/EEC “mineral oil” is assumed to be contaminated with aromatic- and poly-aromatic hydrocarbons and is hence classified by R45 (may cause cancer) corresponding to a concentration threshold value of 0.1 % w/w for H7. It may be noted that Germany permits landfill disposal of waste that contains mineral oil hydrocarbons up to 8,000 mg/kg on landfill sites for non-hazardous waste (See [83]).
Table 8: Derived orientation values to distinguish between hazardous and non-hazardous wastes

<table>
<thead>
<tr>
<th>No</th>
<th>Parameter *)</th>
<th>Individual thresholds</th>
<th>Summation thresholds</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Contents of hazardous substances in the original substance referred to dry matter mg/kg</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Heavy metals and semi-metals</td>
<td></td>
</tr>
<tr>
<td>01</td>
<td>Antimony **)</td>
<td>2,500</td>
<td></td>
</tr>
<tr>
<td>02</td>
<td>Lead **)</td>
<td>2,500</td>
<td></td>
</tr>
<tr>
<td>03</td>
<td>Copper **)</td>
<td>2,500</td>
<td></td>
</tr>
<tr>
<td>04</td>
<td>Nickel **)</td>
<td>2,500</td>
<td></td>
</tr>
<tr>
<td>05</td>
<td>Selenium **)</td>
<td>2,500</td>
<td></td>
</tr>
<tr>
<td>06</td>
<td>Arsenic **)</td>
<td>1,000</td>
<td></td>
</tr>
<tr>
<td>07</td>
<td>Chromium (VI)</td>
<td>1,000</td>
<td></td>
</tr>
<tr>
<td>08</td>
<td>Thallium</td>
<td>1,000</td>
<td></td>
</tr>
<tr>
<td>09</td>
<td>Tin, from organic compounds</td>
<td>1,000</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>Cadmium **)</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>11</td>
<td>Mercury</td>
<td>50</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Organic substances</td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>Benzene / BTEX</td>
<td>Benzene: 25</td>
<td>BTEX: 1,000</td>
</tr>
<tr>
<td>13</td>
<td>Dioxin/Furan TCDD-TE</td>
<td>0.015</td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>Highly volatile halogenated hydrocarbons</td>
<td>25</td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>PAH (16 according to EPA)</td>
<td>200</td>
<td></td>
</tr>
<tr>
<td>16</td>
<td>Benzo-e-pyrene</td>
<td>50</td>
<td></td>
</tr>
<tr>
<td>17</td>
<td>PCB total</td>
<td>50</td>
<td></td>
</tr>
<tr>
<td>18</td>
<td>Aldrin, Chlordane, Dieldrin, Heptachlor, Endrin, Hexachlorbenzene Toxaphene, Mirex, DDT, Hexabromobiphenyl, Chlordecone, Σ α-, β-, γ-HCH</td>
<td>50 for each compound</td>
<td></td>
</tr>
<tr>
<td>19</td>
<td>PCP</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Other substances</td>
<td></td>
</tr>
<tr>
<td>20</td>
<td>Cyanide, total</td>
<td>1,000</td>
<td></td>
</tr>
<tr>
<td>21</td>
<td>Beryllium</td>
<td>1,000</td>
<td></td>
</tr>
</tbody>
</table>

*) In case these substances occur in compounds which according to chemical legislation require more stringent threshold values, these values then apply (for example lead alkyls).

**) Threshold values do not apply if the relevant substances occur in elementary metallic form.

Table 9 presents eluate concentration limits for hazardous property H15. H15 cannot be assigned any categories of danger as there are no risk phrases describing risks from the formation of eluates with hazardous properties. However, EU Decision 2003/33/EC, Section 2.3.1 lays down values for accepting hazardous waste at a landfill for non-hazardous waste.
as an exemption regulation with regard to tolerable leaching. These acceptance values can be used to test for the presence of hazardous property H15. Hazardous property H15 can be considered fulfilled if one of the concentrations limits in Table 9 is exceeded. Though this test addresses specific risks associated with landfill disposal, it may serve to distinguish generally between the hazardous and non-hazardous nature of a waste independently from the envisaged disposal or recovery route. It may be noted that this methodology is comparable to the “Toxicity Characteristic Leaching Procedure” issued by the US Environmental Protection Agency.\textsuperscript{82}

Table 9: Derived orientation values for distinguishing between hazardous and non-hazardous waste acc. to H15\textsuperscript{83}

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Eluate Concentration *\textsuperscript{) }</th>
</tr>
</thead>
<tbody>
<tr>
<td>Antimony</td>
<td>$\geq 0.07 \text{ mg/l}$</td>
</tr>
<tr>
<td>Arsenic</td>
<td>$\geq 0.2 \text{ mg/l}$</td>
</tr>
<tr>
<td>Barium</td>
<td>$\geq 10 \text{ mg/l}$</td>
</tr>
<tr>
<td>Lead</td>
<td>$\geq 1 \text{ mg/l}$</td>
</tr>
<tr>
<td>Cadmium</td>
<td>$\geq 0.1 \text{ mg/l}$</td>
</tr>
<tr>
<td>Chromium, total</td>
<td>$\geq 1 \text{ mg/l}$</td>
</tr>
<tr>
<td>Copper</td>
<td>$\geq 5 \text{ mg/l}$</td>
</tr>
<tr>
<td>Molybdenum</td>
<td>$\geq 1 \text{ mg/l}$</td>
</tr>
<tr>
<td>Nickel</td>
<td>$\geq 1 \text{ mg/l}$</td>
</tr>
<tr>
<td>Mercury</td>
<td>$\geq 0.02 \text{ mg/l}$</td>
</tr>
<tr>
<td>Selenium</td>
<td>$\geq 0.05 \text{ mg/l}$</td>
</tr>
<tr>
<td>Zinc</td>
<td>$\geq 5 \text{ mg/l}$</td>
</tr>
<tr>
<td>Fluoride</td>
<td>$\geq 15 \text{ mg/l}$</td>
</tr>
</tbody>
</table>

\textsuperscript{) }Eluate to be prepared according to DIN EN 12457-4, “Compliance test for leaching of granular waste materials and sludge - Part 4: One stage batch test at a liquid to solid ratio of 10 l/kg for materials with particle size below 10 mm”

To ensure that waste samples collected for testing are representative, a standardized sampling procedure has to be applied (See chapter 8.3.1.).

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\textsuperscript{82} Code of Federal Regulations (CFR) 40 CFR §261.24, outlines 40 contaminants to be subjected to the TCLP analysis tests
\textsuperscript{83} Federal Ministry for the Environment, "Guidelines on the Application of the Waste Catalogue Ordinance", Chapter 3.3 and Annex III, Germany, 2005; H15 is in this document listed under H13.

German Federal Government: “Ordinance Simplifying Landfill Law”, Annex 3, Table 2, 2009
4.3.6. Determination of Hazardous Properties by Direct Testing

As discussed in section 4.3.2., hazard characteristics H1, H2, H3, H9, H12 and H15 can be assessed only by direct testing. Also for H4-H8, H10, H11 and H14, direct testing of hazard characteristics may be preferable sometimes compared to calculating or analyzing the concentrations of dangerous substances. For example, determination of the pH-value of a liquid aqueous waste for checking H8-Corrosivity can be quickly done by simple lab tests.

Direct testing may be also advisable when the composition of a waste is complex as in case e.g. of wastewater treatment sludge. A complex waste matrix may even exhibit new hazardous characteristics via synergistic effects between multiple components which the concentration based approach would fail to detect. Particularly the determination of toxicological and ecotoxic characteristics via concentrations of dangerous substances is problematic in this context.

For assessing the hazardous characteristics of a waste material by direct testing the Waste Framework Directive 2008/98/EC, together with the European List of Waste (Decision 2000/532/EC), refers to the test methods for chemicals and substances in Annex V of Directive 67/548/EEC which is divided into three parts:

- Part A contains methods for the determination of PHYSICO-CHEMICAL properties. In this section methods can be found for H1-Explosive, H2-Oxidizing and H3-Flammable.
- Part B contains methods for the determination of effects on HUMAN HEALTH. This section provides test methods for H4-Irritant, H5-Harmful, H6-Toxic, H7-Carcinogenic, H8-Corrosive, H10-Toxic-for-Reproduction, H11-Mutagenic and H13-Sensitizing.
- Part C contains methods for ENVIRONMENTAL EFFECTS, eco-toxicity and environmental fate which are instrumental for the determination of H14-Ecotoxic.

In its WM2 Guidance the UK Environment Agency provides valuable information for selecting suitable tests and how to proceed with the assessments. The document provides also guidance with respect to the assessment of H9-Infectious, H12-(Release of toxic gas) and H15-(Production of another hazardous substance after disposal). It may be noted that in Germany H15 can be assessed by an eluate test (Table 9).

It has to be mentioned that the test methods specified in Part B &C of Annex V of Directive 67/548/EEC rely largely on destructive animal testing. Animal testing is not only unethical but also time consuming and expensive. The UK Environment Agency suggests in its WM2 Guidance that in future the current referral to 67/548/EEC might be replaced by referral to REGULATION (EC) No 1272/2008.

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84 Current referral to 67/548/EEC might in future be replaced by referral to REGULATION (EC) No 1272/2008
86 H15 is listed in Appendix C of the WM2 Guidance under H13.
Guidance therefore alternative methods in lieu of animal testing such as biosensors (the term biosensor is used for bio tests where the biological responses are translated into an electronic read out signal) and bioassays (general term for testing the effect of a sample or a chemical on a biological target). This biological target can be of different organisational level: biological molecules up to living cells, tissues or organisms); however the number of validated methods is limited. Wherever animal tests cannot be replaced, the UK Environment Agency suggests to follow the precautionary principle and to classify the respective waste as hazardous.

In the waste management sector codes are indispensable during facility licensing, application / approval procedures, administration of transport and disposal operations and eventually for statistics and planning purposes. An efficient waste classification system is therefore an essential prerequisite and important cornerstone for setting up the entire hazardous waste management system.
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Bonn, May 2012

The Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH was formed on 1 January 2011. It has brought together under one roof the capacities and long-standing experience of three organisations: the Deutscher Entwicklungsdienst (DED) gGmbH (German Development Service), the Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ) GmbH (German technical cooperation) and Inwent – Capacity Building International, Germany. For further information go to www.giz.de.
Module 3

Guidance, training, education, and capacity building for waste generators and waste transporters:

On-site Hazardous Waste Management

Preparation for transport of dangerous goods

Control of hazardous waste transport
Guidance, training, education and capacity building are important measures to be addressed in this chapter. They are possibly the most important factors for the successful establishment and operation of waste management systems.

Information-based instruments should be addressed directly to the enterprises generating hazardous waste. Such activities can comprise awareness campaigns and specific guidance on hazardous waste management.

As competent authorities of different administrative levels are generally involved in waste management, they also should be addressed by such campaigns, workshops and other initiatives for knowledge transfers. This chapter especially aims at encouraging competent authorities to actively support industrial companies and parties involved in waste management to take provisions to comply with legal requirements.

The practical application of waste management systems and its successful enforcement is strongly correlated to support provided by informed and trained authorities.

Therefore, it is advisable that the authorities should not only take proper actions to control and monitor activities in the field of waste management, but also to support and train the industry’s stakeholders and waste management companies “to do the right things”. The checklist in the box below should serve as a first approach on how the industry and parties involved can be supported in fulfilling their responsibilities and duties.

\[\text{http://www.giz.de/Themen/de/11324.htm}\]

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87 A special guide on practical aspects of hazardous waste management has been developed by GIZ for waste generating enterprises as well as a corresponding trainer manual. Both can be downloaded at: [http://www.giz.de/Themen/de/11324.htm](http://www.giz.de/Themen/de/11324.htm)
Checklist

The competent authorities should provide guidance documents, and education, as well as training and awareness campaigns to ensure the possibility of a proper practical enforcement of legal provisions related to HW management.

The following questions might help to check if relevant documents and actions have been taken into consideration:

1. Are guidance documents prepared for the waste producer in relation to
   - Obtaining a HW management license?
   - HW prevention/minimisation?
   - HW identification (including documents on how to make a basic characterisation)?
   - HW classification?
   - HW separation?
   - Documentation/Reporting on HW quantities and the specific properties of the HW type
     - On-site storage of HW?
     - On-site treatment of HW?
     - HW collection and its transport (preparing HW for transport)?
     - Proper treatment and disposal of HW?
     - Training of personnel in contact with HW (occupational health/environmental protection)?

2. Are guidance documents prepared for the waste collector/transporter in relation to
   - Obtaining a HW transport license?
   - HW identification?
   - HW classification?
   - HW separation?
   - HW collection and its transport (including the preparation of the HW for transport) and related precautions?
   - Training of personnel in contact with HW (occupational health/environmental protection)?

3. Are guidance documents prepared for the operator of a treatment facility in relation to
   - Obtaining a HW management license?
   - HW identification/classification/separation (in relation to waste acceptance procedures)?
   - Documentation/Reporting on HW quantities and its properties?
   - On-site storage of HW?
   - HW treatment of HW?
   - Proper treatment and disposal of HW?
   - Training of personnel in contact with HW (occupational health/environmental protection)?

4. Are training sessions and awareness campaigns scheduled for the different parties/target groups?

5. Can funds, subsidies or award schemes be used to support waste management service providers?

Further competent authorities should support and inform waste generators on information to be submitted when applying for a hazardous waste license. (see module 5)
The next guidance sections are dedicated especially for waste generators and waste transporters.

5.1. On-site identification, separation, management, temporary storage and preparation for transportation of Hazardous Waste

For on-site HWM, classification of wastes is of paramount importance. Therefore HW should be classified as accurate as possible and a waste code should be assigned to each single waste.

On-site hazardous waste management can include identification, quantification, preliminary sorting, separation, collection, intermediary storage and preparation for transporting to treatment or disposal facilities.

5.1.1. Identification and quantification

Identification and quantification of HW rely on the principles of process flow and material balance and seek to identify, characterize and quantify the „Non-product Output” (NPO) by following the process flow and establishing the balance between material input such as raw materials, additives, water, energy and material output in terms of products and NPOs.

By examining the material flow and the process cycle the wastes can be usually characterized with sufficient accuracy. Components of the materials used in a production process will be present in the products, the emissions, the wastewaters or the wastes. In most cases, the characteristics of the waste will be obvious by examining the process and sampling and analyzing of waste is not required.

Within the companies generating hazardous waste, ensuring the sound management of hazardous waste involves every single staff managing hazardous waste on-site before the waste is handed over to a hazardous waste transporter or a hazard waste treatment facility. Comprehensive information, training and appropriate equipment for the safe management of any kind of hazardous waste generated in the plant are pre-requisites.

5.1.2. Principle of On-site Waste Inspections

On-site inspection is an audit-based investigation procedure for assessing pollutant emissions from industrial sites. It focuses on the industrial activity being undertaken and on the actual

---

88 All enterprises require inputs such as raw materials, energy and water. However, only a proportion of these inputs end up in the desired final product. The rest becomes solid waste, waste-water and emissions to the air – smoke and gases. Together these wastes are termed “non-product output” (NPO).

processes within the enterprise under consideration. The objective of a waste audit however is not only to identify, characterize and quantify all wastes generated by a particular enterprise but also to discover how those waste are currently being managed.

The audit ideally should also identify the real situation including any “hidden” wastes – for example wastes which, instead of being segregated, are being generated but are being allowed to mix with waste-waters or general solid wastes and be discharged as effluents or dumped. Identification of all wastes is of paramount importance for improving the waste management situation; only hazardous wastes correctly identified at the point of generation are visible and are able to be segregated and managed.

Identification and quantification of HW rely on the principles of process flow and material balance and seek to identify, characterize and quantify the „Non-product Output” (NPO) by following the process flow and establishing the balance between material input such as raw materials, additives, water, energy and material output in terms of products and NPOs (by-products, residues, wastes, air emissions and wastewater).

Characterization of wastes generated is one of the more difficult aspects of waste auditing. Again, by examining the material flow and the process cycle the wastes can be usually characterized with sufficient accuracy.

 Constituents of the materials going into a process will be present in the products, the emissions, the wastewaters or the wastes. In most cases, the characteristics of the waste will be obvious by examining the process and sampling and analyzing of waste is not required.

In general, on-site inspections can focus on all types of emission. Given the low “visibility” of hazardous waste however, on-site inspections related to HWM have special significance.

During initial meeting and the meeting after the inspection walk around and:

\[ \text{Production process} \]

\[ \text{desired final product} \]

\[ \text{non product output (NPO)} \]

\[ \text{material} \]

\[ \text{energy} \]

\[ \text{water} \]

\[ ^{90} \text{All enterprises require inputs such as raw materials, energy and water. However, only a proportion of these inputs end up in the desired final product. The rest becomes solid waste, waste-water and emissions to the air – smoke and gases. Together these wastes are termed “non-product output” (NPO).} \]
• determine person with overall responsibility for waste management
• determine persons with line responsibility for waste management issues
• review documentation required by law
• review waste treatment and disposal documentation
• review operational procedures.

Data Collection Forms can ensure a logical, structured approach to data collection.

The forms should content:

• General company information

Information about products

Information about processes

Information about wastes

On site Waste Inspections’ may not only focus on waste generators, but, following the “cradle to grave” approach, also on carriers and operators of storage, utilization and disposal facilities. Principally three basic types of on-site waste inspection can be differentiated:

• Routine inspections
  Rotational inspection of selected HW generating enterprises and operators of utilization/ disposal facilities; pre-announced or unannounced

• Program inspections
  Program focus can be on specific industrial sectors, specific waste types, specific pollutants, specific on-site utilization/disposal methods, on-site storage, selected waste transporters or operators

• Special purpose inspections
  Surveillance inspection after complaints, conspicuous events

It should be noted that on-site inspections are not only a tool for assessing compliance, i.e. for verifying data and information supplied by the regulated community, but also for enforcing compliance with environmental, occupational and health regulation and with site specific license conditions. The conduction of even a limited number of on-site inspections and

---

91 Company address, telephone and fax details, • Contact persons (manager, HSE manager etc.), • Industrial sector (e.g. Chemicals, Food & Beverages, etc.), • Size / ownership, • Establishment / Start date, • Certification (e.g. ISO9000 / ISO14000),

92 For each process: • Description of the processes, • Flow diagrams, • Raw material consumption including water, process chemicals, packaging materials, • Products and by-products, • Wastes and wastewaters generated, If possible: • Very approximate mass balance, Number of employees, operating days/hours, • List of products, • Outline of processes

93 For each waste generated by each process: "Name” of the waste as described by waste generator, • General description of the waste, • Preliminary classification of the waste (if possible), • Quantity of waste generated per year, • Frequency of generation, (periodic / continuous etc.), • How stored at source, • If managed on site: – How and where managed, • If managed off-site: – Who it is collected / transported by,– Where does it go, – How is it managed at the destination
resulting punitive action has a strong educative momentum on the regulated community. By establishing an enforcement presence it promotes voluntary compliance. Moreover, on-site inspections produce also the necessary documentation for taking legal action against violators.

**Checklist for hazardous waste inspections**

On the basis of a template provided by Ministry of State for Environmental Affairs, Egyptian Environmental Affairs Agency and Egyptian Pollution Abatement Project: Hazardous Waste Management – Inspection Manual, 2002 the following information should be checked during inspections. Please note that such information to be included into the checklist need to be adopted to national legislation and therein defined requirements which have to be fulfilled by actors handling hazardous waste.

The checklist should also be used by industrial entities in order to check if all relevant requirements are fulfilled in accordance with current legislation. In addition, the inspection visits not only should serve to control entities handling hazardous waste and to prosecute not compliant actors, but also to support them in improving their waste management system.

Before carrying out the inspection visit, it is recommended that the inspection team prepares a brief summary about the industry and likely related production processes as well as used materials/substances and hence expected waste types generated.

<table>
<thead>
<tr>
<th>Requirement</th>
<th>Compliance status</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. HW Generation</td>
<td>yes</td>
<td>No</td>
</tr>
<tr>
<td>1.1 From the gathered background information, is the establishment likely to generate HW?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. Document review</td>
<td></td>
<td></td>
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<tr>
<td>2.1 Licenses</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.1.1 Does the establishment has the necessary HW license(s)?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.1.2 Is (are) the license(s) valid?</td>
<td></td>
<td></td>
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<tr>
<td>2.3 HW transport</td>
<td></td>
<td></td>
</tr>
<tr>
<td>If the establishment is transporting its own HW off-site</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Does the establishment has a HW transport license? (Copy of permit/license should be available).</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Is the license valid?</td>
<td></td>
<td></td>
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<tr>
<td>Are delivery documents to the receiving treatment facility available?</td>
<td></td>
<td></td>
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<tr>
<td>Is the receiving facility accordingly permitted to treat HW? (Details of permit should be available).</td>
<td></td>
<td></td>
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<tr>
<td>Is routing of the transport vehicles permitted?</td>
<td></td>
<td></td>
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<tr>
<td>If the establishment is not transporting its HW off-site, but delivering to a transporter</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Are agreements/delivery documents to HW transporters available?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Requirement</td>
<td>Compliance status</td>
<td>Comments</td>
</tr>
<tr>
<td>---------------------------------------------------------------------------</td>
<td>-------------------</td>
<td>----------</td>
</tr>
<tr>
<td>Is the transporter permitted to transport HW? (Details of license should be available).</td>
<td>yes</td>
<td>No</td>
</tr>
<tr>
<td>2.4 HW disposal</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.4.1 In case of on-site disposal of HW, does the establishment has a HW disposal license?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.4.2 Is the license valid?</td>
<td></td>
<td></td>
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<tr>
<td>2.5 HW Register</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.5.1 Is the HW register available? Is it compliant with the legal requirements?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.5.2 Are the contents of the HW register describe the situation in the establishment accurately? (Answer after field inspection)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.6 Emergency plan</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.6.1 Is the plan available?</td>
<td></td>
<td></td>
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<tr>
<td>2.6.2 Is the plan compliant and applicable?</td>
<td></td>
<td></td>
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<tr>
<td>2.7 Training records</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.7.1 Are the training records for involved personnel available?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.7.2 Were the trainings compliantly realized according to legislation?</td>
<td></td>
<td></td>
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<tr>
<td>3. HW generating Units</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3.1 Is the HW identified and quantified?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3.2 Are the indications on type and quantity consistent with information given in the HW register?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3.3 Is HW segregated from one another as well as from other non-HW?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3.4 Are the HW collection containers of adequate capacity?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3.5 Does the establishment ensure that no HW is accumulated/stored at the generating units for long time?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3.6 Is the generated HW transferred to the main HW storage area?</td>
<td></td>
<td></td>
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<tr>
<td>3.7 Are the employees aware of proper HW management and trained to act in emergency cases/accidents?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4. Utilities for HW management</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4.1 On-site treatment of HW</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Is the treatment process in compliance with legal requirements?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- If HW is generated from the treatment process, is the waste properly identified and quantified?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- is the HW from the treatment process separated from</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Requirement</td>
<td>Compliance status</td>
<td>Comments</td>
</tr>
<tr>
<td>----------------------------------------------------------------------------</td>
<td>-------------------</td>
<td>----------</td>
</tr>
<tr>
<td>one another as well as from other non-HW?</td>
<td>yes</td>
<td>No</td>
</tr>
<tr>
<td>- Are the employees aware of proper HW management and trained to act in emergency cases/accidents?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4.2 On-site storage of HW</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Is there a specifically designated HW storage area?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Does the storage area meet the legal requirements?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Do the storage containers meet the legal requirements?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Are there clear and correct labels inscribed with the required information on the waste containers?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Is the storage area suitable for the specific waste types and quantities stored?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Are the waste types and quantities of stored HW consistent with the information in the register?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Are the employees aware of proper HW management and trained to act in emergency cases/accidents?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4.3 On-site disposal of HW (if a specific HW disposal area is available on-site)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Is this area in accordance with the legal requirements?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Is the waste disposed of in accordance with legal requirements?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Are the waste types and quantities disposed of consistent with the information in the register?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4.4 HW transport vehicles (if the establishment transports HW)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- are the vehicles equipped and labeled (including type of waste) in accordance with the legal requirements?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Are the drivers properly trained to act correctly in emergency cases/accidents?</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

5.1.2.1. Case Study: Closing the Gap between Declared and Actual Hazardous Waste Generation by On-site Waste Investigations

For overseeing hazardous waste management in their administrational areas the Solid Waste Management Departments of the Environmental Protection Bureaus in the Chinese province Zhejiang rely mainly on the hazardous waste declarations submitted by the hazardous waste generating entities. Hazardous waste generators have to report annually data on hazardous waste generation, storage and external recovery and disposal. It was found however that hazardous waste generation according to the annual reports was way below the expected quantities according to production output. Authorities were looking therefore for ways to verify the data provided by the waste generators.
After consultation with the Sino-German “Environmental Enterprise Consultancy Zhejiang” Program\(^\text{94}\) it was decided to conduct ‘On-site Waste Investigations' (OsWI’s).\(^\text{95}\)

On-site waste investigation is a methodical approach that provides information on types, quantities and whereabouts of hazardous waste by assessing input materials, process flows and approximate material balances. In order to demonstrate the OsWI methodology, two Chinese consultants with environmental audit experience who had undergone prior training on the OsWI method were subcontracted to conduct on-site waste investigations in 17 enterprises belonging to the following manufacturing sectors of Zhejiang:

- Chemical drugs and raw drugs production
- Production of bio-pharmaceutical agents
- Essence & spice production
- Organic chemical raw material production
- Dye production
- Resin production
- Textile printing & dyeing
- Leather tanning
- Inorganic chem. manufacturing
- Asbestos product manufacturing
- Electroplating
- Fastener & spring production

Results of the investigations showed first of all a significant discrepancy in terms of actual waste stream numbers as well as actual waste quantities, compared to the data declared by the enterprises in their annual waste declarations. Whereas the companies had declared a total amount of hazardous waste generation of 20,700 t/a, actual generation according to the investigations was more than five times higher and amounted to 107,700 t/a.

The situation with regard to waste stream numbers is depicted in Fig. 13 and indicates that the number of different hazardous waste types actually generated by each company (blue columns) is much higher than what the companies have reported in their waste declarations (yellow columns). The reason for this difference becomes evident from Fig. 14 which shows that 67% of the total hazardous waste generated is not considered as hazardous waste but rather sold as a commercial good without following the Chinese transfer plan regulation (= a procedure similar to the “record of proper waste management”). Thus, Chinese hazardous waste regulation is bypassed.

\(^{94}\) The Sino-German “Environmental Enterprise Consultancy Zhejiang” Program was implemented in the Chinese Province of Zhejiang from 2003 to 2008. The objective of the hazardous waste management component of this program was to assist Zhejiang in building a hazardous waste management system. Zhejiang has one of the highest GDP’s from all Chinese provinces. It is also considered as China’s pilot province for hazardous waste management.

Fig. 13: Discrepancy between no's of hazardous waste streams reported and found (On-site waste investigation campaign Zhejiang, 17 enterprises investigated, 2007)

As Fig. 14 also shows, 16% of the total HW generated is disposed by on-site combustion in boilers or incineration in small-scale incinerators. Wastes were also found to be mixed with coal and the mixture sold to brick manufacturers. Both these methods have a high risk of creating air pollution.
Officials of the Zhejiang Environmental Protection Bureau agreed that the results of the 17 investigations might be symptomatic for the overall situation in Zhejiang. Reasons are complex and partially interdependent:

- Lack of sufficient disposal capacity for hazardous waste in Zhejiang at the time when the investigation was undertaken. This puts the enterprises into the dilemma to resort to improper management methods
- Absence of a logically structured user-friendly hazardous waste classification system, which is a major reason for
- Inadequate hazardous waste identification and segregation on the side of the waste generators
- A general bias among all stakeholders to overvalue the need for "comprehensive utilization" of production residues while at the same time misjudging risks for environment and human health
- Lack of technical competence and insufficient resources on the side of the Waste Authorities
- Unawareness of hazardous waste generators
- Intentional infringement of hazardous waste generators in order to save disposal costs

The findings further show that using unexamined information from waste generators as a base for Provincial and National statistical data related to hazardous waste may be misleading with regard to decisions, reports and plans derived from such data.
5.1.2. Separation\textsuperscript{96}

After identification and possible quantification the HW fractions should be separated from other (non-hazardous) wastes. Separation of HW fractions from other waste is crucial for a safe and environmental sound management and treatment.

Separation of hazardous waste can be beneficial in many ways.

When hazardous waste is mixed with non-hazardous waste, the whole mixture has to be considered as hazardous. Separating single pollutants from a waste stream on the other hand may enable the entire waste to be managed as non-hazardous thus reducing disposal costs. Similarly separation can reduce downstream pollution and facilitate wastewater- or off-gas treatment. Mixing halogenated and non-halogenated solvents can require the entire batch to be sent for expensive high temperature incineration. Incompatible wastes must not be mixed for safety reasons. Separation enhances also chances and scope of recycling: Separating spent engine oil and spent solvents from cleaning metal parts fosters reclamation of each, again with the potential of cost savings. The level of separation should be discussed mutually with the recipients of such waste streams, in most cases external recycling and disposal companies.

On-site separation shall include the separation into hazardous waste and non-hazardous waste e.g. organic halogenated and non-halogenated wastes from the chemical and pharmaceutical sector (solvents, distillation residues, mother liquors, spent activated carbon).

The main waste streams to be considered for separation are packaging waste (paper, cardboard, plastic foils, PP, PE, PVC, and Styrofoam well as construction and demolition waste (bricks, cement, asbestos-cement, steel, wood, glass, ceramics, and e-waste).

- On-site separation has for example an effect on disposal or recovery of different types of spent solvents and spent oils or separation of sludge from metal surface treatment containing different metals which can then be recycled.

- Package waste

Separation can have also disadvantages by causing additional costs. It may require an increase in storage space and it can lead to higher operating costs for waste transportation. A good understanding of the benefits and costs is therefore important to decide on the best course of action. Normally, due to increased recyclability and better treatment or disposal, the benefits outweigh the initial investments incurred for separating waste streams.

\textsuperscript{96} Segregation of chemicals /wastes means spatial separation (e.g. by a wall or storage on other location). This is important when segregating incompatible chemicals and wastes that could react violently between them during storage see fig 18. Dangerous substances should preferably be stored in dedicated compartments of the warehouse, which are effectively fire-separated from the rest of the building.
5.1.3. Management

The management of hazardous waste by nature poses many hazards to the personnel involved. As part of the on-site management of hazardous waste creating and maintaining safe working will help to prevent injuries, occupational diseases, and as a worst case scenario death. Measures for occupational safety and health are not only valuable from a social point of view, but will also prove beneficial for the employer by reducing loss of workdays due to injury and illness.

In Germany, the respective law requires that any establishment generating hazardous waste must nominate its own officer with responsibility for HW management, before being able to obtain a valid operating permission for waste. This person is often also responsible for pollution prevention and occupational safety and health. This commissioner\(^{97}\) must be reliable and competent. In Germany, the competence and qualification of this person has to be proven through records of instruction in the field of “maintenance and disposal”, or through documentation of long-term practical experience.

Facility personnel involved in the management or management of hazardous waste on-site must be trained to ensure that they are able to respond effectively to emergency situations. All facility personnel working on production lines and processes generating hazardous wastes are to be provided with initial training and annual refresher training covering the following aspects:

- Existence and storage area of specific hazardous materials
- Potential physical and health hazards associated with these materials
- Proper procedures for management and use of these materials, including the use of personal protective equipment (i.e. gloves and protective goggles)
- Storage area and use of the (Material) Safety Data Sheets (M)SDS), and
- Procedures to be followed in an emergency situation

Any waste generated in a workplace must be identified. For the correct identification, the following sources of information have to be considered:

- MSDS of waste components
- Chemical and physical characteristics of the material
- Process of waste generation and its conditions

The waste must be placed in appropriate containers made of material adapted for the specific material/waste – e.g. plastic containers for acids and bases, metal drums or other metal containers for organic solvents.

\(^{97}\) Duly authorized officer
Any container for hazardous waste must be clearly and unambiguously labeled. The labels have to contain the following information (see Fig. 15):

- the warning label “hazardous waste”
- short description of the contents in simple language
- the six digit code from EWL
- indication of hazard properties – e.g. “flammable”, “corrosive”, “toxic”
- department where the waste was generated
- name and telephone number of the employee responsible for internal hazardous waste management
- date of filling the container

Fig. 15: right: Sample of a hazardous waste label and left: TDG pictogram indicating flammability

5.1.3.1. Containers

Containers generally used for collecting waste in the workplace are polyethylene canisters up to a volume of 60 liters, and polyethylene or steel drums of 200 liters capacity (see Fig. 16 and Fig. 17).

The containers should be kept tightly closed unless materials are added or removed. Containers for liquid wastes must not be filled to more than 90 per cent of their volume to leave room for potential expansion.
As soon as the hazardous waste containers at or near the point of generation are filled to capacity, they should be transferred to a central storage area within the company. This central storage area should be in a well ventilated place with an impervious floor, preferably a covered hall with latticework instead of a concrete wall on one side. The access gates should be lockable and no other employees than the personnel responsible for hazardous waste management should be authorized to enter this area. The central storage area should be inspected daily by an authorized person to check the physical condition of the containers and any emission.

For indoor management of hazardous waste, which is common in manufacturing plants, it must be ensured that vapors and dusts possibly spread by the waste are removed from the
breathing area of workers. This can be achieved by opening doors and windows on opposite sides of the building, or by creating, with the assistance of motor-driven fans, an air stream that passes from the worker to the workplace.

Ideally would be that this hazardous waste containers are managed outside the manufacturing plants. These areas should be sufficiently ventilated to prevent inhalation of dangerous vapors or dusts.

To clean up spills of liquid hazardous waste, universal absorbents should be provided near the workplaces where such materials are managed.

Until a batch of hazardous waste is treated in a hazardous waste management facility, two or three steps are required where various staff is involved in the management and transport of containers with hazardous waste. It must be ensured that any personnel engaged in these operations know exactly what type of hazardous waste is in the containers and have the competence to manage it safely.

Containers with incompatible wastes stored in the central accumulation area should be separated by a dyke, berm or wall. The central storage area should be equipped with a dyke or berm also to prevent potential spills from flowing out of this area.

Fig. 18: Segregation of incompatible wastes/materials

In the central storage area, containers of greater capacity may be used, for instance intermediate bulk container (IBC) of 600 up to about 1,000 liters volume (see Fig. 19).

---

Wastes that might react/interact with each other causing risks to the environment or human health
Fig. 19: Sample of IBCs, containers for liquids of 600 up to about 1000 liters volume

For solid hazardous waste, skips with a lid and a capacity of 5, 7 or 10 m³ are usually used (see Fig. 20).

Fig. 20: Sample of skip, 5 to 10 m³ steel skips for solids

Appropriate storage facilities should also be available for HW (see Fig. 23)

Fig. 21: HW Storage facilities
Production plants generating hazardous waste must cope with the fact that this waste needs to be managed on site. On-site management of HW must be performed in such a manner that no risk for staff arises from these activities. This requirement is best fulfilled by nominating a reliable and competent waste commissioner, and by supplying staff with comprehensive information on the nature of the various types of HW generated in the plant and on the potential risk arising from them. Suitable containers for waste collection and safe storage preventing leakage must be provided by the company for temporary on-site storage.

5.2. Internal HW Collection and temporary Storage

Several essential aspects of temporary storage of hazardous wastes have been mentioned in the preceding section. On-site temporary storage must be realized in such a manner that

- subsequent treatment will not be hampered
- no danger for staff will arise from the waste.

The first demand is best fulfilled by keeping the different types of hazardous wastes separate at the source of generation. In order to achieve an utmost extent of separation,

- staff must be informed about the wastes to keep separate
- appropriate containers must be supplied in sufficient numbers
- containers must be clearly labeled as containing hazardous waste
- a short declaration on each container’s content.

Separation of different types of waste may be facilitated by using containers of different colors, for instance:

- red containers for flammable halogen-free solvents
- blue containers for halogenated hydrocarbons such as dichloromethane, trichloroethylene or tetra chlor ethylene

An excellent method of informing staff is to draw up a plant-specific waste guide that lists any waste generated in the plant and indicates how to proceed with it.

In the case of intermediate storage of flammable and explosive liquids, the safety precautions to be observed are the same as for the storage and management of raw materials – i.e. installation of explosion-proof electric and electronic equipment and fire-extinguishing features in the area of intermediate storage.

For liquids stored in tanks, the space above the liquid must be filled with nitrogen to prevent the formation of explosive gas-air mixtures. The stacking ground must be secured by sealing
systems to prevent leaching into groundwater. Usually, the stacking areas are roofed to prevent infiltration by rainfall.

5.2.1. Hazardous waste service providers

In Germany, as common practice hazardous waste management facilities offer advice and additional services to their customers, i.e. the hazardous waste producers. For example the HW producers receive guidance on the packaging and recommended volumes of the containers in which hazardous waste should be transported to the management facility. Another service is to collect and deliver containers. It is recommended to use large volume containers for the transport of HW to the hazardous waste management facility whenever possible, because the management of many small containers is labor-intensive and costly. Fig. 22 and Fig. 23 show Intermediate Bulk Containers (IBC) of 1 m$^3$ that meets the requirements according to GGVS\textsuperscript{99}. These containers are rented from waste management service companies for the waste producers. When the containers are full, they are collected by the waste management companies and replaced by empty ones.

Fig. 22 left: IBC for acids and caustic liquids waste. Right: IBC for solid and pasty waste

\textsuperscript{99} Gefahrgutverordnung Strasse (German laws for the transportation of hazardous goods on the road.)
Fig. 23 left: IBC for liquid organic waste. Right: IBC for waste oil

Fig. 24 Left: Management of IBC. Right: IBC containers can be stacked.

Fig. 25: Containers are equipped with a collision protection guard
In small and medium-sized enterprises, hazardous wastes are often generated only in small quantities. Therefore, on-site collection and temporary storage is necessary until quantities are large enough for shipment by a licensed hazardous waste transporter.

For the collection and transport of small quantities of hazardous waste such as residues from paint, varnish or adhesives, you should be proceeding as follows:

- Containers with HW, for instance waste paint and varnish waste code 08 01 11* or waste adhesives and varnish waste code 08 04 09* of up to 30 liters shall be packed into skips with lid, or polyethylene drums of 200 liters capacity with clamping ring lid.

Fig. 26: Example of filled and closed polyethylene drums

Containers with HW as mentioned above exceeding 30 liters in volume shall be stacked on pallets of a maximum dimension of 80x120 cm.

For detailed information on chemicals management in enterprises see:


UNEP Responsible Production Handbook at: [http://www.unep.fr/scp/sp/saferprod/initiatives.htm](http://www.unep.fr/scp/sp/saferprod/initiatives.htm)
Fig. 27: Example of filled and closed steel drums

Containers for hazardous waste should always be tightly closable. This requirement is particularly important e.g. if the containers are stored in the open air.

Fig. 28: Preparing HW for transport

For safe collection and on-site temporary storage, a plant specific waste guide is very helpful. It should contain a mixing ban for hazardous waste, and provide instructions on the use of suitable containers, correct labeling, as well as the use of appropriate personal protective equipment. Valuable advice on proper packaging and correct size of containers for hazardous waste should be obtained from hazardous waste management facilities or from specialized waste service provider companies.
5.3. Waste Acceptance Procedure

The objective of specific hazardous waste acceptance criteria and procedures should be to ensure that waste accepted for recovery or disposal conforms to the license conditions of the installation. Moreover it should be ensured that accepted waste is identical to the waste as declared by the waste producer. In Germany the waste producer has to submit a ‘Record of Proper Waste Management’ application in which the waste is comprehensively characterized and classified (see chapter 7).

Experience from industrialized countries has shown that a strict waste acceptance procedure is particularly required for hazardous waste landfill disposal. Land filling is, compared to other waste management options, usually the least expensive disposal option. Investigations showed that many waste types that should have been allocated to other -more expensive- management options end up wrongly on landfill sites. European legislation defines specific waste acceptance criteria and procedure for waste acceptance at landfill sites (For details see chapter 11.3. “Acceptance Procedures for Hazardous Waste at Landfills”)

In European legislation Decision 2003/33/EC the cornerstone of the waste acceptance procedure is the “basic characterization” of the waste with regard to its waste production process and its organoleptic, chemical and physical properties. The basic characterization is therefore a “passport” for the waste under consideration and the acceptance procedure defined for landfill sites applies in general also to other recovery and disposal options.(see chapter 8)

In order to avoid damages to soil and groundwater, resources by waste, types of waste unsuitable for landfill disposal has to be known beforehand (see 7.4).

5.4. Special Transport Vehicles for hazardous waste

For the safe transport of liquid or sludge HW special suction tanker trucks should be used. In the following pictures different trucks to be used for the transport of liquid or sludge HW are shown.
Fig. 29: Suction tanker trucks (Source of pictures: Assmann GmbH, Im Brühl 90, D-74348 Lauffen/Neckar, Germany, www.assmann-sonderfahrzeuge.de)

Fig. 30: Suction tanker truck (Source of picture: E. Schultes, HIM GmbH)
Fig. 31: Suction tanker truck (Source of picture: E. Schultes, HIM GmbH)

Fig. 32: Dump truck with tipping container for bulk solid waste (5 - 8 m³)

Fig. 33: Dump truck with flat tipping container for bulk solid waste (approx. 15 m³), suitable e.g. for filter cake; container can be placed under a chamber filter press.
5.5. Preconditions for Transport to the Hazardous Waste Treatment and disposal facilities

5.5.1. Duties of the Hazardous Waste Producer

Enterprises consigning their hazardous waste to a licensed carrier for transport to an external utilization or disposal facility have the following responsibilities:

- To classify HW according to its hazardous properties and if relevant with the regulations for dangerous goods
- To use packages/containers in compliance with the package specifications of the respective dangerous good class and quantity
- To place the respective danger labels on the packages
- To ensure that the carrier has a license for transport of waste/dangerous goods
- To check the equipment and the suitability of the truck sent by the carrier
- To ensure proper tie down of the cargo load
- To supply the truck driver with corresponding documentation such as notification and movement document, (see 3.2.1) consignment note, copies of the “Records of Proper Waste Management” (see chapter 7) and “Transport Emergency Cards” (see section 6.5.7.), relating to the wastes and their hazardous properties

Violations of these duties may have repercussions in case of traffic accidents.

Enterprises that are consignors of dangerous goods are moreover obliged to appoint an “officer for the prevention of the risks inherent in the carriage of dangerous goods/wastes”. Subject to the total quantity of dangerous goods shipped per annum, this obligation can be transferred to a third party. A convenient solution might be outsourcing this function to the carrier and including a respective clause in the transportation contract.

In the EU any carrier transporting hazardous wastes needs a permit of the relevant national or regional competent authority. According to European legislation the waste producer’s responsibility does not end with handing the HW over to the transporter. The waste producer is obliged to verify whether the carrier in charge of the transport has obtained and holds a valid permit for HW transport.

5.5.2. Duties of the Hazardous Waste Transporter – General Personnel

Article 26 of Waste Framework Directive 2008/98/EC specifies that establishments or undertakings which collect or transport waste on a professional basis or which arrange for the disposal or recovery of waste on behalf of others (dealers or brokers) shall, where they are not subject to permit requirements, have to be registered with the competent authorities.
In most European member countries, this provision under the Directive has been incorporated into the national legislation, for example in Germany by the adoption of the Ordinance on Transport Licences of 10 September 1996. Any applicant for such an approval must prove sufficient (I) reliability, (ii) expertise, (iii) integrity and (IV) competence to transport hazardous waste.

For example, with regard to the technical competence of persons responsible for managing and supervising such operations, the German Ordinance on Transport Licenses, requires the following:

(1) The persons responsible for managing and supervising a company for the collection and transport of waste for disposal or hazardous waste shall possess the technical competence required for their tasks. Such competence shall

1. include knowledge acquired in two years of practical experience about the collection and transport of waste;

2. be obtained by participating in one or more training courses which have been recognized by the competent authority and which impart knowledge in keeping with the Annex to this Ordinance (see below).

(2) The following shall also be recognized as sufficient proof of the technical competence pursuant to paragraph (1) No. 1:

1. completion of studies in the areas of engineering, chemistry, biology or physics at a university, or a qualification from a technical college, or a master-craftsman qualification, or completion of commercial vocational training in a field in which the company can be classified due to the nature of its operations; and

2. knowledge, acquired through one year of practical experience, about the collection and transport of waste.

Technical Competence of Persons Responsible for Managing and Supervising a Collection and Transport Company

Such competence shall include the following:

1. technically proper and competent collection and transport of waste, with a special emphasis on proper waste transport techniques and proper labeling of vehicles and containers;

2. the harmful environmental impacts, other hazards, significant impairments and nuisances that may be caused by waste, and measures to prevent or remedy such problems;

3. the type and nature of hazardous waste;
4. provisions of waste-management laws and of other environmental legislation applicable to the specific collection and transport activities

5. references to legislation on goods transport and the transport of hazardous goods;

6. provisions pertaining to company liability.

5.5.3. Special requirements of Hazardous Waste Transporter regarding driver qualification and Vehicles

In Europe, drivers of commercial vehicles transporting not only hazardous waste, but dangerous substances in general, must possess an “ADR license” (ADR: accord européen relatif au transport international des marchandises dangereuses par route = European agreement concerning the international carriage of dangerous goods by road) as required by the European Agreement Concerning the International Carriage of Dangerous Goods by Road. To obtain this license, drivers must complete special training courses covering subjects such as

- introduction to classes of dangerous goods
- legal and regulatory implications of the carriage of dangerous goods, which includes waste materials
- vehicle marking
- load restrictions and segregation of chemicals
- PPE (Personal Protective Equipment) and safety equipment
- practical exercises
- emergency aid
- types of packages
- labeling of packages
- UN approval marking
- limited quantities

The training must be completed in the form of an initial training and refresher training at intervals of 5 years.

\[\text{UNECE, 2009a}\]
The vehicles for hazardous waste transports must carry the consignment note described in annex 9e. In addition, vehicles need to be equipped with the stipulated emergency equipment such as

- two fire extinguishers, one with 6 kg and another with 2 kg of dry powder
- protective gloves
- safety goggles
- a spade
- high-visibility reflector vests for all persons on board
- two warning signs mounted on stable legs

5.5.4. Transport of dangerous goods (TDG)

Transport of dangerous goods (including hazardous waste) needs to be regulated in order to prevent, as far as possible, accidents to persons or property and damage to the environment, the means of transport employed or to other goods. However, with different regulations in every country and for different modes of transport, international trade in chemicals and dangerous products would be seriously impeded, if not made impossible and unsafe.

In order to ensure consistency between all these regulatory systems, the United Nations has developed mechanisms for transport conditions for all modes for Transport of Dangerous Goods (TDG).

Dangerous goods are divided into 9 UN classes on the basis of special chemical characteristics producing the risk. The classes of dangerous goods are subdivided in divisions and specific pictograms for each class or division have been established. See table 10 for details.

Table 10: UN classes for dangerous goods. Clicking in each pictogram will enlarge it. Source: UN Transport regulations Chapter 2.0.1 Classes, divisions, packing groups

---

<table>
<thead>
<tr>
<th>Class</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Explosives substances and articles</td>
</tr>
<tr>
<td>2.1</td>
<td>Flammable gases</td>
</tr>
<tr>
<td>2.2</td>
<td>Non flammable gases</td>
</tr>
<tr>
<td>2.3</td>
<td>Toxic gases</td>
</tr>
<tr>
<td>3</td>
<td>Flammable liquids</td>
</tr>
<tr>
<td>4.1</td>
<td>Flammable solids</td>
</tr>
<tr>
<td>4.2</td>
<td>Substances liable to spontaneous combustion</td>
</tr>
<tr>
<td>4.3</td>
<td>Substances that in contact with water, emit flammable gases</td>
</tr>
<tr>
<td>5.1</td>
<td>Oxidizing substances</td>
</tr>
<tr>
<td>5.2</td>
<td>Organic peroxides</td>
</tr>
</tbody>
</table>
Each entry in the different classes has been assigned a 4 digit UN Number. It is not usually possible to deduce the hazard class of a substance from its UN number: they have to be looked up in a table. An exception to this is Class 1 substances whose UN numbers will always begin with a 0.

5.5.5. Labeling system for HW vehicles UN-Number /ADR Numbers

Vehicles and trucks transporting dangerous goods have to be clearly marked with symbols and labels, thus indicating the content of what they are carrying. This is a precondition to guarantee that during a possible accident more effective help can be provided to people and the environment.

Different placarding systems exist. In this document two labeling systems (UN and the ADR systems) are applied. These two systems are based on lists of different substances and codes.
UN Numbers:

The United Nations (UN) Numbers are four-digit numbers used world-wide in international commerce and transportation to identify hazardous chemicals or classes of hazardous materials. These numbers generally range between 0000 and 3500 and are ideally preceded by the letters "UN" (for example, "UN1005") to avoid confusion with other number codes.

UN numbers are assigned by a committee of the United Nations, the Economic and Social Council (ECOSOC) Committee of Experts (COE) on the Transport of Dangerous Goods which issues "Recommendations on the Transport of Dangerous Goods" (also called "the Orange Book"). See the list of all UN numbers at: http://www.unece.org/trans/danger/publi/adr/adr2009/09ContentsE.html in Annex A under Part 3

ADR-Numbers:

In continental Europe an additional placarding system for vehicles transporting hazardous goods is applied. This system allows a quick identification of the degree and type of hazards which might be encountered with the hazardous goods in the event of an incident/accident. The placards carry a hazard identification number consisting of two or three figures. See the ADR numbers or Hazard Identification Numbers (Kemler codes) and the hazards they indicate at: http://www.ilo.org/legacy/english/protection/safework/cis/products/safetytm/tranann5.htm

The vehicles must display two orange panels on the outside; one on the front and one on the back of the vehicle (see Fig. 34).
Fig. 34: Labeling of vehicles transporting hazardous wastes

Vehicles transporting tanks and tank containers must display orange plates indicating the hazard number corresponding to the ADR and the UN number of the material in the tanks or tank containers, one rear, and one on each side of the vehicle. Fig. 35 shows an example of an orange plate with 33 being the hazard number (ADR) indicating a highly flammable liquid (flash point below 23°C) and 1088 being the UN number for (waste) acetates.

Fig. 35: Example of an orange plate with ADR and UN numbers

For each specific UN class for transport of dangerous goods a specific TDG pictogram (see table 10) must be fixed visibly on the vehicle and on the containers (see Fig. 36:). These TDG pictograms additional indicate the relevant dangerous good class of the transported goods.
5.5.6. Classification of Hazardous Waste according to the Regulations for Dangerous Goods

There is no correlation between the waste codes of the European Waste List and dangerous good classes, and dangerous good classification of hazardous waste can become tricky sometimes. As a rule of thumb, the pollutant contained in the waste that exhibits the highest risks with regard to transport safety determines the dangerous good class for waste transport. Accordingly, reference to the waste generation history will be useful and yield respective information. MSDS of input materials may provide information on dangerous good classification or on UN Codes (if MSDS according to the EU-format are available, respective information may be found in section 13 or 14 of the respective MSDS). This facilitates classification e.g. of expired raw materials such as pesticides.

If either the names or the UN Codes of the key pollutants are known, dangerous good classification details can be found in Part 3 of the “UN Recommendations on the Transport of Dangerous Goods”. Guidance on classification by testing is provided in Part 2, guidance on the use of packaging in Part 4. There is also an alphabetical index of UN Numbers for substances and articles.

Wastes may exhibit new properties that are not easily foreseeable with reference to their input materials. This has also relevance for transport safety and dangerous good classification of hazardous waste. A waste type that has become “famous” in this regard is ‘spent wiping cloths, contaminated with mineral oil’ which is a waste generated in abundance across many sectors. Several incidents have been reported where such waste has caught fire during collection and transport. Whereas neither wiping cloth nor mineral oil (flashpoint > 60 °C) on its own is considered flammable in the sense of dangerous goods regulation, it was understood that a waste consisting of both materials may become self-ignitable by means of additive effects. (For information, this waste is disposed by co-processing as an

alternative fuel in cement plants.) This waste type may serve to exemplify the difference between waste- and dangerous good classification.

According to EWL-classification this waste is listed in subchapter 1502, “Absorbents, filter materials, wiping cloths and protective clothing”, under a mirror entry:

<table>
<thead>
<tr>
<th>Code</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>15 02 02*</td>
<td>Absorbents, filter materials (including oil filters not otherwise specified), wiping cloths, protective clothing contaminated by dangerous substances</td>
</tr>
<tr>
<td>15 02 03</td>
<td>Absorbents, filter materials, wiping cloths and protective clothing other than those mentioned in 15 02 02*</td>
</tr>
</tbody>
</table>

In this case the hazardous part of the mirror entry would be used in view of the carcinogenic nature of mineral oil.

Classification according to Dangerous Goods Regulation (Germany):

- UN Code: 3175, Solids containing flammable liquid, not otherwise specified.
- Dangerous Good Class: 4.1, Flammable solids, self-reactive substances

Whereas EWL classification emphasizes the carcinogenic nature of the waste, the focus of dangerous goods classification is on flammability.

When dealing with other wastes containing waste oil, it has to be considered that small amounts of petrol can bring down the flash point of mineral oil significantly so that flammability of such waste becomes an issue with regard to collection and transport safety.

If in doubt during dangerous good classification of hazardous waste, it is always better to assume a higher risk than a risk too low. Mistakes made during classification may have legal repercussions in case of traffic accidents.

5.5.7. Transport Emergency Card

According to ADR, the transport of a hazardous chemical or waste container must be accompanied by “instructions in writing”, which is in practice commonly done by means of a Transport Emergency (TREM) Card, which contains safety information. The TREM card is not only on information purpose for the driver of the vehicle transporting the chemical or HW container, but important for anyone who arrives at the scene of the accident when the driver cannot act in order to prevent further damage or harm. The TREM Card will inform such a person on what type of chemical or waste is being transported and how to prevent further harm.

The TREM Card includes the following information:
- Name of chemical (hazardous waste) transported
- Nature of a possible hazard
- Type of proper Personal Protective Equipment (PPE) to be used when dealing with a specific HW
- First Aid to take in case of emergency
- Emergency Telephone Number
- General instructions to be taken by the transporter during an emergency
- Instructions in case of fire
- Supplementary information for emergency services
- Date issued/revised

The TREM Card has to be kept inside an orange box in a designated area inside the vehicle transporting the HW container. It must be kept alongside with the hazardous waste manifest document (consignment note). A separate TREM Card for each type of chemical or hazardous waste being transported is required. TREM cards are to be issued by the sender of the chemical or hazardous waste container. The TREM Card has a limited validity and must be renewed in the case of expiry.

Fig. 37: Left: Safe transport of HW; Right: Unsafe transport of HW

In Europe, waste and hazardous waste transporters need an ADR license and are supervised by the authorities. The HW producer must make sure that the transporter, to whom the waste is handed, has the proper license for transporting such waste. Vehicles for the transport of hazardous waste must be marked to indicate the types of waste transported, and must carry emergency equipment.
Control for Hazardous Waste Transport

This chapter is dedicated to explaining permitting and control procedures and to highlighting the importance of control actions to be carried out by competent authorities.

6.1. Preliminary Remarks

The EU Waste Framework Directive 2008/98/EC (WFD) demands that waste is being managed according to the principles of the Waste Management Hierarchy (See chapter 2.5.). According to this Directive, EU Member States shall take all the action necessary to ensure that the production, collection and transportation of HW as well as its storage and treatment are carried out in conditions providing protection for the environment and human health. This includes that MS shall take actions to ensure traceability from production to final destination and control of HW. Obligatory record keeping for HW is determined in the new WFD as well as requirements for enforcement and penalties in case of non-compliance.
According to the WFD, competent authorities are required to control and monitor all above mentioned HW management activities and are in charge of consequently controlling compliant waste management.

Some low and middle income countries have already implemented monitoring systems for tracing hazardous waste “from the cradle to the grave”. However, relatively few low and middle income countries have also enacted application/approval procedure for the permit of the waste management operation intended by the waste producer. Without such a procedure however the entire waste management system has a critical loophole: The notification of waste streams to disposal and recovery options and facilities is entirely left to the discretion of waste producers and facility operators, without control of the competent authorities. Chances are high that waste management gets driven by commercial interests while aspects of public welfare, protection of environment and resources, occupational health and safety are sidelined. It should be clear that stand-alone implementation of a manifest system cannot avoid that a waste type e.g. such as a distillation residue ends up wrongly on a landfill site (where disposal costs may be low) rather than being sent to a hazardous waste incinerator (what would be the appropriate destination, however where disposal costs may be higher).

Involving the competent authorities of a country or a region in HW management is in general also beneficial for waste producers.

The first sections in this chapter outline the basic features of the ‘Record of Proper Waste Management’ (RPWM) procedure as well as the consignment note procedure as being successfully implemented in Germany for more than twenty years. Both are management tools for off-site or external waste recovery and disposal. In addition to these off-site measures another important issue that requires control is internal or on-site management of hazardous waste which takes place within the premises of the hazardous waste generating entity. The last section of this chapter discusses therefore challenges and principles with respect to on-site management of hazardous waste.

6.2. Certificate of Proper Waste Management of Waste in Germany

6.2.1. The “Record of Proper Waste Management” (RPWM) Procedure

Waste producers in Germany generating more than 2000 kg hazardous waste per year have to follow the RPWM procedure for each type of HW generated. The RPWM requires a certification of the intended treatment of a waste type by the competent authority. A RPWM approved by the competent authority allows the waste producer to send the waste to a specific recovery or disposal facility over a maximum period of 5 years. Individual shipments
do not require further approval. The details of the RPWM procedure are laid down in the “German Ordinance on Waste Recovery and Disposal Records of 20 October 2006”

The following table summarizes the key players and their roles and definitions according to the ‘Record of Proper Waste Management’ procedure.

Table 11: Key players and their role during the ‘Record of Proper Waste Management’ procedure

<table>
<thead>
<tr>
<th>Key player</th>
<th>Role</th>
</tr>
</thead>
<tbody>
<tr>
<td>Waste producer</td>
<td>The entity producing hazardous waste</td>
</tr>
<tr>
<td>Competent authority of the waste producer</td>
<td>The competent Government authority that is responsible for supervising waste management activities in its administrative region to which the waste producer belongs</td>
</tr>
<tr>
<td>Waste management facility</td>
<td>The facility that is receiving hazardous waste from the waste producer for recovery or disposal</td>
</tr>
<tr>
<td>Competent authority of the waste management facility</td>
<td>The competent Government authority that is responsible for supervising recovery- and disposal activities in its administrative region to which the waste management facility belongs. This authority has to ensure that operations of the waste management facility have no adverse effects on the environment and human health.</td>
</tr>
<tr>
<td>Transporter</td>
<td>The carrier who transports hazardous waste from the waste producer to the waste management facility</td>
</tr>
</tbody>
</table>

Documentation requirements

For the documentation of the RPWM procedure the German Regulator has issued a dossier comprising 5 document forms with four carbon copies each which is called “Record of Proper Waste Management” (See Table 12).

Table 12: Overview of forms included in the ‘Record of Proper Waste Management’ dossier

<table>
<thead>
<tr>
<th>No</th>
<th>RPWM Form, contents</th>
<th>Party filling in the relevant document</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td><strong>Cover sheet (CS) for application</strong>, containing contact details of the waste producer and other relevant information</td>
<td>To be filled in by the waste producer, to be confirmed by the competent authority of the administrative region to which the waste producer belongs</td>
</tr>
<tr>
<td>2</td>
<td><strong>Declaration of Responsibility (DR)</strong>, containing information on the waste to be transported to the treatment facility, e.g. relevant waste code, information on the</td>
<td>To be filled out by the waste producer with legally binding signature</td>
</tr>
</tbody>
</table>
No | RPWM Form, contents | Party filling in the relevant document
--- | --- | ---
3 | **Declaration Analysis (DAn)**, characterizing the waste and its key pollutants by chemical analysis | To be elaborated by an independent laboratory on behalf of the waste producer (A declaration analysis is only required if the competent authority of the waste management facility deems it necessary)

4 | **Declaration of Acceptance (DA)**, (i) confirming that the waste management company is in a position to treat the waste in compliance with respective regulations; (ii) providing a brief description how the waste will be treated | To be filled in by the waste management facility with legally binding signature

5 | **Official Confirmation (C)** - Approval or denial of the intended waste treatment | To be filled in by the competent authority of the waste management facility

**Information Flow**

The information flow during the RPWM application procedure includes four steps which are depicted in Fig. 39 and explained below:

1) The waste producer fills in the Cover Sheet (CS), provides requested information on the waste and signs the Declaration of Responsibility (DR) (legally binding signature). He attaches the Declaration Analysis (DAn) (if required) and sends the entire dossier to the waste management facility where the waste shall be treated.

2) The waste management facility fills in and signs the Declaration of Acceptance (DAc) declaring that the waste will be accepted and treated properly. A copy of the Declaration of Acceptance (DAc) is sent to the waste producer for internal communication. The waste management facility forwards the dossier with 4 forms completed (CS, DR, DAn, DA) to the competent authority responsible for the waste management facility.

3) The competent authority of the waste management facility checks the permissibility of the intended waste management, approves or denies it, and lays down its final decision in the confirmation (C). The authority then sends the original version of the entire dossier including the confirmation (C) back to the waste producer and accordingly a copy to the waste management facility.

4) In case the competent authority of the waste producer is different from the one responsible for the waste management facility (the waste producer and the waste
management facility may be located in different Counties, Districts or States so that they fall under different jurisdiction), the waste producer sends also a copy of the entire dossier to his competent authority.

After receipt of the confirmed RPWM dossier, the waste producer can send the declared waste by a licensed carrier to the waste management facility. The waste producer has to provide a copy of the RPWM dossier to the carrier as part of the movement documents.

During the validity period of the RPWM no further application/approval procedures are required with regard to the respective waste stream. The competent authorities of the waste producer and of the waste management facility are kept informed about the progress of waste shipment via notifications belonging to the respective RPWM dossier.

Fig. 39: Information Flow of the ‘Record of Proper Waste Management’ application procedure

The “Collective Record of Proper Waste Management” Procedure

A possible variation of the RPWM is the so-called “collective” RPWM. A carrier intending to collect a specific waste type within a certain area may act as waste producer in the sense of the RPWM procedure and therefore apply for a “collective” RPWM (see Fig. 40). With a collective RPWM, a waste transporter is allowed to collect a specified waste type from different waste producers located in a specified area. All wastes to be collected from the different waste producers must have similar characteristics, i.e. they must belong to the same waste code, and they have to be delivered to the same recovery or disposal facility.
For each collection tour, the transporter (= acting as combined waste producer and carrier) submits one consignment note indicating the total hazardous waste amount collected during the tour (See 6.2.1.1).

When handing over the waste to the transporter, the waste producer receives a handover certificate (= receipt) which he must keep in his records and forward to his competent authority on request.

![Diagram of waste management process](image)

**Fig. 40: The ‘Collective Record of Proper Waste Management’**

The collective RPWM is a simplification of the standard RPWM. It is a valuable management tool since it reduces monitoring and supervision efforts of the competent authorities. Its application is particularly useful for:

- waste producers generating small quantities (it saves them the effort to apply for an individual RPWM)
- For control of waste streams in areas where a lot of similar waste types are being generated (e.g. in industrial clusters specialized on one industry).

A case for applying a collective RPWM procedure is for example the collection of waste oil from workshops and garages.

Given that small and medium scale industries belonging to the same industrial sector are often concentrated in so called industrial clusters, the collective RPWM is an important approach for substantial improvement of hazardous waste management.
6.2.1.1. Consignment Notes (CN) for Proving Completion of Hazardous Waste Operations

Each type of hazardous waste produced and handed over to a waste transporter for shipment to a recovery or disposal facility must be accompanied by a separate set of consignment notes, each set consisting of six copies. These copies of six different colors must be distributed according to the German Ordinance on Waste Recovery and Disposal Records (see Fig. 41):

- Copies 1 (white) and 5 (gold) shall be added to the waste producer's records
- Copies 2 (pink) and 3 (blue) shall be submitted to the competent authority
- Copy 4 (yellow) shall be added to the waste transporter's records; if there is a change of transporter, it shall be added to the last waste transporter's records
- Copy 6 (green) shall be added to the records of the party (facility) responsible for waste management

Fig. 41 Proof of completed waste management operations in the form of sextuplicate consignment note

6.2.1.2. Application of Management Information Systems

The RPWM and the consignment note procedure are important management tools for regulators and enforcing agencies. Consignment note data are an important information...
source for statistical and planning agencies. If the consignment note data are correctly completed and consequently controlled by competent authorities, the collected data from the documentation can provide a realistic picture of the actual waste recovery and disposal situation including information on waste codes, quantities, origin and destination of hazardous waste. However manual evaluation of vast quantities of consignment notes is cumbersome. For making the complex information flow of both procedures more convenient and for facilitating downstream use of data, paper based communication systems are being replaced by electronic state-of-the-art technology.

Since 1 April 2010 the electronic data management of hazardous waste shipment is mandatory. All involved parties avoid the use of paper copies for the monitoring of hazardous waste shipments. The system is called “eANV”¹⁰⁴ and uses a central server with SSL (Software Site License) key, to which all parties can gain access via an internet browser¹⁰⁵. Electronic “Records of Proper Waste Management” and consignment notes are transferred from the internal software to the server and from the server to the competent authorities, transporters and waste management facilities as well as to the waste producers. Users of the system have to acquire digital signatures in order to sign the electronic documents. Waste producers and carriers are yet permitted to use manual signatures during a transition period until 2011. A pilot version of the electronic consignment note procedure has already been in place in the German state of Bavaria since 2003.

Hazardous waste management is subject to supervision and control by the responsible competent authorities. Waste producers, waste transporters, waste management facilities and operating companies have to provide the relevant information to the responsible authorities. Any planned hazardous waste management operation requires the permit and approval of the authorities. Certification of completed hazardous waste management operations shall be provided in form of consignment notes. This can be done by using paper copies or electronic data management systems.

¹⁰⁴ eANV = Electronic Waste Verification Procedure (= elektronisches AbfallNachweisVerfahren (in German))
¹⁰⁵ For further information please refer to www.ebegleitschein.de (only in German).
Editable set of the record of proper waste management (RPWM) forms according to the German procedure

- **Form “Cover sheet for records of proper waste management”**

<table>
<thead>
<tr>
<th>Record of Proper WM / Collective RPWM / SR / SC</th>
<th>No.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Please tick applicable □ or fill</td>
<td></td>
</tr>
<tr>
<td>(to be filled by the waste producer)</td>
<td></td>
</tr>
<tr>
<td>RP</td>
<td></td>
</tr>
<tr>
<td>□ Record of Proper Waste Management (RPWM)</td>
<td></td>
</tr>
<tr>
<td>□ for recovery □ for disposal</td>
<td></td>
</tr>
<tr>
<td>for wastes to which records obligations apply</td>
<td></td>
</tr>
<tr>
<td>CR</td>
<td></td>
</tr>
<tr>
<td>□ Collective RPWM</td>
<td></td>
</tr>
<tr>
<td>□ for recovery □ for disposal</td>
<td></td>
</tr>
<tr>
<td>for wastes to which records obligations apply</td>
<td></td>
</tr>
<tr>
<td>SR</td>
<td></td>
</tr>
<tr>
<td>□ Simplified Record</td>
<td></td>
</tr>
<tr>
<td>□ for recovery □ for disposal</td>
<td></td>
</tr>
<tr>
<td>for waste that needs supervision as defined by law</td>
<td></td>
</tr>
<tr>
<td>SC</td>
<td></td>
</tr>
<tr>
<td>□ Simplified Collective Record</td>
<td></td>
</tr>
<tr>
<td>□ for recovery □ for disposal</td>
<td></td>
</tr>
<tr>
<td>For wastes that need to be monitored</td>
<td></td>
</tr>
</tbody>
</table>

**Contact data of the waste producer**

<table>
<thead>
<tr>
<th>Company/corporation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Street</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Number</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Postal code</th>
<th>City</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Contact person</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
</tr>
</tbody>
</table>
If more than one waste of a waste producer is to be recovered/ disposed in the same facility, they can all be included in the same “RPWM” form. For each source of waste generation you need to fill a separate „declaration of responsibility” form.

The sources of waste generation have to be consecutively enumerated in the form „Acceptance confirmation” of the waste management company – and if applicable – they must related to the corresponding confirmation of the relevant authority

This RPWM contains the following (DR) declaration(s) of responsibility numbers: DR Nr.

**For the waste producer’s** (fill for RPWM/ Collective RPWM)

<table>
<thead>
<tr>
<th>Date of receipt, confirmed by the authority</th>
</tr>
</thead>
<tbody>
<tr>
<td>☐☐☐☐☐☐☐☐☐☐</td>
</tr>
</tbody>
</table>

Documents complete

Expiration of the period pursuant Art 5(5) OWRDR\(^{106}\)

Copies of the Declaration of Responsibility and Declaration of Acceptance and Authority’s Confirmation

(if so requested by the OWRDR) were sent to the competent authority on

---

\(^{106}\) Ordinance on Waste Recovery and Disposal Records (NachwV)
## Form “Declaration of Responsibility”

### Declaration of Responsibility (DR) No.

- Consecutive No. 0001 DR ∙-
- Page 2 is included ☑

(to be filled by waste producer)

<table>
<thead>
<tr>
<th>1</th>
<th>Waste origin (do not complete in cases of collective waste management)</th>
<th>For internal remarks of authorities</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.1</td>
<td>Operational site, other permanent facility, structure, land parcel or immobile technical facility</td>
<td></td>
</tr>
</tbody>
</table>

The facility has been licensed pursuant to the Federal Immission Control Act (FICA), No. Column of the annex to the 4th FICA.

- No. of the operational site according to FICA permission

- Responsible company waste commissioner consecutive No.

| 1.3 | Street or coordinates waste producer number |
| 1.4 | Postal code City |
| 1.5 | Contact person |
| 1.6 | Telephone Telefax E-mail |
| 1.7 | The operational site where the waste originates from has been notified to the |
### Authority

<table>
<thead>
<tr>
<th>Yes</th>
<th>No</th>
</tr>
</thead>
</table>

- If yes, provide notification

No:

### 2 Waste origin (complete only in cases of collective waste management)

#### 2.1 Province/Provinces in which waste is collected

#### 2.2 Transporter number/number plate

- **Name**
- **Street or coordinates**
- **Postal code**
- **City**

- **Contact person**

- **Telefon**
- **Telefax**
- **E-mail**
• Form „Declaration Analysis“ (DA)

**Declaration Analysis**

- to the RPWM / Collective RPWM
- first issue
- change / amendment

To be filled by the waste producer in coordination with the waste disposer. Please tick X or fill out where appropriate.

- Chemical/physical treatment
- Above-ground landfill
- Other treatment
- Incineration
- Under-ground landfill
- Recovery/recycling operations

To be determined are those parameters, that are relevant with regard to the waste type and the envisaged recovery or disposal operation. Where necessary parameters have to be agreed between waste producer and waste disposer.

<table>
<thead>
<tr>
<th>Ref-to No.</th>
<th>(No. to be filled by competent authority)</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Unit</th>
<th>Parameter</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arsenic</td>
<td>mg/l</td>
<td>TOC</td>
<td>mg/l</td>
</tr>
<tr>
<td>Lead</td>
<td>mg/l</td>
<td>AOX</td>
<td>mg/l</td>
</tr>
<tr>
<td>Cadmium</td>
<td>mg/l</td>
<td>EOX</td>
<td>mg/l</td>
</tr>
<tr>
<td>Chrome-VI</td>
<td>mg/l</td>
<td>pH-value</td>
<td></td>
</tr>
<tr>
<td>Copper</td>
<td>mg/l</td>
<td>Conductivity</td>
<td>μS/cm</td>
</tr>
<tr>
<td>Nickel</td>
<td>mg/l</td>
<td>Lipophilic substances of low volatility</td>
<td>mg/l</td>
</tr>
<tr>
<td>Mercury</td>
<td>mg/l</td>
<td>Extractable portion of the original substance</td>
<td>% by Weight</td>
</tr>
<tr>
<td>Zinc</td>
<td>mg/l</td>
<td>Extractable lipophilic substances</td>
<td>% by</td>
</tr>
</tbody>
</table>

1. Arsenic
2. Lead
3. Cadmium
4. Chrome-VI
5. Copper
6. Nickel
7. Mercury
8. Zinc
<table>
<thead>
<tr>
<th>No.</th>
<th>Substance</th>
<th>Unit</th>
<th>No.</th>
<th>Property</th>
</tr>
</thead>
<tbody>
<tr>
<td>9</td>
<td>Fluoride</td>
<td>mg/l</td>
<td>29.</td>
<td>Ignition loss dry</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>% by Weight</td>
</tr>
<tr>
<td>10</td>
<td>Chloride</td>
<td>mg/l</td>
<td>30.</td>
<td>Water-soluble component</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>% by Weight</td>
</tr>
<tr>
<td>11</td>
<td>Cyanide</td>
<td>mg/l</td>
<td>31.</td>
<td>Water content</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>%</td>
</tr>
<tr>
<td>12</td>
<td>Ammonium</td>
<td>mg/l</td>
<td>32.</td>
<td>Vane shear strength</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>kN/m²</td>
</tr>
<tr>
<td>13</td>
<td>Sulfate</td>
<td>mg/l</td>
<td>33.</td>
<td>Axial deformation</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>%</td>
</tr>
<tr>
<td>14</td>
<td>Nitrite</td>
<td>mg/l</td>
<td>34.</td>
<td>Uniaxial compressive strength</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>kN/m²</td>
</tr>
<tr>
<td>15</td>
<td>Phenols</td>
<td>mg/l</td>
<td>35.</td>
<td>Melting point</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>°C</td>
</tr>
<tr>
<td>16</td>
<td>Fluor</td>
<td>% by Weight</td>
<td>36.</td>
<td>Flash point</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>°C</td>
</tr>
<tr>
<td>17</td>
<td>Chlorine</td>
<td>% by Weight</td>
<td>37.</td>
<td>Boiling point</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>°C</td>
</tr>
<tr>
<td>18</td>
<td>Bromine</td>
<td>% by Weight</td>
<td>38.</td>
<td>Gross calorific value</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>kJ/kg</td>
</tr>
<tr>
<td>19</td>
<td>Iodine</td>
<td>% by Weight</td>
<td>39.</td>
<td>Vapor pressure at 30°C</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>hPa</td>
</tr>
<tr>
<td>20</td>
<td>Sulphur</td>
<td>% by Weight</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
40. Gas formation due to after-reactions

40.1 In the package

40.2.1 In contact with air

40.3 In contact with the rock salt

40.4 At temperatures starting from °C

41. Information about hazardous components 1)

41.1 of wastes

41.2 of products of decomposition

<table>
<thead>
<tr>
<th>Other parameters 1)</th>
<th>Value</th>
<th>Dimension</th>
<th>Other parameter 1)</th>
<th>Value</th>
<th>Dimension</th>
</tr>
</thead>
<tbody>
<tr>
<td>42.</td>
<td></td>
<td></td>
<td>47.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>43.</td>
<td></td>
<td></td>
<td>48.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>44.</td>
<td></td>
<td></td>
<td>49.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>45.</td>
<td></td>
<td></td>
<td>50.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>46.</td>
<td></td>
<td></td>
<td>51.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

52. Other information
### Form „Declaration of Acceptance“

<table>
<thead>
<tr>
<th>Declaration of Acceptance</th>
<th>No.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(No. to be filled by competent authority)</td>
</tr>
<tr>
<td></td>
<td>Consecutive No. 0001 DA 1)</td>
</tr>
<tr>
<td></td>
<td>Page 2 is included ☒</td>
</tr>
</tbody>
</table>

(to be filled by the waste management company)

<table>
<thead>
<tr>
<th>1 Information about the waste management company</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1.1 Company/corporation</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>1.2 Street</td>
<td></td>
</tr>
<tr>
<td>Number</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>1.3 Postal code</td>
<td>City</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>2 Waste Management Facility</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>2.1 Disposal procedure</td>
<td>☐ Recovery ☐ or Disposal ☐</td>
</tr>
<tr>
<td>2.2 Self-disposal within the premises of the waste producer</td>
<td>☐ if</td>
</tr>
<tr>
<td>2.3</td>
<td>Designation of the waste management facility</td>
</tr>
<tr>
<td>-----</td>
<td>---------------------------------------------</td>
</tr>
<tr>
<td>2.4</td>
<td>Street</td>
</tr>
<tr>
<td>2.5</td>
<td>Country 🏙 Postal Code City</td>
</tr>
<tr>
<td>2.6</td>
<td>Contact person</td>
</tr>
<tr>
<td>2.7</td>
<td>Telephone Telefax E-mail</td>
</tr>
<tr>
<td>2.8</td>
<td>The facility has been exempted pursuant to article 7 ORWDR</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

If yes, Exemption number

Listing and description of wastes according to type, consistency and quantity for applications according to § 13 ORWDR on separate sheet.
6.3. Case Study: The ‘Solid Waste Management Information System’ (SWMIS) of Zhejiang, China

6.3.1. Background

Hazardous waste management and its monitoring is a crucial issue in the global perspective. More and more countries have started using information systems to manage and monitor the HW shipment by making use of electronic information transfer.

In China huge amounts of hazardous waste are generated every year due to fast economic growth and increasing industrial production. In Zhejiang, one of China’s most developed provinces (see Fig. 42), hazardous waste generation from registered enterprises reached 440,400 tons in 2006, according to official figures. In order to strengthen the enforcement of national HW related regulation and to streamline the approval procedures and control functions of hazardous waste shipment, the ‘Zhejiang Solid Waste Management and Supervision Centre’ in collaboration with the Sino-German Cooperation Program, ‘Environment-oriented Enterprise Consultancy Zhejiang’ (EECZ), developed the ‘Solid Waste Management Information System’ (SWMIS) to enable the electronic processing and standardization of the Chinese “Hazardous Waste Transfer Plan and Manifest Regulation”. This regulation is the Chinese analogue to the German “Ordinance on Waste Recovery and Disposal Records”. The SWMIS supports all Zhejiang-based ‘Environmental Protection Bureaus’ (EPB’s) to monitor and control hazardous waste.

Fig. 42: Zhejiang Province in China and its eleven city districts
6.3.2. Features of the ‘Solid Waste Management Information System’

The ‘Solid Waste Management Information System’ is unique in its design and the first of its kind in China. The system:

- Provides system access to 103 EPB departments dealing with hazardous waste in Zhejiang at the provincial, city and county level as well as to 57 licensed operators of hazardous waste recovery and disposal facilities
- Enables electronic implementation of China’s core regulation for hazardous waste disposal and utilization through the “Hazardous Waste Transfer Plan and Manifest Regulation”
- Requires operators to enter hazardous waste related data into the system on behalf of approx. 3,000 registered hazardous waste producers
- Provides records of all relevant documentation in editable electronic formats
- Links data entered and performs plausibility checks, creates reports and generates statistical data for the competent authorities
- Is internet-based, and does not require users to install special software

The SWMIS was jointly developed by the ‘Zhejiang Solid Waste Management and Supervision Center’ (ZSWMSC), local IT experts and the consulting agency ERM GmbH subcontracted for implementing the HWM component of the Sino-German EECZ Program. The development of the SWMIS was delayed due to amendments of China’s national hazardous waste legislation and lasted from April 2004 to December 2007.

6.3.3. How does it work?

The Solid Waste Management Information System is composed of a Regulatory Module which feeds into Control and Statistical Functions.

The regulatory module processes data to enable the electronic management of (i) licenses for hazardous waste recovery and disposal facilities, of (ii) transfer plans and of (iii) manifests.

**Licenses**

Operational licenses are issued to operators of hazardous waste recovery and disposal facilities. Licenses specify hazardous waste types and maximum quantities that operators are permitted to accept per calendar year.

**Transfer Plan**

The Transfer Plan is the Chinese analogue to the German “Record of Proper Waste Management”. Prior to sending hazardous waste to an external recovery or disposal facility, the waste producer has to submit a
“Transfer Plan” application to his competent authority in order to get the approval for the intended waste management procedure of the waste type under consideration.\textsuperscript{107}

In contrast to the standard paper-based application procedure, operators of recovery or disposal facilities enter the transfer plan data into the SWMIS on behalf of the hazardous waste producers who do not have access to the system. All data from waste producers, waste transporters and waste receiving units is entered into the system. The transfer plan is then submitted to the competent authority of the waste producer for approval or denial. The transfer plan enables the editing of all relevant documents in EXCEL format for the convenience of the competent authorities, operators and waste producers. Fig. 43 shows the information flow between the relevant stakeholders during transfer plan application. It should be noted that for legal purpose the paper-based application procedure has yet to be retained in parallel because exclusive electronic implementation of the procedure requires recognition of the electronic signature which is obligatory in China.

For developing the electronic management function of the transfer plan, principal similarity between the regulations on hazardous waste transfer and manifest in both countries, China and Germany, was conducive, because it enabled adoption of proven and tested features from the German system, such as the separate legal statements to be made by waste producers and operators, including the “Declaration of Responsibility” of the waste producer and the “Declaration of Acceptance” of the operator (see chapter 7.2.1). The ‘Zhejiang ‘Environmental Protection Bureau’ decided to integrate these formats also into the paper-based application procedure.

Manifest

The Hazardous Waste Manifest, also known as “consignment note procedure”, is a tool for tracking the shipment of hazardous waste while it is transferred from a waste producer to a disposal or recovery facility. The Manifest is completed after the waste has arrived at its destination. Operators then enter the manifest data (= information on waste producer,

\textsuperscript{107} This is in contrast to the German “Record of Proper Waste Management” procedure where the application is approved by the authority responsible for the waste recovery or disposal facility.
carrier, waste type and quantity) into the ‘Solid Waste Management Information System’.

Control and Statistical Functions

The control function connects license data, transfer plan data and manifest data and performs plausibility checks. The statistical function is based on the transfer plan data and manifest data and generates statistics, tables and figures, using parameters such as industrial sectors, locations, time periods, waste codes, enterprise details, types of utilization and disposal, and types of shipments (inter-county, inter-city, inter-province).
Fig. 43: Information flow between stakeholders during transfer plan application in Zhejiang, China. Paper based communication can be abandoned once the electronic signature has gained legal recognition.
Table 13 shows the stakeholders and their access to functions of the SWMIS. EPB staff and operators were given special training on how to use the system.

Table 13: User groups and their access to system functions of the ‘Solid Waste Management Information System’

<table>
<thead>
<tr>
<th>User Groups</th>
<th>Regulatory Functions</th>
<th>Control and Statistical Functions</th>
<th>Access to General Information</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>License Management</td>
<td>Transfer Plan Management</td>
<td></td>
</tr>
<tr>
<td>Environmental Authorities</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Waste Producers</td>
<td>( ✓ ) Read only</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Operators</td>
<td>( ✓ ) Read only</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Transporters</td>
<td>( ✓ ) Read only</td>
<td>( ✓ ) Read only</td>
<td>✓</td>
</tr>
<tr>
<td>The Public</td>
<td>( ✓ ) Read only</td>
<td></td>
<td>✓</td>
</tr>
</tbody>
</table>
6.3.4. Benefits

Usage of the SWMIS is beneficial for stakeholders engaged in HWM.

- For the competent authorities:
  - Improved work efficiency, reduction of admin workload
  - Instant communication between the different competent authorities involved in hazardous waste shipment supervision, reducing the duration of transfer plan approval
  - Availability of all hazardous waste-related data for internal reporting, planning tasks and statistics in electronic formats

- For operators and hazardous waste producers:
  - Quicker decision of the competent authority with regard to approval or denial of the intended waste transport, compared to slow paper-based communication
  - Availability of relevant documentation related to HW recovery and disposal in electronic formats, useful for developing internal management and monitoring systems. The system features editing all relevant documents in MS EXCEL format which allows straightforward information exchange between operators and waste producers outside of the SWMIS.
  - Capacity to integrate data and electronic reports generated by the SWMIS into business software, e.g. for accounting (operators)

6.3.5. Status

Operation of the Information System began on 1 January 2008. By the end of August 2008, 1,510 transfer plans and 2,921 manifests had been processed. Meanwhile, the system has been adjusted to the new Chinese hazardous waste catalogue notified by the Central Government in August 2008. The results and experiences made in Zhejiang are presently being used for the development of a Solid Waste Management Information System at the national level.
6.3.6. Challenges and Lessons Learned

- Development of an information system should be initiated only after implementation of HWM legislation. Otherwise changes of the regulatory framework will cause delays by requiring extra efforts for re-adjusting the information system.

- System development has to be well documented to enable modifications to be made at a later stage or in case key software developers resign.

- Host organizations should be aware that information systems cause expenses also after completion of the system development due to servicing and maintenance.

- ‘Solid Waste Management Information Systems’ are only as good as the quality of the data entered. Results of the EECZ-Program’s On-site Waste Investigation Campaign have shown that hazardous waste identification and declaration by waste producers is highly erratic and causes underestimation of hazardous waste generation and shipment. The competent authorities may use the time saved due to SWMIS support for training hazardous waste producers on classification and quantification of HW and for improved HWM.

6.4. Monitoring and Control of On-Site Hazardous Waste Management

The previous sections focus on monitoring of external or off-site management of hazardous waste. In the European Union and other high income countries hazardous waste is generally sent to specialize waste management facilities operated by external service providers; this under the premise that an adequate waste management infrastructure must be available including proper collection systems and safe treatment facilities such as incinerators, chemical physical treatment plants and landfill sites (See chapters 8 and 10).

In low and middle income countries where such infrastructure is often not yet available many hazardous waste producers resort unfortunately to other solutions. Indiscriminate practices have been observed such as dumping hazardous waste along roadsides or in low lying areas, discharging liquid wastes together with wastewater to the sewerage system or selling waste with residual value to downstream users without considering adverse effects on human health, in particular on workers and the environment.

On the other hand, there are many initiatives that aim at recovering thermal or material value from hazardous waste or disposing non-recoverable waste within the company’s premises, including measures such as:

- Combusting solid hazardous waste in the company’s boiler as a secondary fuel (e.g. distillation residues) or in small-scale incinerators
- Treating toxic aqueous waste in the own wastewater treatment plant (e.g. cyanide containing liquids from plating baths)

- Disposing solid hazardous waste on self-designed and -constructed landfill sites

It should be clear however that many of these methods imply negative impacts for the environment and in relation to occupational health and safety. Combustion of hazardous waste in boilers or small-scale incinerators may create severe air pollution. Disposal in self-designed landfill sites without expertise and consideration of the hydro-geological situation may pose long-term threats to groundwater resources (see Fig. 45). Competent authorities are sometimes not aware of such practices or even keep a blind eye as they are not in a position to provide better solutions for the time being.

Fig. 45: Poorly managed hazardous waste landfill site belonging to a refinery in Asia. Backing-up of leachate causes hydraulic pressure on the liner and enhances risks of groundwater pollution. See problems associated with pit design in section 11.5

As a general rule, on-site treatment of hazardous waste should always be subject to a licensed procedure and environmentally sound HWM. Applicants should be required to certify necessary documentation including ‘Standard Operation Procedures’ (SOP’s) and safety instructions with regard to management of dangerous substances etc.
Within the framework of a license, chemical-physical batch treatment of liquid inorganic waste is usually feasible on-site (legislators consider such residues sometimes as wastewater rather than liquid hazardous waste). Applications for thermal treatment and landfill disposal have to be scrutinized strictly and decided on case by case. License holders should be obliged to conduct self-monitoring, on top of the monitoring required by the competent authority.

More promising than resorting to on-site incineration and on-site landfill disposal could be joining hands with other industries and forming an association for developing and operating centralized facilities. The association should request the competent authorities to come forward with a master plan for the region’s hazardous waste disposal infrastructure and to arrange for government funding in order to share the financial burden.
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• **Module 4**

• *Allocation of hazardous waste to treatment and disposal facilities*

• *Generalities about Chemical Physical Biological Treatment (CPT) facilities*
Allocation of Hazardous Waste to Recovery and Disposal Options

According to the chemical and physical properties of the waste, the environmentally most friendly waste management option should be chosen according to the waste five-step hierarchy as set out by EU legislation (Waste Framework Directive 2008/98/EC).

5 step waste hierarchy

Life-cycle thinking is an additional new aspect to be considered in order to apply the waste management option with the minimum negative effect on the environment.

Waste management is an area where local conditions often influence the choice of policy options.

Typical questions that can arise in local or regional settings include:

- Is it better to recycle waste or to recover energy from it?
- What are the trade-offs for particular waste streams?
- Is it better to replace appliances with new, more energy efficient models or keep using the old ones and avoid generating waste?
- Are the greenhouse gas emissions created when collecting waste justified by the expected benefits?

The following figure shows the systematic approach of EU waste management, including examples of operations critical to classify.
European waste policy aims to reduce the negative environmental impacts of waste generation and management, and to contribute to an overall reduction of the environmental impact of the use of resources. The evaluation of environmental impacts of different waste management options can be a complex task because:

- Benefits and burdens can occur at different stages of the life cycle (e.g. waste prevention in the production stage or recycling of used products)
- Benefits and burdens can occur in different geographic regions and over a long time scale (e.g. emissions from landfills)
- Benefits and burdens can occur in very different forms (e.g. in the form of credit for recovered energy)
- Benefits and burdens can be difficult to identify, quantify and compare

It is therefore important to define information and data, in consultation with key stakeholders and supporting guidance documents. This information can then be used to make Life Cycle Thinking easy to use in waste management decision-making from local to European level, with an agreed approach and methodology.

Further for identifying the adequate treatment option wastes may require testing of their chemical and physical properties. In the European Union, waste types that recovery and disposal facilities are permitted to accept, have to be laid down in their operational licenses. (see details in modules 5, 6 and 7 and supplement to module 4). This is to ensure that accepted wastes correspond to the treatment method and to the pollution control devices of those facilities.
7.1. **Allocation Criteria**

According to the waste management hierarchy, waste prevention (including reuse) and waste recovery are the preferred options in comparison to disposal. Recovery can be differentiated into recycling (material recovery), energy recovery and other waste treatment options. Recycling makes use of the material value embedded in waste whereas energy recovery utilizes the calorific value. When selecting between material- and energy recovery for a given waste type (provided both options are possible), priority should be given to the option that has less negative environmental impacts.

In the supplement to module 4 a more detailed allocation to the different EWL codes is presented.

7.1.1. **Recycling**

Recycling is a form of recovery. Under the WFD, the definition of ‘recycling’ is “any recovery operation by which waste materials are reprocessed into products, materials or substances whether for the original or other purposes. It includes the reprocessing of organic material but does not include energy recovery and the reprocessing into materials that are to be used as fuels or for backfilling operations”. Thus, specific waste management activities that are classed as recycling under the WFD include (but are not limited to) material recycling such as plastic products or components into plastic feedstock materials; glass into glass cullet; glass for building aggregate; paper into recycled paper; paper into tissue products; etc.

Recycling means that a waste changed into a product again by means of recovery procedures. It differs from other recovery operations, which result merely in a change in the nature or composition of the waste. Recycling is different to other forms of recovery in that it results in the substance in question ceasing to be waste when it is transformed.

It follows from the WFD recycling definition, that only the reprocessing of waste into products, materials or substances can be accepted as recycling.

7.1.2. **Other recovery - Energy recovery/use as a fuel**

The principal purpose of energy recovery is to make use of the energy value embedded in the waste. Liquid, slurry and solid wastes with sufficient calorific value such as spent lube oil, solvents, tank bottom sludge, solid and semi-solid grease, wax, organic distillation residues, waste wood and saw dust, waste paper & plastic packaging material, etc. can be used as a
substitute- or alternative fuel for all industrial processes that require thermal energy input. During the combustion process organic pollutants contained in the material are degraded by oxidation. Alternative fuels made from waste may replace a certain portion of the regular fuel used (co-incineration).

According to current German regulation energy recovery from waste is permissible when the calorific value is $\geq 11,000 \text{ kJ/kg}$ (prior to blending with other materials) while the combustion efficiency of the combustion furnace in which energy recovery takes place must not be less than 75% $^{108}$.

7.1.3. Other recovery - back filling

Backfilling can be understood as the use of materials to refill excavated areas (such as underground mines, gravel pits) for the purpose of slope reclamation or safety or as filling in landscaping or on landfill. In Germany material used for back filling has to comply with contamination limits which are related to, but stricter than limits applied as acceptance criteria for landfill.

7.1.4. Chemical/physical and biological treatment (CPT)

CPT is of high relevance for the treatment of liquid and slurry hazardous wastes. CPT of waste includes the following types of plants:

For hazardous waste:

- Chemical physical treatment plants for liquid and semisolid hazardous waste
- Biological treatment plants for contaminated soils

To enable mass transfer in a chemical/physical treatment plant, waste must be pumpable. In general, waste that neither meets the strength- nor the eluate criteria of Table 22 needs chemical/physical treatment, or, in other terms, stabilization in addition to solidification. Particularly inorganic liquid and slurry hazardous wastes require chemical/physical treatment. The solids resulting from the treatment are filter cakes that can be disposed on landfill sites.

Also liquid and slurry aqueous wastes with an emulsified or separate organic phase require chemical/physical treatment. A typical example is cutting oil emulsions with an oil content of $< 10\%$. Another prominent waste type generated in huge quantities across many sectors is content of oil interceptors. The organic phase isolated by the treatment can be utilized for energy recovery or has to be incinerated. See more details on CPT in chapter 9.

$^{108}$ Act for Promoting Closed Substance Cycle Waste Management and Ensuring Environmentally Compatible Waste Disposal (KrW-/AbfG), Article 6; Germany 1994 [http://www.gesetze-im-internet.de/krw_abfg/BJNR270510994.html](http://www.gesetze-im-internet.de/krw_abfg/BJNR270510994.html) (Please note that a recent review proposal does not contain these provisions anymore)
Bioremediation\textsuperscript{109} is defined as use of biological processes to degrade, break down, transform, and/or essentially remove contaminants or impairments of quality from soil and water. Bioremediation is a natural process which relies on bacteria, fungi, and plants to alter contaminants as these organisms carry out their normal life functions. Metabolic processes of these organisms are capable of using chemical contaminants as an energy source, rendering the contaminants harmless or less toxic products in most cases.

7.1.5. Landfill disposal

Important assignment criteria for landfill disposal are low organic content and sufficient strength (in other words the threshold value for ignition loss is \( \leq 10\% \), and threshold value for vane shear strength is \( \geq 25 \text{ kN/m}^2 \), according to German regulation). A threshold value for ignition loss of \( \leq 10\% \) is very rigid as enforced in Germany for hazardous waste landfill disposal. Enforcement may require allocation of waste types hitherto disposed on landfill sites to thermal pre-treatment by incineration. Implementation of this regime needs therefore a transition period of sufficient length in order to provide time for stakeholders to adjust. A staged implementation is recommended with more lenient values enforced at the beginning.

Wastes that meet all the criteria of Table 22 (in chapter 11) can be directly disposed on a landfill site. (see module 7)

7.1.5.1. Solidification

Wastes that meet all the threshold values of Table 22 except the strength criteria require solidification with appropriate agents such as lime, fly ash or cement. Afterwards it can be disposed in a landfill.

7.1.6. Incineration

Solid or slurry waste with an organic content too high for landfill disposal is a case for incineration (ignition loss \( \geq 10\% \), according to German regulation). Also liquid organic wastes that cannot be used as alternative fuels due to high contamination levels require incineration. Liquid aqueous waste with high dissolved organic content may be incinerated unless appropriate waste water treatment or chemical/physical treatment is feasible. (see module 6)

7.1.7. Underground disposal (High-safety above-ground disposal)

Solid waste with water soluble content \( \geq 10\% \), or special solid waste containing cyanide, mercury and arsenic should be disposed in an underground disposal site. In case such a facility is not available, the barrier function of dedicated cells in an above-ground landfill site

\textsuperscript{109} http://waterquality.montana.edu/docs/methane/Donlan.shtml
has to be enforced accordingly e.g. by cement concrete structures and additional lining. Water access to such cells must be excluded under all circumstances. Waste should also be packed and sealed in drums. These cells require permanent supervision.

7.2. Regulating Hazardous Waste Acceptance in the Licenses of the Facilities

According to EU legislation HW shall be only send to recovery and disposal facility licensed for HW in order to protect the environment and human health.

7.2.1. Application of Positive and Negative Lists for Facility Licensing

7.2.1.1. Negative lists

Negative lists designate waste types that operators of hazardous waste recovery or disposal facilities shall not accept. On landfill sites waste that is liquid, explosive, corrosive, oxidizing, flammable or infectious must not be accepted. (In the EU this is regulated in specific legislation on landfill of waste Directive 1999/31/EC) For underground disposal facilities negative acceptance criteria are given in Table 25 in chapter 12. At centralized hazardous waste incinerators waste that is radioactive, explosive or infectious must not be accepted (acceptance of infectious waste is only permitted if special devices such as sluices are installed in the bunker area for avoiding spread of germs).

Negative lists can be also more specific and designate specific waste types that are not permitted for acceptance. For example EU waste legislation sets out that used tires must not be accepted for landfill disposal.

7.2.1.2. Positive lists

Positive lists should designate waste types that can be accepted at a facility. Therefore, they should be more restrictive than negative lists. Positive lists are usually based on a national or international hazardous waste catalogue. On European scale positive lists are stipulated in the Waste Acceptance Criteria Decision (2003/33/EC) for inert waste. Individual positive lists can be included in facility permits.

An example of a positive list is shown in table 16 that presents an excerpt of a site specific ‘waste acceptance catalogue’ of a German HW facility consisting of a chemical/physical treatment plant and a HW incinerator. The catalogue lists selected waste codes acceptable at this facility according to its permit. In addition, the treatment type is specified.

Waste acceptance lists/catalogues are an important management tool of competent authorities for waste stream control. Acceptance catalogues are also helpful for waste producers during pre-screening of adequate recovery or disposal facilities that can treat the wastes they are generating. After having found an operator that can treat his waste, both
parties may conclude a disposal contract and prepare the ‘record of proper waste management’ (see chapter 6).

Positive lists may be also very specific and designate single waste streams of individual waste producers. This is useful for example in case of permits for trial operation before a permanent license is granted (e.g. co-processing).

Some links for positive and negative lists from Germany are given below:\textsuperscript{110}

Table 14: Excerpt of a positive list (waste acceptance catalogue) of a HW disposal facility (chemical/physical treatment (first raw:CPT) and HW incineration (second raw:HWI), \(x\) = permitted for acceptance)

<table>
<thead>
<tr>
<th>CPT</th>
<th>HWI</th>
<th>EWL Code</th>
<th>Waste Categories, Waste Names</th>
</tr>
</thead>
<tbody>
<tr>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td>11 01</td>
<td></td>
<td></td>
<td>Wastes from chemical surface treatment and coating of metals and other materials (for example galvanic processes, zinc coating processes, pickling processes, etching, phosphating, alkaline degreasing, anodising)</td>
</tr>
<tr>
<td>x</td>
<td>11 01 05*</td>
<td></td>
<td>pickling acids</td>
</tr>
<tr>
<td>x</td>
<td>11 01 06*</td>
<td></td>
<td>acids not otherwise specified</td>
</tr>
<tr>
<td>x</td>
<td>11 01 07*</td>
<td></td>
<td>pickling bases</td>
</tr>
<tr>
<td>x</td>
<td>11 01 08*</td>
<td></td>
<td>phosphatising sludges</td>
</tr>
<tr>
<td>x</td>
<td>11 01 09*</td>
<td></td>
<td>sludges and filter cakes containing dangerous substances</td>
</tr>
<tr>
<td>x</td>
<td>11 01 10</td>
<td></td>
<td>sludges and filter cakes other than those mentioned in 11 01 09</td>
</tr>
<tr>
<td>x</td>
<td>11 01 11*</td>
<td></td>
<td>aqueous rinsing liquids containing dangerous substances</td>
</tr>
<tr>
<td>x</td>
<td>11 01 12</td>
<td></td>
<td>aqueous rinsing liquids other than those mentioned in 11 01 11</td>
</tr>
<tr>
<td>x</td>
<td>11 01 13*</td>
<td></td>
<td>degreasing wastes containing dangerous substances</td>
</tr>
<tr>
<td>x</td>
<td>11 01 14</td>
<td></td>
<td>degreasing wastes other than those mentioned in 11 01 13</td>
</tr>
<tr>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td>12 01</td>
<td></td>
<td></td>
<td>wastes from shaping and physical and mechanical surface treatment of metals and plastics</td>
</tr>
<tr>
<td>x</td>
<td>12 01 06*</td>
<td></td>
<td>mineral-based machining oils containing halogens (except emulsions and solutions)</td>
</tr>
<tr>
<td>x</td>
<td>12 01 07*</td>
<td></td>
<td>mineral-based machining oils free of halogens (except emulsions and solutions)</td>
</tr>
<tr>
<td>x</td>
<td>12 01 08*</td>
<td></td>
<td>machining emulsions and solutions containing halogens</td>
</tr>
</tbody>
</table>

\textsuperscript{110} Some examples of Positive lists:
http://www.dbv-velbert.de/resources/Positivliste+IS+Stand+30+11+05.pdf

Negative lists:
http://www.dbv-velbert.de/Resources/kli_dateien/landkreis/landkreis_dokumente/Abfallentsorgungssatzung_2007_Anhangen2.3.pdf
7.2.2. Prescription of Specific Limit Values for Waste Acceptance

There are several reasons for imposing limit values for waste acceptance at hazardous waste recovery and disposal facilities:

- Protection of the environment (= environmentally viable allocation of waste streams to disposal options)
- Protection of occupational health and safety
- Quality requirements of the product
- Requirements related to the process

Limit values for the last two issues are determined in most cases by operators or are defined by product quality standards unless regulated otherwise.

7.2.2.1. Limit Values Related to Environmental Protection

In addition to negative and positive lists specific limit values for pollutants contained in waste should be used as acceptance criteria.

An example for a limit list for landfill disposal is shown in Table 22. Most of the limit values focus on groundwater protection. Wastes that do not comply with these criteria need either chemical/physical treatment, stabilization, solidification or have to be foreseen for other disposal options such as incineration or underground disposal.

Limit values for chemical/physical treatment refer usually to the secondary wastes/residues generated by the treatment. Chemical/physical treatability is tested by performing the envisaged treatment at a lab scale on a sample of the respective waste. When the resulting filter cake meets the criteria for landfill disposal and the resulting aqueous phase meets the wastewater discharge standards, the waste is considered treatable.

Thermal treatment plants are usually obliged by license conditions to control input of pollutants that may cause air pollution. This is in order to enable adequate feed of waste into
the rotary kiln and to avoid emissions and the overload of the Air Pollution control (APC) system. Concentration of the following parameters should be checked:

- nitrogen,
- sulphur,
- halogens,
- halogenated organics,
- arsenic,
- antimony,
- heavy metals
- mercury,
- cadmium
- thallium.

Heavy metals in general should be measured and in particular volatile heavy metals of which mercury, cadmium and thallium are already listed above.

According to EU legislation on waste incineration, waste that contains ≥ 1% w/w halogenated organics has to be incinerated in high temperature incineration above 1100 °C (Article 6 of Directive 2000/76/EC).

Designated limit values for hazardous waste co-processing in cement kilns should be also set. Switzerland has notified a positive list of alternative fuels and raw materials that are permitted to be used for cement kiln co-processing (this list is based on the Swiss waste catalogue [http://www.bafu.admin.ch/suchen/index.html?lang=de&keywords=Abfallverzeichnis&search_mode=OR&from_day=&from_month=&from_year=&to_day=&to_month=&to_year=&site_mode=intern&nsb_mode=yes#volltextsuche]). The list specifies additionally limit values for relevant pollutants.\(^{111}\)

For limit values of underground disposal, refer to Table 25

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\(^{112}\) European Agency for Safety and Health at Work ([http://osha.europa.eu](http://osha.europa.eu))
Additionally the Waste Framework Directive 2008/98/EC of 19 November 2008 lays down the principles of waste management. This document emphasizes that the protection of the environment and human health against harmful effects caused by the collection, transport, treatment, storage and tipping (final disposal) of waste should be the overall objective of any waste management activity.

7.2.2.2. Limit Values Related to Protection of Occupational Health and Safety

Competent authorities may impose limit values on pollutants contained in waste also in order to ensure protection of occupational health and safety in hazardous waste treatment facilities. For example, when measures for fire protection in the bunker area or in the tank battery of an incinerator are insufficient, there may be flashpoint limitations for wastes to be accepted.

When batch reactors of chemical/physical treatment plants are not encapsulated and equipped with suction fans and off gas treatment, toxic gases such as nitrous oxides or ammonia may be released to the workplace atmosphere from reactions like acid cleavage of emulsions or precipitation of heavy metals. As a proactive measure for protecting workers health, competent authorities may impose concentration limits on respective pollutants contained in the waste.

Of course, application of such threshold limitations makes only sense in regions where sufficient alternative facilities are available. This approach, using limits for achieving better occupational health and safety conditions, has been used e.g. in the German State North-Rhine Westphalia where the hazardous waste management infrastructure is largely organized by private operators who would experience such limitations as economical loss unless they upgrade their installations.

7.2.3. Licensing and Ensuring Compliance with License Conditions

As discussed above competent national authorities usually specify waste types that hazardous waste recovery and disposal facilities are licensed to accept by means of negative and positive lists as well as by suitable limit- or control values. These acceptance criteria should be part of the facilities’ operational licenses.

Furthermore, conditions that oblige operators to establish and to record compliance with the national acceptance criteria via self-monitoring should be laid down in the license. Operators
should have to document all types and quantities of wastes accepted. It should be mandatory to document compliance with the national acceptance criteria. From each consignment accepted a sample should be taken as a reference. This sample should be kept for a period of time determined by the competent authority considering the HW class/type of waste (see also section 11.3.4., “on-site verification”).

Competent authorities should realize random visits to the operators located in their administrative area and check the operator’s documentation.

7.3. Chemical Analysis of Hazardous Waste

Sampling and testing for basic characterization and compliance testing shall be carried out by independent and qualified persons and institutions. Laboratories shall have proven experience in waste testing and analysis and an efficient quality assurance system.

Analysis methods should namely be able to detect heavy metals, salts, and organic pollutants. Tests used for chemical analysis of hazardous waste shall follow standardized methods, whenever possible in order to assure sufficient reliability of results.

In the European Union such standards are established for a number of wastes and substances.

As long as a CEN standard is not available as formal EN, Member States will use either national standards or procedures or the draft CEN standard, when it has reached the prEN stage.

Available CEN standards can be found at: http://esearch.cen.eu/ (ICS code 13.030.-)

7.3.1. Sampling

The objective of waste sampling is the extraction of a subset representative for the entire batch of the waste material from where the sample is taken. Waste sampling should follow specific indications as under certain circumstances it is not as easy as that to take a representative sample. For example it can be a challenge to sample waste if the waste material is solid and inhomogeneous regarding the distribution of components, particularly in combination with a high variation in particle size.

Moreover sampling should consider whether samples are taken from drums, containers, tanker trucks or waste piles.

Liquid wastes are usually homogeneous and do not pose a problem with regard to sampling. Slurries or wastes with several phases have to be temporarily homogenized by stirring before a sample is taken.
In order to ensure representative sampling from heterogeneous solid waste materials, several single samples have to be taken and united to composite samples for subsequent analysis. Number and volume of single and composite samples is subject to the quantity and volume of the waste batch to be sampled, to the expected extent of heterogeneity, to the particle size of the material.

For proper waste sampling the following points should be taken into consideration:

- Objective of the sampling
- Origin of the respective waste
- Expected types of pollutants
- Extent of heterogeneity
- Parameters to be determined

For on-site sampling, a sampling plan has to be elaborated that should consider issues such as:

- Local conditions (samples to be taken from drums, piles, moving waste streams etc.)
- Quantity/volume of the waste batch to be sampled
- Heterogeneity of the waste batch
- Lumpiness or particle size of the waste material (solid waste)
- Sampling procedure
- Determination of the minimum number of single and composite samples to be taken
- Determination of the minimum volume of single samples to be taken

Each waste batch should be sampled individually. Sampling of waste should be conducted only by qualified persons and if possible by an independent laboratory. For more detailed information about sampling special literature may be referred to. 113, 114, 115

7.3.2. Objective and Methods of Testing

A basic characterization of the waste should include information of the following parameters:

- consistency and composition
- hazardous properties, for example as listed in Annex III to Waste Framework Directive 2008/98/EC

113 Laenderarbeitsgemeinschaft Abfall: “LAGA PN 98. Richtlinien für das Vorgehen bei physikalischen, chemischen und biologischen Untersuchungen im Zusammenhang mit der Verwertung/Beseitigung von Abfällen”; Mainz, Germany; 2004 (German version only) http://www.google.de/url?q=http://www.laga-online.de/servlet/is/23874/M32_LAGA_PN98.pdf%3Fcommand%3DdownloadContent%26filename%3DM32_LAGA_PN98.pdf&sa=U&ei=KKOT7GGLMLChAfQKniCg&ved=0CBQQFjAA&usg=AFQjCNFRpVz5zwELij3Wzivo1CyyvPZhQ
115 European Commission: “Reference Document on Best Available Techniques for the Waste Treatment Industries” Chapter 4.1.1.4 “Sampling” Sevilla, Spain, 2005
• presence or absence of R-phrases/hazard statements according to Regulation (EC) No 1272/2008 (CLP)
• appearance, color
• odor
• combustion properties under normal condition
• eluate behavior
• reactions with water and other substances

One objective of a chemical analysis is to make sure that the hazardous waste is generally appropriate for the particular treatment option. The analysis should be carried out on a representative sample with standardized methods. Often a waste producer has a production process which is not changed in its process (using same machines, same chronological order etc.) and the same input materials are used (raw materials, materials used during the production process). Therefore, the results of the chemical analysis and the basic characterization can be valid for a longer period of time (also years) and as long as the production process and input materials are not changed. However, a compliance check of the delivered waste should be made frequently (e.g. with rapid tests) in order to ensure that no divergences exist and that the same waste as declared is delivered.

Rapid tests can consist e.g. of quick leaching test on 20 to 100 g (or 20 to 100 mg) of each waste delivered for landfills. A detailed analysis of the waste is essential to chose the best treatment option. Therefore additional chemical analysis, e.g. the determination of the gross calorific value are useful to be carried out to clarify if the HW can be incinerated according to its material composition.

*In the case of recycling* the relevant parameters for chemical analysis depend mainly on the product that should be obtained. For example in case of metal recycling the metal concentration is essential for the analysis.

*In the case of chemical-physical treatment*, the chemical analysis depends mainly on the particular activities of the plant. For the treatment of oil-polluted wastewater, for example, an aqueous phase and an oil-rich sludge are generated by addition of chemical substances. Therefore, the cleavage property has to be tested. Also the chemical precipitation of heavy metals has to be tested and this information is of importance for the precipitation. An additional simple test with nickel salt for the existence/concentration of complex-forming agents is also very useful.

*Limit values for chemical/physical treatment refer to the secondary wastes/residues generated by the treatment. Chemical/physical treatability is tested by performing the envisaged treatment on a sample of the waste at a laboratory. When the resulting filter cake*
meets the criteria for landfill disposal and the resulting aqueous phase meets the wastewater discharge standards, the waste is considered treatable.

In the case of incineration, the following parameters are checked continuously or at the start of operation/after changes in operational procedures:

- dust
- total carbon
- chlorine, fluoride and sulphur, NOx
- mercury
- heavy metals (at start of operation/after changes)
- polychlorinated dibenzo-p-dioxins and dibenzofurans (at start of operation/after changes)

In the case of co-processing for cement production also the amount of salts (mainly chloride) and of some volatile metals like mercury or cadmium and/or chromium (to avoid high hexavalent chromium-concentration in the cement) are tested.

In the case of a ground-level hazardous waste landfill, the following parameters are of relevance according to the Landfill Directive (Directive 1999/31/EC) (the list of parameters for Germany set out in Table 22 is slightly different, since EU Member States are allowed to add additional parameters than stipulated in the Landfill Directive):

[1] Total organic carbon (TOC) or loss of ignition (LOI)
[2] Acid neutralization capacity (ANC)

Batch leaching test at L/S = 2 or L/S = 10 or percolation leaching test

[3] pH, electric conductivity, arsenic (As), barium (Ba), cadmium (Cd), chromium (Cr total), copper (Cu), mercury (Hg), molybdenum (Mo), nickel (Ni), lead (Pb), antimony (Sb), selenium (Se), zinc (Zn), fluoride, chlorine and sulphate or total amount of dissolved substances (TDS), dissolved organic carbon (DOC).

Other parameters such as polycyclic aromatic hydrocarbons (PAH) in solid matter, or cyanide in the leachate, can be of interest to the surveillance authority or the landfill operating company.

For a chemical analysis of the parameters, for the sampling procedure and the performance of leachate tests (see Fig. 47 and Fig. 48), EU standards are available and outlined in the corresponding Directives (for example: CEN (2002): EN 12457/1-4 Characterization of waste
Leaching - Compliance test for leaching of granular waste materials and sludges- Parts 1-4

CEN

Fig. 47  Examples for preparation of the eluate (overhead room shaker; gentle overhead movement for waste analysis)

Fig. 48: Percolation test; water is pumped upstream through waste material (black) in a column, and collected and analyzed at a certain L/S-ratio (e.g. 0.1 or 2.0)\textsuperscript{117}

The extent and number of analytical tests that are performed on a batch of hazardous waste depends on the intended treatment and disposal route. Incineration or thermal treatment require percentage assay of inorganic elements such as cadmium, mercury, thallium and

\textsuperscript{116} Can be retrieved from  \url{http://www.cen.eu/cenorm/homepage.htm}

\textsuperscript{117} A L/S-ratio (L/S: Liquid to Solid) of 2 means that 2 parts of water and 1 part of waste (dry) are leached and a L/S-ratio of 10 means that 10 parts of water and 1 part of waste (dry) are leached, for example 100 g of dry waste with 1000 g of distilled water
sulphur, as well as of chlorine and highly toxic organic compounds such as dioxins. For above ground hazardous waste landfill, a leachate test and assay of parameters such as total organic carbon and dissolved organic carbon are essential. If physical-chemical treatment is intended, the requirements for the chemical analysis depend on the activities of the treatment facility.

Regarding possible disposal routes for hazardous waste, reuse and recycling processes are considered first. Possible ways to eliminate hazardous substances contained in the waste are chemical oxidation, reduction or stabilization. Stabilization of hazardous waste can sometimes be performed using another waste, e.g. coal fly ashes.

Other relevant information is available from different institutions:

- E-waste is provided e.g. by the Indo-German-Swiss e-waste Initiative\(^{118}\)
- Used oil is given in the Basel Convention Technical Guidelines on Used Oil Re-Refining or Other Re-Uses of Previously Used Oils\(^{119}\).
- Basel Convention technical guidelines at: [http://archive.basel.int/meetings/sbc/workdoc/techdocs.html](http://archive.basel.int/meetings/sbc/workdoc/techdocs.html) provide useful information on available techniques to choose recovery or treatment options for some specific hazardous waste.

**Best waste treatment options for each waste code in line with the EWL as recommended by the Ministry for the Environment and Transport Baden-Wuerttemberg\(^{120}\) as modified by Vida 2010. The table can be used as a first orientation step. (see supplement 1)**

### 7.4. Recovery and Disposal Codes

The Basel convention defines 15 D-Codes for disposal operations and 13 R-Codes for recovery operations that are not only applied for allocating waste streams during trans-boundary shipment of hazardous waste but also serve as a reference in many national waste legislations and international agreements. On the other side the EU Directive 2008/98/EC enumerates thirteen possible recovery operations. Each of these options can be identified with an R code for recovery. Also this Directive assigns specific identification codes (D-codes) for fifteen different disposal operations:

**Recovery operations** Recovery operations according to Directive 2008/98/EC, Annex II

\(^{118}\) For Information on the project refer to [http://www.asemindia.com/indo_german.html](http://www.asemindia.com/indo_german.html)
\(^{120}\) Ministry for the Environment and Transport Baden-Wuerttemberg, 2003
R 1 Use principally as a fuel or other means to generate energy (*)
R 2 Solvent reclamation/regeneration
R 3 Recycling/reclamation of organic substances which are not used as solvents (including composting and other biological transformation processes) (**)
R 4 Recycling/reclamation of metals and metal compounds
R 5 Recycling/reclamation of other inorganic materials (***)
R 6 Regeneration of acids or bases
R 7 Recovery of components used for pollution abatement
R 8 Recovery of components from catalysts
R 9 Oil re-refining or other reuses of oil
R 10 Land treatment resulting in benefit to agriculture or ecological improvement
R 11 Use of waste obtained from any of the operations numbered R 1 to R 10
R 12 Exchange of waste for submission to any of the operations numbered R 1 to R 11 (****)
R 13 Storage of waste pending any of the operations numbered R 1 to R 12 (excluding temporary storage, pending collection, on the site where the waste is produced) (*****)

Disposal operations

If a particular waste cannot be recycled or recovered, the respective waste needs to be referred to a facility for further treatment or final disposal. To assign hazardous wastes to specific treatment procedures criteria need to be applied. The objective is to render the hazardous waste non-hazardous, or to dispose it of, or encapsulate it in a manner such as to prevent harm to the environment and human health.

Disposal operations and codes according to Directive 2008/98/EC, Annex I

D 1 Deposit into or on to land (e.g. landfill, etc.)

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(*) This includes incineration facilities dedicated to the processing of municipal solid waste only where their energy efficiency is equal to or above: — 0,60 for installations in operation and permitted in accordance with applicable Community legislation before 1 January 2009, — 0,65 for installations permitted after 31 December 2008, using the following formula: Energy efficiency = (Ep - (Ef + Ei))/(0,97 × (Ew + Ef))
In which: Ep means annual energy produced as heat or electricity. It is calculated with energy in the form of electricity being multiplied by 2,6 and heat produced for commercial use multiplied by 1,1 (GJ/year) Ef means annual energy input to the system from fuels contributing to the production of steam (GJ/year) Ew means annual energy contained in the treated waste calculated using the net calorific value of the waste (GJ/year) Ei means annual energy imported excluding Ew and Ef (GJ/year) 0,97 is a factor accounting for energy losses due to bottom ash and radiation. This formula shall be applied in accordance with the reference document on Best Available Techniques for waste incineration.

(**) This includes gasification and pyrolysis using the components as chemicals.

(*** ) This includes soil cleaning resulting in recovery of the soil and recycling of inorganic construction materials.

(****) If there is no other R code appropriate, this can include preliminary operations prior to recovery including pre-processing such as, inter alia, dismantling, sorting, crushing, compacting, pelletizing, drying, shredding,conditioning, repackaging, separating, blending or mixing prior to submission to any of the operations numbered R1 to R11.

(***** ) Temporary storage means preliminary storage according to point (10) of Article 3.
D 2  Land treatment (e.g. biodegradation of liquid or sludgy discards in soils, etc.)
D 3  Deep injection (e.g. injection of pumpable discards into wells, salt domes or naturally occurring repositories, etc.)
D 4  Surface impoundment (e.g. placement of liquid or sludgy discards into pits, ponds or lagoons, etc.)
D 5  Specially engineered landfill (e.g. placement into lined discrete cells which are capped and isolated from one another and the environment, etc.)
D 6  Release into a water body except seas/oceans
D 7  Release to seas/oceans including sea-bed insertion
D 8  Biological treatment 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 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.)
D 10  Incineration on land
D 11  Incineration at sea (*)
D 12  Permanent storage (e.g. emplacement of containers in a mine, etc.)
D 13  Blending or mixing prior to submission to any of the operations numbered D 1 to D 12 (**)
D 14  Repackaging prior to submission to any of the operations numbered D 1 to D 13
D 15  Storage pending any of the operations numbered D 1 to D 14 (excluding temporary storage, pending collection, on the site where the waste is produced) (***)

(*) This operation is prohibited by EU legislation and international conventions.
(**) If there is no other D code appropriate, this can include preliminary operations prior to disposal including pre-processing such as, inter alia, sorting, crushing, compacting, pelletising, drying, shredding, conditioning or separating prior to submission to any of the operations numbered D 1 to D 12.
(***) Temporary storage means preliminary storage according to point (10) of Article 3.

122
8.1. General Chemical / Physical Biological Treatment of HW for Disposal

Physico-chemical treatments apply to waste waters, waste solids and sludges. Physico-chemical treatment applies more than 133 techniques for waste treatment, prevention and management. Techniques applied for waste waters and sludges comprise neutralization, precipitation, oxidation/reduction, flocculation and evaporation, filtration, sieving, dewatering, decanting and centrifuging.

For solid granular wastes the most important technique is solidification/immobilization (mechanical) or stabilization (chemical).

The procedures serve the specific application of physico-chemical reactions for material conversion (e.g. neutralization, oxidation, reduction) and for material separation (e.g. filtration, sedimentation, distillation, ion exchange).

By quantity ‘Chemical-Physical Treatment’ (CPT) is mostly used for pre-treatment of inorganic and organic liquid aqueous wastes. Pre-treatment refers to treatment prior to recovery or final disposal. Wastes that undergo CPT may be also slurry or pasty in nature, however in order to enable the material flow in a CPT plant, the materials must be pumpable (including e.g. dusts, ashes). Wastes to be treated are from various industrial and commercial production processes, and from maintenance, repair and cleaning activities.

Supplement 2: Basel Convention Y list code and allocation to physico-chemical treatment methods

or

Basel Convention technical guidelines at:
http://archive.basel.int/meetings/sbc/workdoc/techdocs.html

See also Supplement 1: allocating EWL waste codes to recovery and disposal options

By consulting also the DEFRA Guideline you will be guided on how to implement the waste hierarchy principle. More information at:
http://www.google.de/url?q=http://www.defra.gov.uk/publications/files/pb13687-hazardous-waste-hierarchy-111202.pdf&sa=U&ei=2CKMT5uNM4qFhQe4kdHsCQ&ved=0CBkQFjAC&usg=AFQjCNF8Zn6VWw52F AHYZKbQIC_Q9sR1g
Characteristic waste types are:

- Inorganic wastes
  - Various liquids and slurries containing pollutants such as heavy metals, Cr(VI), cyanide, nitrite, complexing agents, ammonia and others e.g. from metal processing- and finishing industries
  - Acids (e.g. from pickling) and alkaline solutions

- Organic wastes
  - Spent cooling oil emulsions
  - All types of oil/water mixtures
  - All types of oil/water/solid slurries such as contents of settling chambers, oil/water separators etc.
  - Paint sludge and latex residues

Inorganic hazards wastes are treated in basins equipped with dosage devices for the addition of reducing or oxidizing chemicals or addition of alkaline solutions for the precipitation of toxic heavy metals, and with devices for the removal of the precipitated heavy metal hydroxides. Inorganic hazardous substances like cyanide can be chemically oxidized by agents such as sodium-hypochlorite or hydrogen peroxide. Hazardous hexavalent chromium can be reduced by reducing agents (e.g. sodium bisulfite, ferrous sulfate) and precipitated subsequently.

For the treatment of organic hazard waste such as oil-contaminated waste waters, emulsions – basins with mechanical equipment for oil separation and dosage, devices for the addition of demulsifying chemicals must be installed. For emulsions containing hydrocarbons, a cleavage of the emulsion by addition of acids is the most favored treatment option. Chemical oxidation is also possible for some organic substances.

Physico-chemical treatment plants are designed and equipped in order to ensure that the maximum amount of recyclable materials can be separated so that a minimum amount of auxiliary materials is used.

According to the BREF document on waste treatment, the purposes of physico-chemical treatment plants are to:

- enable delivery of environmental protection goals, in particular, water quality management. In such plants, materials which may be hazardous to water are either treated, withheld and/or converted to a non-hazardous form;
– enable the correct disposal of large quantities of (generally) aqueous liquid waste and waste requiring special controls
– separate oil or organic fraction to be used as fuel.

Physico-chemical treatment plants are configured on a case-by-case basis depending on requirements and/or application. Each physico-chemical treatment plant has a specific individual technological and operational concept; this is geared to the waste to be treated. For this reason, there is no ‘standard’ physico-chemical treatment plant. Although all plants have inspection and process laboratories and tend to have a neutralization function, the range of pretreatment processes, sludge handling methods and the combination of input waste streams makes each a unique operation.

**Installations for the physico-chemical treatment of waste waters**

This sector is represented by a large range of processes categorized as ‘chemical treatments’. These range from blending systems with no actual chemical interactions to complex plants with a range of treatment options, some custom designed for specific waste streams. An example of a physico-chemical treatment facility of waste waters typically contains the following unit processes: cyanide destruction, chromium reduction, two-stage metal precipitation, pH adjustment (e.g. neutralization), solid filtration, biological treatment, carbon adsorption, sludge dewatering, coagulation/flocculation and some others.

**Physico-chemical treatments of waste solids and waste sludges**

The main goal in the physico-chemical treatments of waste solids and waste sludges is to minimize the long-term release by leaching out the primarily heavy metals and low biodegradable compounds. The available treatment options act to prolong the leaching time period by releasing, for example, heavy metals at lower and more environmentally acceptable concentrations for an extended period of time. Typical physico chemical treatments of waste solids and waste sludges are extraction and separation, thermal treatment, mechanical separation, conditioning, immobilization (this treatment covers solidification and stabilization), dewatering, drying, thermal desorption, vapor extraction from excavated soil, solvent extraction from solid waste (e.g. excavated soil), excavation and removal of excavated soil and soil washing.

Unit level operations applied in CPT can be differentiated with respect to their impact on the pollutants into those that degrade or convert pollutants into less hazardous substances and those that separate or concentrate pollutants. The most prominent unit level operations and their respective effects are shown in Table 15.
Table 15: Unit level operations for chemical-physical treatment and their effect on pollutants

<table>
<thead>
<tr>
<th>Unit operation</th>
<th>Effect on pollutants</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Degradation, conversion</td>
</tr>
<tr>
<td>Neutralization (chem.)</td>
<td>x</td>
</tr>
<tr>
<td>Oxidation (chem.)</td>
<td>x</td>
</tr>
<tr>
<td>Reduction (chem.)</td>
<td>x</td>
</tr>
<tr>
<td>Precipitation (chem.)</td>
<td>x</td>
</tr>
<tr>
<td>Acid cleavage of emulsions (chem.)</td>
<td>x</td>
</tr>
<tr>
<td>Flocculation (phys.)</td>
<td>x</td>
</tr>
<tr>
<td>Sedimentation (phys.)</td>
<td>x</td>
</tr>
<tr>
<td>Filtration (phys.)</td>
<td>x</td>
</tr>
<tr>
<td>Centrifugation (phys.)</td>
<td>x</td>
</tr>
<tr>
<td>Adsorption (phys.)</td>
<td>x</td>
</tr>
<tr>
<td>Stripping (phys.)</td>
<td>x</td>
</tr>
<tr>
<td>Distillation (phys.)</td>
<td>x</td>
</tr>
<tr>
<td>Membrane processes (phys.)</td>
<td>x</td>
</tr>
</tbody>
</table>

Output from chemical-physical treatment

As a result of CPT, there are three output streams:

- Separated organic materials, in most cases mineral oil that is sent to other facilities for use as a secondary fuel or, if it does not meet the required specifications, to an incinerator.
- Solid dewatered residues, in most cases filter cakes containing immobilized heavy metals in sparingly soluble compounds as well as other fixed pollutants. These materials have to be disposed on hazardous waste landfill sites.
- Wastewater that meets industrial discharge standards and can be discharged to a domestic wastewater treatment plant for final treatment

Process design

*Operation of a CPT plant makes only sense in combination with recovery facilities (material recycling or energy recovery) or/and disposal facilities (incineration, landfill).*

CPT is carried out by a batch operation. The treatment line for the inorganic waste stream is strictly separated from the organic treatment line. Experiences from Germany and other European countries have shown that separated treatment lines for organically and inorganically contaminated liquid hazardous wastes are necessary for an effective treatment. Only in the last stage of the treatment – the mechanical dewatering of the sludge arising from the treatment – the streams can be combined (see Fig 49)

The treatment line for the organic hazard waste stream includes the following main elements:
- Delivery stations for the receipt of all types of oil water mixtures and emulsions
- Heated tank for storage and separation of oil–emulsions
- Reactor for phase separation of emulsions
- Settling tank
- Storage tank for separated oil phase

The line for the inorganic hazard waste stream includes the following main elements:

- Delivery stations for the receipt of waste acids, metal concentrates, alkaline lyes and chromate
- Separate storage tanks for the different inorganic wastes
- Reactor for neutralization, chromate reduction and heavy metal precipitation

For the solidification of the sludge mechanical dewatering by chamber filter presses is recommended. Compared to the alternative solidification with additives the chamber filter press leads to volume and quantity reduction of the resulting waste.

- Heated tank for storage and separation of oil–emulsions
- Reactor for phase separation of emulsions
- Settling tank
- Storage tank for separated oil phase

The line for the inorganic waste stream includes the following main elements:

- Delivery stations for the receipt of waste acids, metal concentrates, alkaline lyes and chromate
- Separate storage tanks for the different inorganic wastes
- Reactor for neutralization, chromate reduction and heavy metal precipitation

For the solidification of the sludge mechanical dewatering by chamber filter presses is recommended. Compared to the alternative solidification with additives, the chamber filter press leads to volume and quantity reduction of the resulting waste.
Fig. 49: Process scheme of a chemical-physical treatment plant with two treatment sections (organic and inorganic)

Source: E. Schultes, HIM GmbH
Occupational health and safety requirements

Chemical/physical treatment (CPT) is a method of final disposal that is often underestimated in its complexity. In the course of a CPT, reactive or even highly reactive alloys / mixtures are often handled. This kind of reactivity can potentially lead to hazardous incidents. For instance, neutralisations, i.e. reactions between acids and leachates, are frequently not carried out with pure substances. When, for example, the residue of a strong mineral acid (e.g. from a pickling / etching process) is to be neutralised, this can be done by adding some type of lye like sodium hydroxide. The use of a pure substance, however, would be relatively costly. These costs can be reduced if another waste substance consisting of an alkaline solution (i.e. lye) also has to be neutralised. In this case, neutralisation could be reached by mixing the two types of chemical waste in the correct mixing ratio. This method cannot be criticised on economic nor on ecological grounds – on the contrary, it is in fact ecologically sound as well as economical.

If, however, additional components of the solution lead to side-effects in the form of chemical reactions apart from the intended neutralisation, this can be critical for the facility. One potential side-effect that could be generated is a redox reaction. If the pickling solution were to contain divalent iron salts and the lye on the other hand nitrates, this could lead to the creation of nitrous gases in the defined pH-range. This redox reaction constitutes only one of many potential scenarios for chemical reactions that might lead to an incident in the facility.

This is the reason why it is problematic to mix wastes / residues the composition of which is not sufficiently clear or clarified. Consequently, it is essential to obtain information on the provenance and composition of the chemicals prior to the mixing of the waste substances. In that context, there should also be at least one employee in the enterprise with a basic knowledge of chemistry (at least on the level required for this purpose). In the case of new types of waste of unknown origin, conducting a chemical analysis is highly advisable.

Furthermore, a “tube test” (“beaker glass test”) should be carried out routinely for bigger quantities of distinct chemicals prior to their intermixture, even if the waste type and origin are known. The term “tube test” denotes a test in which small quantities of the two waste substances in question are combined and mixed in a beaker in a laboratory under practical conditions in order to detect and identify any potential chemical reactions that might lead to incidents beforehand.

The design and operation of the facility must comply with occupational health and safety requirements:

- The complete installation including storage areas has to be sealed to prevent sub soil contamination
- Gaseous emissions have to be collected and treated in suitable gas cleaning installations
- All tanks and reactors have to be equipped with leakage monitoring systems
- The health and safety equipment has to fulfill the requirements of comparable installations of the chemical industry

Ancillary Equipment

Essential for the operation of a CPT plant is the following ancillary equipment:

- **Laboratory:** The delivered waste has to be checked by quick tests if it complies with the criteria of the basic characterization analysis, the treatment methods have to be developed and the quality of the discharged materials (waste water, filter cake, oil) have to be monitored.

- **Intermediate storage:** It is recommended to operate tank farms for organic materials like oil – water – mixtures or oil – emulsions and for oil after treatment. For acids, lyes and heavy metal containing wastes a storage area for containers or drums should be planned.

In order to ensure that only waste water, complying with national discharge standards, is discharged to the sewerage system, two or three compensation tanks with sufficient capacity should be installed. In these tanks the waste water is collected and analyzed prior to discharge.

The final design of a CPT plant depends strongly on the quantities and qualities of the waste to be treated. Especially the ratio between organic and inorganic waste or special waste types like hydrofluoric acids have a great influence on the final specification.

### 8.2. Scale of CPT plants – Economy of scale

In contrast to incinerators, chemical-physical treatment plants are relatively independent from the scale, with respect to technical as well as economical aspects.

Table 16 presents various financial parameters for CPT plants of different capacities ranging from 10,000 to 30,000 t/a. Calculations refer to CPT plants with two treatment lines (inorganic–organic) and were made during a hazardous waste infrastructure planning project in the Chinese Province Zhejiang as part of the “Environmental Enterprise Consultancy Zhejiang” Program (GTZ). As the table shows, the investment required for CPT plants is much less than for incinerators, and the specific costs per ton of waste to be incinerated drop only to a minor extent with increasing capacity of the facilities.

The input materials for CPT are usually waste types that are liquid, pasty or slurry in nature, meaning waste with a considerable water content. From an economical point of view it is therefore sensible to separate the water content of such waste close to the point of generation and prior to transport thus reducing the overall amount of the materials that have
to be transported to the final treatment and disposal destinations (recovery facilities, incinerators, landfills).

Keeping in mind that the investment for CPT plants is relatively low, it is obvious that CPT plants are usually implemented on a much lower level of centralization than expensive incinerators or landfill sites. CPT plants are ideally suited to cater to the industries of a city or of an industrial park. CPT plants may moreover serve as collection points for other waste types to assemble them to transport units for further transfer to other centralized facilities such as incinerators and landfill sites.

**Details of calculations of specific costs CPT in China**

Table 16: “Economy of Scale” effect for chemical-physical treatment plants of different capacities (based on estimated local costs, China, 2007. 1RMB = 0.1€)

<table>
<thead>
<tr>
<th>Capacity</th>
<th>10,000</th>
<th>20,000 (2 shifts)</th>
<th>15,000</th>
<th>30,000 (2 shifts)</th>
<th>tons/a</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Investment CPT</strong></td>
<td>20</td>
<td>20</td>
<td>25</td>
<td>25</td>
<td>Mio. RMB</td>
</tr>
<tr>
<td><strong>Annual costs</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Amortization</td>
<td>1.33</td>
<td>1.33</td>
<td>1.67</td>
<td>1.67</td>
<td>Mio. RMB/a</td>
</tr>
<tr>
<td>Interest</td>
<td>0.8</td>
<td>0.8</td>
<td>1</td>
<td>1</td>
<td>Mio. RMB/a</td>
</tr>
<tr>
<td><strong>Capital costs per year</strong></td>
<td>2.13</td>
<td>2.13</td>
<td>2.67</td>
<td>2.67</td>
<td>Mio. RMB/a</td>
</tr>
<tr>
<td>Maintenance</td>
<td>1.50%</td>
<td>3.00%</td>
<td>1.50%</td>
<td>3.00%</td>
<td>(% of invest.)</td>
</tr>
<tr>
<td>Personnel</td>
<td>0.45</td>
<td>0.61</td>
<td>0.49</td>
<td>0.73</td>
<td>Mio. RMB/a</td>
</tr>
<tr>
<td><strong>Fixed operating costs</strong></td>
<td>0.75</td>
<td>1.21</td>
<td>0.87</td>
<td>1.48</td>
<td>Mio RMB/a</td>
</tr>
<tr>
<td><strong>Total annual fixed costs</strong></td>
<td>2.88</td>
<td>3.35</td>
<td>3.53</td>
<td>4.15</td>
<td>Mio. RMB/a</td>
</tr>
<tr>
<td><strong>Specific costs per ton</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Capital costs per ton</td>
<td>213</td>
<td>107</td>
<td>178</td>
<td>89</td>
<td>RMB/ton</td>
</tr>
<tr>
<td>Fixed operating costs per ton</td>
<td>75</td>
<td>61</td>
<td>58</td>
<td>49</td>
<td>RMB/ton</td>
</tr>
<tr>
<td><strong>Total fixed costs per ton</strong></td>
<td>288</td>
<td>167</td>
<td>236</td>
<td>138</td>
<td>RMB/ton</td>
</tr>
<tr>
<td>Variable operating costs per ton</td>
<td>527.35</td>
<td>527.35</td>
<td>527.35</td>
<td>527.35</td>
<td>RMB/ton</td>
</tr>
<tr>
<td><strong>Total var. &amp; fixed op. costs</strong></td>
<td>602</td>
<td>588</td>
<td>585</td>
<td>577</td>
<td>RMB/ton</td>
</tr>
<tr>
<td><strong>Total costs per ton:</strong></td>
<td>815</td>
<td>695</td>
<td>763</td>
<td>666</td>
<td>RMB/ton</td>
</tr>
</tbody>
</table>

---

Cost assessment from the Sino – German cooperation project in Zhejiang, China for a CPT plant

The following 3 tables present a detailed cost assessment for a chemical physical treatment plant with an operation period of minimum 20 years with one or two shift operation and treatment of 10.000 -30.000 tones waste per year. The data is from China, 2007. (1RMB = 0.1€)

The cost assessment consists of:

1. Staff costs as part of the fixed operating cost of CPT
2. Total and Specific Capital and Operating Costs of CPTs with different Capacities
3. Consumption per ton as part of the operating Costs of CPT

Explanation of the different cost types

<table>
<thead>
<tr>
<th>Cost Type</th>
<th>Explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Annual costs</strong></td>
<td></td>
</tr>
<tr>
<td>Capital costs per year</td>
<td>Amortization + interest rate</td>
</tr>
<tr>
<td>Fixed operating costs per year</td>
<td>Maintenance and staff costs</td>
</tr>
<tr>
<td><strong>Specific costs per ton of waste</strong></td>
<td></td>
</tr>
<tr>
<td>Capital costs per ton</td>
<td>Amortization + interest rate</td>
</tr>
<tr>
<td>Fixed operating costs per ton</td>
<td>Maintenance and staff costs</td>
</tr>
<tr>
<td>Variable operating costs per ton</td>
<td>- as calculated -</td>
</tr>
<tr>
<td>Total operating costs per ton</td>
<td>Variable and fixed operating costs</td>
</tr>
<tr>
<td>Transport costs per ton</td>
<td>Flat rates for transport assuming transport in a 20 t truck</td>
</tr>
<tr>
<td>Total costs per ton</td>
<td>Sum of capital costs, fixed operating and variable operating costs (if indicated also transport costs)</td>
</tr>
</tbody>
</table>
## CPT Staff Cost

<table>
<thead>
<tr>
<th>Capacity</th>
<th>No of Staff for</th>
<th>Salary / month (RMB/m)</th>
<th>Salary / year (RMB/y)</th>
<th>Annual Staff Cost per given Capacity (RMB/y)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>10' t/y 20' t/y 15' t/y 30' t/y</td>
<td>1 shift 2 shifts 1 shift 2 shifts</td>
<td>10' t/y 20' t/y 15' t/y 30' t/y</td>
<td></td>
</tr>
<tr>
<td>Employees</td>
<td></td>
<td></td>
<td>(t/y/1shift) (t/y/2shift) (t/y/1shift) (t/y/2shift)</td>
<td></td>
</tr>
<tr>
<td>Head</td>
<td>1 1 1 1</td>
<td>3500 45,500</td>
<td>45,500 45,500 45,500 45,500</td>
<td></td>
</tr>
<tr>
<td>Secretary</td>
<td>1 1 1 1</td>
<td>1800 23,400</td>
<td>23,400 23,400 23,400 23,400</td>
<td></td>
</tr>
<tr>
<td>Department heads (Engineers)</td>
<td>2 2 2 2</td>
<td>2400 31,200</td>
<td>62,400 62,400 62,400 62,400</td>
<td></td>
</tr>
<tr>
<td>Shift leader</td>
<td>1 2 1 2</td>
<td>2000 26,000</td>
<td>26,000 52,000 26,000 52,000</td>
<td></td>
</tr>
<tr>
<td>Plant worker</td>
<td>6 10 8 14</td>
<td>1800 23,400</td>
<td>140,400 234,000 187,200 327,600</td>
<td></td>
</tr>
<tr>
<td>Workshop</td>
<td>2 3 2 3</td>
<td>1800 23,400</td>
<td>46,800 70,200 46,800 70,200</td>
<td></td>
</tr>
<tr>
<td>Laboratory</td>
<td>3 4 3 4</td>
<td>2000 26,000</td>
<td>78,000 104,000 78,000 104,000</td>
<td></td>
</tr>
<tr>
<td>Dispatcher</td>
<td>1 1 1 2</td>
<td>1800 23,400</td>
<td>23,400 23,400 23,400 46,800</td>
<td></td>
</tr>
</tbody>
</table>

| B total RMB/t | 445,900 | 614,900 | 492,700 | 731,900 |

|          | 45      | 31      | 33      | 24      |
## Total and Specific Capital and Operating Costs of CPTs with different Capacities

<table>
<thead>
<tr>
<th>Capacity</th>
<th>10,000</th>
<th>20,000 (2 shifts)</th>
<th>15,000</th>
<th>30,000 (2 shifts)</th>
<th>tons/year</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Investment CPT</strong></td>
<td></td>
<td></td>
<td>20</td>
<td>20</td>
<td>25</td>
</tr>
<tr>
<td><strong>Annual costs</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Amortisation Interest</td>
<td>1.33</td>
<td>0.8</td>
<td>1.33</td>
<td>0.8</td>
<td>1.671</td>
</tr>
<tr>
<td><strong>Capital costs per year</strong></td>
<td>2.13</td>
<td>2.13</td>
<td>2.67</td>
<td>2.67</td>
<td>Mio. RMB/a</td>
</tr>
<tr>
<td>Maintenance</td>
<td>1.50%</td>
<td>3.00%</td>
<td>0.3</td>
<td>0.6</td>
<td>1.50%</td>
</tr>
<tr>
<td>Personnel</td>
<td>0.45</td>
<td>0.61</td>
<td>0.49</td>
<td>0.73</td>
<td></td>
</tr>
<tr>
<td><strong>Fixed operating costs</strong></td>
<td>0.75</td>
<td>1.21</td>
<td>0.87</td>
<td>1.48</td>
<td>Mio. RMB/a</td>
</tr>
<tr>
<td><strong>Total annual fixed costs</strong></td>
<td>2.88</td>
<td>3.35</td>
<td>3.53</td>
<td>4.15</td>
<td>Mio. RMB/a</td>
</tr>
<tr>
<td><strong>Specific costs per ton</strong></td>
<td>213</td>
<td>107</td>
<td>178</td>
<td>89</td>
<td>RMB/ton</td>
</tr>
<tr>
<td>Capital costs per ton</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fixed operating costs per ton</td>
<td>75</td>
<td>61</td>
<td>58</td>
<td>49</td>
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</tr>
<tr>
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<tr>
<td>Variable operating costs per ton</td>
<td>527.35</td>
<td>527.35</td>
<td>527.35</td>
<td>527.35</td>
<td>RMB/ton</td>
</tr>
<tr>
<td><strong>Total variable and fixed operating costs</strong></td>
<td>602</td>
<td>588</td>
<td>585</td>
<td>577</td>
<td>RMB/ton</td>
</tr>
<tr>
<td><strong>Total costs per ton</strong></td>
<td>815</td>
<td>695</td>
<td>763</td>
<td>666</td>
<td>RMB/ton</td>
</tr>
</tbody>
</table>
Consumption per ton as part of the operating Costs of CPT

<table>
<thead>
<tr>
<th>Cost item</th>
<th>Per ton of waste</th>
<th>Price/unit [RMB]</th>
<th>Specific costs [RMB/t]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lime</td>
<td>0.05 tons</td>
<td>350</td>
<td>17.50 RMB/t</td>
</tr>
<tr>
<td>Electricity</td>
<td>200 kWh</td>
<td>0.25</td>
<td>50.00 RMB/t</td>
</tr>
<tr>
<td>Activated Carbon</td>
<td>0.0005 tons</td>
<td>200</td>
<td>0.10 RMB/t</td>
</tr>
<tr>
<td>Industrial water</td>
<td>0.1 m³</td>
<td>2.5</td>
<td>0.25 RMB/t</td>
</tr>
<tr>
<td>Caustic soda</td>
<td>0.03 tons</td>
<td>3200</td>
<td>96.00 RMB/t</td>
</tr>
<tr>
<td>Iron-salts</td>
<td>0.01 tons</td>
<td>250</td>
<td>2.50 RMB/t</td>
</tr>
<tr>
<td>Acids</td>
<td>0.01 tons</td>
<td>100</td>
<td>1.00 RMB/t</td>
</tr>
</tbody>
</table>

Production per ton:

<table>
<thead>
<tr>
<th>Production per ton:</th>
<th>Per ton of waste</th>
<th>Price/unit [RMB]</th>
<th>Specific costs [RMB/t]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Residues for Landfill</td>
<td>0.2 tons</td>
<td>800</td>
<td>160.00 RMB/t</td>
</tr>
<tr>
<td>Residues for incineration</td>
<td>0.1 tons</td>
<td>1800</td>
<td>180.00 RMB/t</td>
</tr>
</tbody>
</table>

Other costs:

| Other costs:         |                  |                  | 20.00 RMB/t            |

Variable operating costs

| Variable operating costs |                  |                  | 527.35 RMB/t           |
Fig. 50: Chemical / Physical Treatment Plant of HIM GmbH at Kassel, Germany (Total capacity = 31,000 t/a; thereof 25,000 t/a capacity for oil emulsion treatment)

8.3. Clarification of terms: Stabilization – Solidification – Chemical-physical treatment

“Stabilization” and “solidification” are two terms frequently mentioned in the context of pre-treating hazardous waste. Whereas “chemical-physical treatment” designates pre-treatment prior to all management options such as recovery, incineration or, land filling. “Stabilization” and “solidification” usually refer exclusively to pre-treatment prior to land filling.

EU Decision 2000/532/EC defines: “Stabilization processes change the dangerousness of the constituents in the waste and thus transform hazardous waste into non-hazardous waste. Solidification processes only change the physical state of the waste (e.g. liquid into solid) by using additives without changing the chemical properties of the waste.”

Solidification as exclusive treatment is therefore not sustainable; in order to render hazardous waste non-hazardous it must always be encompassed by stabilization. Stabilization and solidification are mainly applied to inorganic waste. Hazardous substances like heavy metals cannot be destroyed chemically. They have to be immobilized into
insoluble forms so that they cannot be leached out. Common stabilization processes often work with fixation in cement phases.

Stabilization processes include also the chemical unit operations listed in Table 15. The effectiveness of stabilization may be checked by eluate tests.

Solidification uses binders such as cement, lime/limestone or pozzolana based systems. In contrast to chemical/physical treatment where stabilized products are only solidified by dewatering, solidification with the use of additives is accompanied by an increase in mass and volume and, accordingly, causes additional operating costs and landfill space consumption.

Stabilized hazardous wastes have their own identification code in the European waste list (EWL). They are referred to as “stabilized/solidified wastes” and coded with 19 03. Stabilized/solidified hazardous waste is e.g. used as construction material on domestic waste landfills in Germany.

The concept of solidification and stabilization originates from Anglo-Saxon countries. In USA “stabilization” and “solidification” are also applied to organic hazardous waste and are mainly used for the rehabilitation of polluted soils. US EPA has its own definition of these terms.\textsuperscript{124}


Fig. 51: Different types of residues from physico-chemical treatment containing dangerous substances, disposed on an above-ground hazardous waste landfill
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Convention Project Chemical Safety
Responsible: Dr. Frank Fecher

Authors: Jochen Vida, Adi Heindl, Ulrike Potzel, Peter Schagerl, Franziska Frölich, Ferdinand Zotz, Anke Joas, Uwe Lahl and Alberto Camacho

Contact person at the Federal Ministry for Economic Cooperation and Development (BMZ):
Heiko Warnken

Bonn, May 2012

The Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH was formed on 1 January 2011. It has brought together under one roof the capacities and long-standing experience of three organisations: the Deutscher Entwicklungsdienst (DED) gGmbH (German Development Service), the Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ) GmbH (German technical cooperation) and Inwent – Capacity Building International, Germany. For further information go to www.giz.de.
Module 5

Practical aspects of implementation and enforcement

Permitting and inspection (HW Incinerators and landfills)
• Practical aspects of Implementation and Enforcement

This chapter includes a brief introduction to the basic principles of implementation and enforcement of legal objectives to be considered for the establishment of a successful hazardous waste management system. Particularly the main enforcement tools for an appropriate hazardous waste management are highlighted.

In addition, an overview of the main actors involved in (hazardous) waste management as well as their main responsibilities is given.

9.1. Basic principles and procedures of implementation and enforcement of legal objectives

As a starting point, considering both legal and practical aspects of waste management, the following elements and enforcement tools are of crucial importance:

• **Regulatory instruments** comprise policy instruments such as bans and mandatory requirements. These instruments are usually clearly defined by legislation. A legal framework on waste management has to be established by the government/competent authorities. Main elements of EU legislation can serve as a first point of orientation and in a number of cases as valuable example. Most of the basic principles and general provisions for (hazardous) waste management can be adopted in low and middle income economies legislation on waste. (see manuals 1 and 2)

After the development of a legal framework, the following enforcement tools (planning, permitting/licensing, inspection/control, guidance, awareness, economic instruments, environmental agreements, integrated product policy) can support the implementation and enforcement of the legal requirements set. Throughout their application, they will also help to identify needs for additional legal regulation in waste management.

• **Waste Management Planning**, including an inventory on national/regional generation as a first step and a main basis for subsequent decision making related to policy and infrastructural investments for HWM, identification and establishment of appropriate infrastructure, technical standards and potential cooperation between regions and with other countries, and instructions for allocation of waste types to appropriate treatment options. Regional and national waste management plans are **important instruments for the implementation and achievement of policies and targets set up in the field of hazardous waste management** (see module 8).

• **Permitting/Licensing/Authorization** is a pre-condition for environmentally sound and compliant waste management **infrastructure**. It includes the necessity for
guidance or training if permitting is in the responsibility of regional and local authorities

- **Inspection/Control** is a pre-condition for the environmentally sound and compliant operation of a waste management infrastructure as well as for the correct allocation of waste types to the appropriate waste treatment option; control includes inspection and monitoring of activities as well as the corresponding prosecution of violations and in general requires effective cooperation between the various competent authorities (CA) involved.

- **Guidance/Education/Training/Awareness Raising**, including technical assistance and information, as well as communication and information-based tools such as eco-labels, special recognition or awards, belongs to one of the most important additional tools to make a new waste management system work. In order to raise awareness and to ensure continuous capacity building, guidance documents for the different competent authorities involved on the national, regional and local level need to be prepared for an efficient knowledge on transfer and enforcement. These might comprise specific advice and explanations e.g. on permitting, control inspections, on how to elaborate and enforce a waste management plan etc. Creating awareness in the industrial sector is also part of this tool, addressing in particular the industry involved in order to convince stakeholders to comply with and support the waste management system. Such awareness raising also aims at influencing the industrial production processes, e.g. to foster waste prevention by new (eco) design and improved hazardous waste management.
Other instruments comprise implementation and enforcement tools such as reduced administrative burdens for certified facilities (e.g. reduced frequency of inspections, or of monitoring and reporting requirements), economic incentives / financial support (e.g. taxes, reimbursement schemes, subsidies, research grants, funding), preferences through green public procurement, environmental agreements and integrated product policy.

It is recommended to take a stepwise approach, starting from more basic requirements to a sophisticated system depending on which level of enforcement system already is in place. But organize measures in a way to ensure and promote constant improvement, expansion and further development of the system.

In addition please be aware that hazardous waste is only a part of waste generated by societies and that a comprehensive waste management system needs to also address any other waste stream.

It is recommendable to establish a registration and licensing/authorization of all actors involved in hazardous waste management

The majority of recommendations provided in this guidance can be applied in principle also for these other waste streams.
For additional information there are also twenty-three Technical Guidelines, seven Training Manuals and five Guidance Manuals published by the Basel Secretariat. View [http://basel.int](http://basel.int) or the Guidance Documents elaborated under the OECD\textsuperscript{126}.

The organization of waste management in a country is, in the first instance, a question of assigning responsibilities. Bodies Responsible can be public institutions on different administrative levels on the one hand and the private economy on the other.

9.2. Main actors

The major actors identified in the management activities are the competent environmental authorities at national, regional and local level, waste producers, waste collectors/transporters and operators of waste treatment facilities. Brokers and dealers may be involved as additional parties, but these last two will not be considered in detail below.

All actors involved in waste management have to fulfill certain duties. Whereas competent authorities (CAs) have major responsibilities in setting up the legal framework, planning, authorization, control and education, the private sector is responsible for proper application and compliance with the established provisions and standards (e.g. classification, separation, collection, transport, treatment, documentation, monitoring and reporting).

Basic allocation of major responsibilities is illustrated in Tables 17 and 18.

Table 17: Responsibilities of competent authorities

<table>
<thead>
<tr>
<th>CA level</th>
<th>Legislation*</th>
<th>Waste Management Planning</th>
<th>Permitting/Licensing/Authorization</th>
<th>Control/Inspection</th>
<th>Guidance/Education/Training/Awareness Raising</th>
</tr>
</thead>
<tbody>
<tr>
<td>CA national</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>CA regional</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>CA local</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
</tbody>
</table>

*including provisions for Waste Management plans, Permitting/Licensing/Authorization, Control/Inspections, Classification, Collection, Transport, Treatment.

\textsuperscript{126} [http://www.oecd.org/department/0,3355,en_2649_34395_1_1_1_1_1_1_00.html](http://www.oecd.org/department/0,3355,en_2649_34395_1_1_1_1_1_1_00.html)
In principle the CA at all different administrative levels (national, regional or local) are responsible for all of the fields of activities as shown in table 10. However, the responsibilities differentiate both in geographical scope and level of involvement and specific task. The responsibilities hence entail different implementation and enforcement activities as illustrated here below.

Fig. 53: Involved authorities and services for waste management planning and related tasks

In general the national competent authorities comprise the following major bodies: the Ministry of Environment, the Environmental Protection Agency/Agencies and the Environmental Inspectorate.

The Ministry of Environment and its departments for waste management are responsible for the development and implementation of a legal framework in harmonization with the State environmental legislation. In addition, the ministry’s task is to elaborate national waste policies setting priorities for action and defining long-term objectives. The ministry is further in charge of waste management planning on a national scale which usually includes the development of a national waste management plan. The ministry is also responsible for the overall supervision of practical enforcement of national waste legislation.

The Environmental Agencies and Environmental Inspectorate usually work in close cooperation with the Ministry of Environment to support the completion of the above mentioned tasks. While Environmental Agencies often carry out scientific studies and elaborate guidance documents, it is also evolved in permitting and supervision of enforcement.
On regional level, Regional Agencies and Regional Environmental Inspectorates provide regional waste planning (development of regional waste management plans), support practical enforcement. These administrative bodies are also of high importance to control proper enforcement and to carry out inspections of waste treatment and disposal facilities in their specific region.

On local level Municipalities are in charge of the practical enforcement. This includes activities related to permitting, management and control. Often municipalities are responsible for local waste collection infrastructure, collection schemes and organization of waste collection in cooperation with private service companies.

Apart from these competent authorities, a number of additional associations, industry stakeholders, NGOs and scientific institutions might be involved in the above mentioned waste management planning activities. They are present on all different levels.

Table 18: Main private sector actors* and specification of responsibilities for each actor involved in (hazardous and non-hazardous) waste management which has to be reflected in relevant legal framework

<table>
<thead>
<tr>
<th>Actor</th>
<th>Classification</th>
<th>Separation</th>
<th>Preparation for transport including labeling</th>
<th>Documentatation/ Reporting</th>
<th>Collection</th>
<th>Transport</th>
<th>Treatment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Producer</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Collector/Transporter</td>
<td></td>
<td></td>
<td>X</td>
<td></td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Operator of treatment facility</td>
<td></td>
<td></td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Actors involved in waste management are mainly: producer, collector, transporter, operator of facility, waste management associations

9.3. Practical aspects: responsibilities and duties of main actors

9.3.1. Responsibilities and duties of the competent authorities

Governments can be considered the backbone of the implementation of waste management programs and activities. Regional expert centers (e.g. inspectorates, cleaner production centers or Basel Convention focal points) are key elements needed to implement the established policies at the regional and local level. The mobilization of the industry and non-
governmental organizations is important to ensure the practical application of environmentally sound management.

Regional authorities or expert centers can play an important role in developing inventories, technical guidelines that address specific wastes streams, adapting the existing technical guidelines to their region, and organizing training and awareness raising workshops. They can cooperate and coordinate synergies, promote capacity building, technology transfer and information on the environmentally sound management of hazardous wastes and other wastes; all with the objective of preventing damage to health and the environment at national, sub-regional and regional level. Effective waste management requires coordinated inter-Government environmental policies, a strengthening of environmental management, establishment of National Agencies for Environment and Forestry and Natural Resource, etc. (See Basel Convention report on the implementation of a strategic plan127)

(1) Legislation (regulatory instruments)

Authorities of different administrative levels should be responsible for the drafting of hazardous waste legislation, taking into account the principles of environmentally sound waste management and approaches of representative legislation (e.g. Basel Convention model legislation (see reference 47), OECD Guidance manual on Waste Management128. EU Waste Framework Directive 2008/98/EC129). Authorities should be in charge to assign specific responsibilities and obligations, duties for all actors involved in waste management. Further, the CA should ensure that the main actors are involved in consultation processes to achieve awareness and acceptance of the legislation. Both aspects will crucially influence the implementation of hazardous waste legislation. Major regulatory instruments are treatment bans (e.g. landfill ban), the setting of environmental standards (maximum emissions limits to air, water, soil), recycling targets or minimum percentages of recycled material used in products.

(2) Waste Management Planning (WMP)

Administrative bodies of national, regional and local level should start the preoperational tasks as a step in preparing the planning procedure. The authorities should take care of the involvement of all affected actors so as to obtain all the needed information and to elaborate the best solutions for hazardous waste management. Major outcomes from WMP need to be appropriate collection and separation schemes for recyclables and an appropriate treatment

infrastructure comprising recovery and disposal facilities. Such infrastructure can be completed by suitable cooperation with other countries or regions in the form of waste transport in order to be viable.

(3) Permitting/Licensing/Authorization

The preparation of permitting formats, and therefore the definition of minimum standards for facilities, should be in the responsibility of national (or regional) authorities. The authorities should also be involved in the administration and control of such permitting formats which includes the issuing of permits and approval of the latter in the case of applications.

(4) Control/Prosecution

Authorities should ensure frequent controls of treatment and disposal facilities with specialized experts. In EU Member States, typically, enforcement bodies (such as national and regional inspectorates) are in charge of inspections and control visits. They are also responsible for the documentation of such visits.

5) Guidance/Education/Training/Awareness Raising

National and regional authorities should elaborate guidance documents for the main actors involved. In addition, information dissemination via internet, publications, workshops etc. for involved parties should be supported and organized by the authorities. Technical support in applying for environmental management schemes (e.g. helpdesk services, information events), information on innovative initiatives and technologies (e.g. via data base services, workshops, etc.), eco-labels and awards are further approaches that can be applied in this context. Further educational, communication and information-based instruments are information campaigns, brochures on various topics, such as separate collection, etc.; Education and awareness are preconditions to understanding the importance of a proper hazardous waste management and its complexity. Awareness and acceptance of regulations by the industry crucially influence the success of the implementation of hazardous waste legislation.

The Basel Convention considers raising the awareness of waste and recycling business and industry about where to send waste and where waste/resources end up as an important aspect in the successful enforcement of ESM (Environmental Sound Management). It can help to improve reuse, recycling and recovery as well as waste minimization. A possible tool for awareness raising, could be pilot programs run with industry involvement. (See Basel Convention report on implementation of strategic plan 2010)
Information exchange should also comprise interaction between CAs, waste experts and waste producers. If waste management service providers (collectors, transporters, and/or plant operators or the corresponding associations) make producers aware of the difficulties they face when recycling end-of-life products, the producers will be in a better position to design products that can be recycled more easily in an environmentally sound manner and may thus increase the recovery of wastes (source: OECD Guidance Manual on Waste Management). This approach is also known as ‘integrated product policy’ and is in line with Extended Producer Responsibility (EPR) policies. The fora where this information exchange could take place include sectoral trade and industry associations, conferences, journals, but also internet sites such as web-based markets for secondary materials or “platforms” where industrial producers, retailers and consumers can exchange information on take-back systems, collection, recycling and disposal of end-of-life products.

(6) Other instruments

Competent authorities can establish reduced administrative burdens for facilities that comply with certified environmental treatment standards e.g. via reduced frequency of inspections or lowered monitoring and reporting requirements. This may even comprise permitting, in terms of combined permits, in case various schemes exist. It is important however, that measures for the reduction in administrative burdens target administrative costs and not on an elimination of control as such. Furthermore CAs can establish economic incentives/financial support by means of introducing (e.g.) taxes, reimbursement schemes, subsidies, research grants or, funding.

Further potential instruments are policy approaches based on well-known principles, such as voluntary environmental agreements such as partnerships with the industry, take-back programs, integrated product policy or „Design for Environment (DFE)“ that adopt a life-cycle approach and green public procurement. Public authorities can also benefit from being involved in the exchange of information. Here below some examples of other instruments/additional enforcement tools

**Reduction in administrative burdens** may be used as incentives to increase the number of facilities that apply and implement environmental certification and management standards. Administrative burdens for facilities that comply with certified environmental treatment standards could be minimized, e.g. via reduced frequency of inspections or monitoring and reduced reporting requirements. This may even comprise permitting, in the form of combined permits in case various schemes exist. It is, however, important that measures for reduction

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130 Waste management service providers (including plant operators and associations), scientist, other competent stakeholders including NGOs.

in administrative burdens target administrative costs and **not** on an elimination of control as such.

**Market based instruments** are in general economic instruments such as taxes, charges, product fees etc. They can be applied to subsidize environmentally friendly treatment and disposal and to make undesirable options more expensive. Economic instruments help to realize environmental, economic and social policy objectives simultaneously and are an effective tool to provide a stimulus for producers to change their behavior/production in favor of more eco-efficient use of natural resources and the utilization of less hazardous substances. Main economic instruments used in waste management are e.g. taxes and environmental charges.

Certain treatment options such as uncontrolled landfill could be penalized by additional taxes, environmental funds could be used to reimburse facilities or local authorities and having installed or using a good treatment infrastructure. Facilities with an EMS may be wholly or partly exempted from registration/permit licensing fees, and part of their EMS implementation costs may be reimbursed. Deposit-refund systems may be suitable in order to promote separation and collection of hazardous waste types. Research grants and other methods can be offered for the development of new waste management options (e.g. elimination of hazardous waste streams or conversion of hazardous wastes into useful products).

Note: Aim at designing economic incentives in a way that environmental and human health costs resulting from waste management practices (external costs) are reflected in the financial costs of waste management. If financial costs of waste management are less than total social costs, waste generators and managers may not have sufficient incentive to adopt an appropriate level of waste management within their facilities. In the same way, any environmental benefits of production from waste should be internalised into waste management decisions at the facility level. (see OECD recommendation 8; OECD Guidance Manual on Environmentally Sound Management of Waste)

In addition, but normally to a smaller degree, environmental subsidies and incentives or tradable permits can also be used in (hazardous) waste management.\(^{132}\)


The OECD provides an “Environmentally Related Taxes Database” with pre-defined queries on national taxes, including waste taxes available at: www.oecd.org/env/policies/database
Voluntary agreements envisage the voluntary participation as well as the voluntary agreement of industries with the government/competent authorities. For hazardous waste, this can be realized via take-back programs or via integrated product policy or „Design for Environment (DFE) approaches reducing the hazardousness of the generated waste by replacing substances“, for example.

The Basel Convention report\(^\text{133}\) on the Implementation of Strategic Plan 2010 concludes that it is important to achieve Partnership Program with active involvement and support of industry and business organizations and nongovernmental organizations in order to work on BAT and BEP in waste management for specific waste streams. It is considered an important approach to waste management by the Basel Convention. In this context, guidance developed e.g. by the Basel Convention may be used as a starting point and guideline model (see [www.basel.int/techmatters](http://www.basel.int/techmatters)). A study carried out by the European Environmental Agency is available at [http://reports.eea.eu.int/92-9167-052-9](http://reports.eea.eu.int/92-9167-052-9).

Detailed information and recommendations on appropriate schemes for Extended Producer Responsibility (EPR) are provided in the following OECD documents\(^\text{134}  \text{135}  \text{136}\).

Green Public Procurement can be an important instrument to privilege enterprises that are branches of an industry innovative and ambitious in reducing environmental hazards from production and waste through appropriate management. A detailed guidance on the advantages and limitations as well as the practical application of green public procurement is described in a manual developed by the OECD\(^\text{137}\).

Additional information and details on appropriate policies and instruments to achieve Sustainable Material Management (SMM)\(^\text{138}\) and waste prevention and minimization\(^\text{139}, \text{140}\) have been developed by the OECD.

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9.3.2. Responsibilities and duties of the waste producer

The ‘waste producer’ refers to anyone whose activities produce waste (original waste producer) or anyone who carries out pre-processing, mixing or other operations resulting in a change in the nature or composition of this material.

(1) Classification

The waste producer usually possesses the best knowledge of the generated waste as he is informed about the raw materials used in the production process and the technologies applied.

He should be in charge of the proper classification of his waste. If already available, the national classification system should be used. In any case, a basic characterization with the indication of the main physical and chemical properties is necessary. Further, information on other hazardous properties should be indicated, such as “explosive”, “corrosive” etc. If possible, indications for the appropriate waste treatment could already be given (e.g. methods of stabilization).

(2) Separation

The waste producer should be responsible for the separation of non-hazardous from hazardous wastes and, if possible, the sorting of waste according to its properties.

(3) Preparation for transport

The waste producer should be in charge of organizing environmentally safe transport of the waste. Often, this is best organized in cooperation with specialized collection and transport companies. The preparation for transport includes also correct labeling of the waste.

(4) Documentation/Reporting

The waste producer should report frequently on the generated amount of hazardous waste in his facility and document all information related in regard to the waste’s properties and to which treatment or disposal facility the waste is transported to.

(5) Collection

The waste producer should be liable for the appropriate waste collection, also when carried out by a third party like a contracted company.

(6) Transport

The waste producer should be liable for proper waste transport, also when done by a third party, like a contracted company.

(7) Treatment
The waste producer should take care that the wastes will be treated (recycled, disposed of, etc.) in proper way.

9.3.3. Responsibilities and duties of the waste collector/transporter

The responsibilities and duties for the waste collector are similar to the ones of the waste transporter; they can act as notifiers (similar to waste producers) under, EU Regulation 1013/2006 on the Shipment of Waste.

Note: Waste collection and transport companies should be authorized by CA and registered in a national register for licensed/authorized waste collection/transport companies. In addition, the waste collector/transporter should be a registered company obtaining a license for transporting hazardous waste. The waste collector/transporter needs to meet standards for hazardous waste transport. He should be obliged to train his drivers and staff involved. Only through proper education and training, compliance with environmental and safety requirements can be ensured.

(1) Collection

The waste collector/transporter should be responsible for adequate waste collection. This also includes the preparation of the waste for safe transport (e.g. packaging of hazardous waste).

(2) Transport

The waste transporter should be in charge of safe transport of the waste in relation to the environment and human health, also considering occupational health. The waste collector/transporter has to ensure that the hazardous waste is correctly packaged for transport and that certain precautions for transport action are taken.

9.3.4. Responsibilities and duties of operators of waste treatment facilities

The waste treatment facility should be registered and obtain a license for hazardous waste treatment. The related standards should be legally binding and set by competent authorities. The permits/authorizations may only be issued in case the standards are respected and met by the facility.

Separation

In case the waste is not yet separated, the first operation activity of the operator should be to separate the waste for proper further treatment.

Documentation/Reporting
The operators of waste treatment facilities should be in charge of frequently reporting on the waste they accept for treatment and disposal. In addition to the quantity of waste, basic characterization/information on the types of waste should also be submitted to the competent authorities.

_Treatment_

Waste treatment facilities should be obliged to comply with legally binding provisions and standards with regard to waste acceptance procedures and should be responsible for controlling and monitoring of the waste treatment and disposal facility. Landfill operators should be obliged to monitor the landfill (e.g. emissions etc.) also after its closure (after-care). After-care is a very important aspect needed to ensure the protection of the environment and human health.

- Permitting and inspection/control (HW incinerators and landfills)

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Good permitting is an important basis for any effective monitoring and control, because all major requirements (technical and operational) to be complied with by the plant operator are generally set and specified in the authorisation document (license or permit) of the individual plant.

The introduction of registration and permits implies the establishment of concrete control measures and of penalties applicable to infringements.

Specific provisions for authorization, including constructional requirements, operational practice, monitoring, aftercare and financial guarantees are defined in EU waste legislation (Landfill Directive -Dir. 1999/31/EC-, Waste incineration -Dir. 2000/76/EC- and IPPC installations -Dir. 2008/1/EC-). 141

According to Articles 23-26 of Directive 2008/98/EC, waste treatment installations need to be registered and need a permit/authorization for their activities.

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141 The integrated pollution prevention and control (IPPC) Directive aims at minimising emissions from major industrial sources throughout the European Union by setting permitting, reporting and monitoring requirements and be requesting to use best available techniques (BAT). The Directive will be replaced by new EU Industrial Emissions Directive 2010/75/EU that shall be implemented by 2013 in EU Member States.)
Example from Egypt: according to the Ministry of State for Environmental Affairs, Egyptian Environmental Affairs Agency and Egyptian Pollution Abatement Project: Hazardous Waste Management – Inspection Manual, 2002 the following information (adopted and partly changed) - provided by industrial establishments and other parties managing (hazardous) waste- is required for the issue of a permit:

<table>
<thead>
<tr>
<th>Topic</th>
<th>Minimum information to be provided</th>
</tr>
</thead>
<tbody>
<tr>
<td>Waste description/Basic characterization</td>
<td>Provide complete description of the types and composition of the hazardous substances used within the production process and the hazardous waste generated</td>
</tr>
<tr>
<td>Waste quantity</td>
<td>Determine the (annual or if not applicable occasional) quantity of the hazardous substances used and the hazardous waste generated</td>
</tr>
<tr>
<td>Storage of the waste</td>
<td>Describe the intended mean of HW packaging (barrels, tanks etc.)</td>
</tr>
<tr>
<td></td>
<td>Describe the period and storage methods/conditions of hazardous substances an hazardous waste</td>
</tr>
<tr>
<td></td>
<td>Be committed to clearly label the containers of hazardous substances and hazardous waste indicating the content and the actions taken in the case of emergency</td>
</tr>
<tr>
<td>Waste transport</td>
<td>Describe the intended modes of hazardous waste transport, routing and time schedule; if applicable also the transport company</td>
</tr>
<tr>
<td>Waste treatment</td>
<td>Provide a comprehensive description of the intended hazardous waste treatment and disposal (describing the treatment processes and methods the waste is intended to undergo)</td>
</tr>
<tr>
<td></td>
<td>If applicable indicate the envisaged treatment facility</td>
</tr>
<tr>
<td>Emergency plan</td>
<td>Provide detailed information on the emergency plan for accidents/uninspected incidents</td>
</tr>
<tr>
<td></td>
<td>The plan should be reviewed and approved by the the permit issuing authority</td>
</tr>
<tr>
<td>Previous experience</td>
<td>Provide documents for previous experience in the management of hazardous substances and hazardous waste</td>
</tr>
<tr>
<td>Commitments</td>
<td>Provide a written commitment to the following:</td>
</tr>
<tr>
<td></td>
<td>No mixing of hazardous substances and waste with other hazardous or non-hazardous substances and waste</td>
</tr>
<tr>
<td></td>
<td>Take all necessary (legally defined) measures for proper packaging storage and transportation of hazardous waste</td>
</tr>
<tr>
<td></td>
<td>Keep records of the waste as defined by legislation</td>
</tr>
<tr>
<td></td>
<td>Keep documents at least for the legally defined period (e.g. 5 or 10 years)</td>
</tr>
<tr>
<td>Declaration</td>
<td>Provide a declaration of the correctness of the indicated data</td>
</tr>
</tbody>
</table>

Permits/Licenses for the management of hazardous substances and waste should be valid for a limited period (e.g. for five renewable years).

The permit should be suspended by the competent authorities by justification in the following cases:

1. If the permit/license has been issued upon the submission of incorrect information.
2. If the party granting the permit/license has not fulfilled or violated its conditions.
3. If an activity results in severe adverse effects on human health and the environment which were not foreseen at the time of permit issuance.
4. If new technologies become available, that may, if implemented with minor modification result in considerable reduction of the negative effects during production process and waste management.
5. If competent authorities conclude that it is unsafe to manage the hazardous substances and waste under the given conditions as declared.
The information provided should be also contained in the waste register.

**Basic principles and questions related to waste management authorization / permitting**

Competent authorities need to answer the questions listed in Fig 54 and have to overcome the deficits and solve the problems that are commonly related to permitting. Such deficits are mostly related to the ‘expertise’ of the competent officer responsible for permitting. In this context, it has to be taken into consideration that the authorization of a major waste management facility is not a standard procedure, but normally only occurs once or few times in the professional carrier of a policy officer.

- How to realise the basic permit requirements in practice?
- How to prevent that facilities work without permit?
- How to structure permits to achieve optimum compliance with intended objectives?
- Expertise of responsible expert
- Interpretation of legal provisions
- Knowledge of BAT/BEP for landfilling
- Knowledge of critical aspects in permitting

**Fig. 54** Major priorities (?) and potential deficits (-) in waste management permitting

In general, authorization documents should specify on the following 12 aspects of waste management as compiled in the box here below.

1. Operational procedures
2. Training/expertise
3. Technical requirements for landfill construction
4. Gas recovery, leachate treatment
5. Acceptable wastes and limits
6. Monitoring requirements
7. Acceptance procedures
8. Pre-treatment requirements
9. Closure and aftercare
10. Information and documentation
11. Definition of offenses and according penalties
12. Financial guarantee

These different aspects could be reflected in the permit document as individual chapters specifying in detail the procedural requirements and technical features that have to be complied with.

Due to the fact that local or regional authorities commonly responsible for authorization do not have all necessary background knowledge and expertise on how to draft an ideal permit document, it is advisable to establish guidance documents/trainings and standards on a national scale. Model information for potential contents of permits can be derived e.g. from EU legislation on integrated pollution prevention and control (Directive 2008/1/EC), the Waste Incineration Directive 2000/76/EC or the EU landfill directive 1999/31/EC, as well as the upcoming industrial emissions directive as soon as it has entered into force.

Additional examples of how training and guidance on permitting could be implemented and enforced at national level can be found in the following box.

| 1. Inclusion of concrete permit conditions and related aspects in national legislation |
| 2. Development of a standard structure for permit documents (structures following legal documents in order to cover all aspects) |
| 3. Guidance documents (e.g. waste permit/license condition document) |
| 4. Regular (e.g. annual) workshops for all experts responsible in regional authorities |
| 5. Helpdesk function in competent central authority |
| 6. Notification of an up-coming permit to the central authority and other stakeholders |

**Register for waste treatment activities**

Not all waste management activities are sufficiently complex and associated with environmental risks in order to justify a permitting scheme including monitoring and reporting obligations and regular control by competent authorities. Nevertheless, it is considered important and recommended to get and remain in control of the waste management system in all phase of the treatment chain and eventually even to establish certain minimum standards for such services.

For this purpose any persons or enterprises dealing with (hazardous) waste -such as collectors, transporters, dealers and brokers- should apply for and be registered in a central
register, and only registered companies should have the right to perform waste management activities.

**Basic principles and questions to be answered in waste management controlling**

Facilities and enterprises involved in waste management and subject to authorization schemes or obligatory registrations need to be controlled in order to verify compliance with the set provisions.

Competent authorities control activities should comprise inspection visits of:

- Hazardous waste treatment installations (e.g. physical treatment installations, chemical treatment installations, biological treatment installations, incineration facilities, hazardous waste landfills)
- Professional collectors or transporters of hazardous waste (inspections should cover the origin, nature, quantity and destination of the waste)
- Brokers and dealers of hazardous waste
- Hazardous waste producers

In order to ensure that hazardous waste is managed adequately the control of other actors involved in (non-hazardous) waste will also be necessary.

A checklist for hazardous waste inspection is available in Annex 3 to the Manual.

In addition, **competent authorities should prohibit the abandonment, dumping or uncontrolled management of hazardous waste.**

The introduction of a waste management control system should help to answer the questions listed in Fig 55 and should thus be suitable to overcome the deficits that are commonly associated with waste management control from the perspective of the authorities involved.
Organization of inspections

For the proper and efficient organisation of inspections, a relevant inspectorate infrastructure needs to be set up, comprising the elements listed in the following box:

1. National, regional, local inspection authorities
2. Waste experts/departments on all levels of inspectorates
3. Supervision, coordination, harmonization, training, information exchange function of central authority
4. Coordination officer for the management of the complete waste chain (permit, control of producers, treatment facilities, waste shipment) and cooperation with other authorities involved (police, customs)
5. Waste units in operational customs and police services
6. Mobile customs and police units, environmental emergency units in inspection authorities

As regards inspection and monitoring, the following aspects should be covered and taken into account by competent authorities:

1. **Risk analysis / strategic planning** of inspections and monitoring activities (in order to determine which areas and operations should be prioritised)
2. **Realisation of inspections** including most appropriate methods
3. Information on how **waste classification** should be taken into account when planning and organising the inspections
4. **Follow-up** and **reporting** including administrative **ruling**, **court decision** and **penalties**

For both permitting and inspection, **training and guidance** for competent authorities of the different levels will be needed. It is also recommended to organise effective **networking** amongst officials in competent authorities on local, regional and national level to ensure highly efficient controls.

**Environmental inspection cycle**

![Environmental inspection cycle diagram](image)

**Fig. 56**: Planning measures to assure effective control [inspired by: Doing the Right Things II_2008]

Fig 56 shows a simplified environmental inspection cycle developed by the European Union Network for the Implementation and Enforcement of Environmental Law (IMPEL), an international association of environmental authorities in Europe within the project “Doing the Right Things II” [142].

The four main inspection steps/stages and corresponding sub-topics are briefly introduced in the following:

**Strategic Planning of Inspections and control actions**

Strategic planning is a cyclic process, since review of the inspection plan may lead to the development of a new inspection plan or modification of the existing one. The strategic planning process, described in the IMPEL document contains four main steps (i.e. describing the context, setting priorities, defining objectives and strategies and planning and reviewing).

In the first step ‘**describing the context**’ the inspecting authority looks at its statutory tasks.

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The scope of the inspection plan is set and the necessary information is collected for performing a risk assessment. In the second step ‘setting priorities’ the risk assessment is performed, which results in a list of installations or activities that are ranked and classified. Besides, in this step the list of priorities is developed, which is the input for the next step ‘defining objectives and strategies’. Within this step the authority responsible for inspections identifies quantitative and qualitative inspection objectives and targets. The inspection strategies can be defined or modified in order to meet the set objectives and targets. The output of this step, the objectives, targets and inspection strategies will be part of the input to the next step. In the last strategic planning step, the ‘inspection plan’ is developed, including inspections schedules and ‘reviewing’ of the process.

**Execution Framework**

Before inspections can be executed, it is obligatory to meet all given requirements / conditions. The working procedures and instructions, powers and competences, equipment and other resources should be in place by now.

**Realization of Inspections**

In this step the actual inspection work is done. The routine and non-routine inspections are carried out and reports of findings are composed. The inspection reports, also including accidents, incidents, occurrences of non-compliance etc., have to be stored in an easy accessible database. Furthermore, this step possibly includes the exchange of information with partner organisations.

**Monitoring/Follow-up of inspection and control activities**

To ensure that all objectives and targets are met, it is necessary to monitor the emissions of waste management facilities. This information can then be used for reviewing the plans and for reporting to different stakeholders, e.g. at regional or national level. Based on the monitoring results, the inspection plan should be reviewed and possibly amended.

**Effective control of all activities related to hazardous waste generation, transport and treatment**

Effective control of all activities related to hazardous waste generation, transport and treatment is important to assure compliance with set legal provisions and requested environmental standards. In order to become efficient, controls should be backed by appropriate infrastructure (e.g. network of trained inspectors, cooperation and information exchange with other authorities) and need to be well planned and targeted using hazard assessment and risk profiling.

For more details see EU guidance and practical toolbox on permitting and inspections at [http://ec.europa.eu/environment/waste/framework/inspections.htm](http://ec.europa.eu/environment/waste/framework/inspections.htm)
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• Module 6a

• Incinerators and Air Pollution Control
Hazardous Waste Incineration

10.1 Process

The combustion of carbon-rich waste does not differ with respect to the chemical-physical processes occurring from combustion of the well-known standard fuels for energy production. The main chemical reaction is:

\[ C + O_2 \rightarrow CO_2 + 393.77 \text{ kJ / mol of C} \]

In other words, carbon is converted to carbon dioxide emitting a high amount of energy. Besides the oxidation of carbon, also hydrogen which is contained in the waste gets oxidized to water during the combustion process. Sulfur is oxidized to sulfur dioxide, and also other quantitatively less significant components of the waste are oxidized, which proportionally increases the amount of energy being released.

The total amount of energy being released through waste incineration depends on the water content of the waste and on the amount and composition of organic content in the waste. Thus, it is possible to calculate from the elemental composition (mainly C, H, O, N, S) and the water content of the waste, the expected energy (commonly known as heating value). This calculation of the elemental composition provides a good estimation which is very close to reality.

The heating value can also be determined by analysis in the laboratory (using a calorimeter).

When stating the heating value the upper heating value is distinguished from the lower. The lower heating value is relevant to techniques where the generated water passes the exhaust chimney in gaseous state. The upper heating value is of importance for the use of techniques where the water leaves the procedure in liquid state. In general the lower heating value is critical and determinative for the incineration of waste. The lower heating value can be calculated from the upper heating value.

Waste incineration as a part of waste management is used to utilize the existing energy contained in the waste. Thus, waste incineration plants are combined with steam generators. The generated steam is converted into electricity using turbines and generators. This electricity can be used for personal purposes, while the surplus can be fed into the grid. In some cases it is also possible to use the residual heat of the steam for electricity production (cogeneration; combined heat and power).
Two other purposes of waste incineration are reducing both the volume and the danger of the waste. For incineration of hazardous waste, the reduction of the waste’s dangerous potential is the primary purpose. From highly toxic or technically dangerous wastes emerge less concerning slag and ashes. The generation of energy is also an important purpose, but not the main motivation for the incineration of hazardous waste.

- **10.2 Available incineration techniques**

For more than 30 years it has been argued about the question of the most appropriate method of hazardous waste disposal. The rather experimental suggestions include high temperature processes such as the plasma technology, induction technology, chemical reactors, or gasification process.

Through investments in the experimental domestic and hazardous waste sector, Germany made expensive errors in the amount of more than one billion DM during the 1990’s. Many market participants, whose "inventions" failed in this period, are still active at the market. Therefore, at this point great caution should be exercised when techniques that have failed in industrialized countries, are about to be used in developing countries.

For example, in Germany several projects that used special gasification technology to treat waste, called pyrolysis, failed repeatedly. Here, the tightness of the system had been technically problematic in a number of cases. Furthermore it turned out that the products could not be reused and had to be considered as hazardous waste once again.

- **10.3 Rotary kiln incineration technique**

In the Western industrialized countries, the rotary kiln has prevailed as the preferred technology as a hazardous waste incinerator. A major reason was, and still is, its robustness.

A hazardous waste incinerator of this type is constructed with units as follows:

- Volume measurement and inspection of the input
- Temporary storage of waste and equipment resources
- Waste pretreatment
- Loading/feeding facilities
- Incinerator facilities
- Power generation

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- Exhaust gas treatment and chimney
- Wastewater treatment and discharge
- Storage for ashes, slags, etc.
- Infrastructure facilities

Fig. 57: Rotary kiln of the hazardous waste incineration plant in Schwabach (Germany)
Fig. 58: Scheme of a rotary kiln incinerator (source: INDAVER at http://www.indaver.be/Rotary-kiln.1728.0.html?&L=0)
10.3.1. Volume measurement and inspection of the input

The entrance area should have a scale to record the amount of waste by its weight.

Further, it is necessary to have inspections of the incoming waste at the entrance. For this purpose it is helpful have constructions that allow the staff to inspect the loading surface of the truck and also to safely take samples without much climbing. It is necessary to have space for waiting and storage of several trucks outside the actual facility. This is necessary to refuse passage to vehicles, till abnormalities or other open issues can be resolved.

The operation of a hazardous waste incinerator should be assisted by a qualified on-site laboratory. The laboratory works in close coordination with the input inspectors.

The laboratory will inspect of the incoming waste by the initial analysis. In the case of recurring deliveries the laboratory has to check the conformity of the delivery with the known waste quality (conformity analysis). The laboratory plays an important role for the design of the waste menus and burning schedule. Furthermore, the laboratory can be involved in advising clients.

10.3.2. Temporary storage of waste

Experience from plant run operation in Europe show that the incoming waste can strongly differ in its physical and chemical nature. The mass of waste streams can also be liquid, pasty or even solid. The delivery is often dominated by solid wastes with a 40% share, while pasty (35%) and liquid wastes (25%) can also form a high share. Therefore, adequate storage space must be provided for all three types of waste. Also additional space for the required treatment and the application techniques is needed.

In general, the different types of wastes are delivered irregularly. It is therefore necessary to hold up sufficient storage volumes. In some cases it may also be necessary to temporarily store waste while waiting for laboratory results.

The storage facilities are provided for solid waste and barrels as well as for liquids and pasty wastes. In practice it has been proven of value, to store the waste separately according to its consistency (solid, pasty, liquid). Further, it is necessary to keep reactive waste separate in these storage facilities. Here, safety distances and facilities to collect volumes of leaking material are of importance.

The storage itself is a security risk and is therefore built to an advanced technical level. Fire protection regulations must be complied as well as prevention and control facilities constructed for preventing hazardous waste emissions to the air and from sewage to running waters or ground water.
For some storage areas a potential explosion risk is also assumed. In addition to the usual precautions sufficient ventilation of those storage areas must be assured. A suction of the supplying air to the incinerator can be created through the appropriate arrangement of the bearings and the technical facilities.

Hazardous waste incineration plants require the temperature in the combustion chamber to exceed the heating value of the hazardous waste itself. Since the incoming wastes have very different qualities, it is necessary to offer the system a menu of waste, which combines the high-caloric and the rather low-caloric wastes so that the necessary energetic operating conditions, the minimum temperature, will be reached. The burning schedule then determines how the menu is being modified over time. It determines the different kinds of waste, when they are to be incinerated and what amounts per unit of time can be put into the incinerator. In addition to maintaining a minimum temperature, it is also important to consider that the amount of the input can cause excessive heat in the furnace and implement an energetic overload of the system.

To execute storage and subsequent combustion without interference, the delivered waste should be preconditioned. The preconditioning is to be accomplished by the waste producer or by an authorized service provider. Table 19 below shows a selection of key points of a conditioning framework.

<table>
<thead>
<tr>
<th>Requirements</th>
<th>Solid waste</th>
<th>Pasty waste</th>
<th>Liquid waste</th>
</tr>
</thead>
<tbody>
<tr>
<td>Delivery</td>
<td>Container, loading/cargo area</td>
<td>Container, tanker</td>
<td>Container, tanker</td>
</tr>
<tr>
<td>Consistency</td>
<td>Solid, dry, pourable</td>
<td>Pasty, pumpable</td>
<td>liquid, pumpsble</td>
</tr>
<tr>
<td>Size</td>
<td>Edge length &lt; 500 mm</td>
<td>Particle/grain size &lt; 50 mm</td>
<td>-</td>
</tr>
<tr>
<td>pH-value</td>
<td>5 – 9</td>
<td>5 – 9</td>
<td>5 – 9</td>
</tr>
<tr>
<td>Heating value, Hu</td>
<td>&gt; 9.000 kJ/kg</td>
<td>&gt; 9.000 kJ/kg</td>
<td>&gt; 2.000 kJ/kg</td>
</tr>
<tr>
<td>Density</td>
<td>-</td>
<td>&lt; 1.5 g/cm³</td>
<td>&lt; 1.2 g/cm³</td>
</tr>
<tr>
<td>Content of pollutants up to %</td>
<td>Chlorine 10, sulfur 1, PCB 0,1, alkali metal 2</td>
<td>Chlorine 10, sulfur 1, PCB 0,1, alkali metal 2</td>
<td>Chlorine 10, sulfur 1, PCB 0,1, alkali metal 2</td>
</tr>
</tbody>
</table>

Table 19: Examples for the determination of a conditioning framework for delivered hazardous waste
10.3.3. Waste pretreatment

In hazardous waste treatment plants waste preconditioning plays no major role as the conditioning frame enforces pretreatment by the waste producers. In individual cases, the mixing of waste or the separation of high water contents may be required, for example, if an error occurred in the confirmation analysis. Often it is not easy for smaller companies to perform the necessary conditioning themselves (such as gas stations with oil separators). In this case chemical-physical treatment plants (CPB) offer their service. If these are not on the market, the hazardous waste treatment facility itself can expand its service to offering and providing chemical-physical pretreatments to waste producers if it is technically equipped for this purpose.

In designing the incinerator it should be audited whether the region is in a need for chemical-physical waste treatment (CPB) plants. It may be useful in some cases, to integrate required CPB plants into the hazardous waste incinerator facility as a pretreatment plant.

10.3.4. Feeding devices

Different feeding techniques are available for hazardous waste incineration. The system is loaded from the front side of the rotary kiln.

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Fig. 59: Cross section through a rotary kiln for the incineration of hazardous waste

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Solids are given over a gripper into a receiving hopper and fall in the direction of a “door” on the front side of the rotary kiln, which can be opened for loading. Barrel content can also be placed into the oven as seen in Fig. 59 by “drum feeding”.

The establishment of gates with electrically locked doors ensures that the content released from the barrels and solids do not make contact with outside air.

In addition to the burner which is operated with conventional fuels such as oil or gas, in the front side lances are mounted to introduce the pasty and liquid waste.

When introducing filled barrels it has been proven in practice to limit the mass to 50 kg in order to master high heating values well when heat is being released from the wastes.

Wastes with high water contents, it has to be ensured that the lining of the furnace are not damaged due to water vapor pressure waves.

10.3.5. Incinerators

The rotary kiln is the technically sensitive part of the whole system. The load-bearing part of the rotary kiln, the rotating drum, which is made of steel, cannot handle the temperatures required for a hazardous waste incinerator without protection. Therefore, the drum is lined with special refractory bricks. The lining is partly built up in layers. It is divided into zones, which vary according to the different load in the type of stone and brick lining. In particularly sensitive areas of the rotary kiln system is also protected by cooling devices (front side, scope, chute and cinder output). In addition, the lining itself should be protected by a “slag fur” even while operating. The “slag fur” consists of mineral residues of the hazardous waste and specifically added additives for the construction of the “fur” such as glass or sand. The “slag fur” may have a thickness of up to 0.5 m.

Due to the extreme conditions the cooling devices, “slag fur” and lining are a sensitive, coordinated system, which requires competent management. With good management, the lining can operate at over 10,000 hours, some even up to 15,000 hours \(^{145}\). If errors occur during operation of the plant, resulting in damage to the lining, the rotary kiln is to be shut down early to repair or renew the lining completely. This can result in several weeks of stagnation and associated logistical and economic consequences.

The rotary kiln has a length of eight to twelve meters. The temperature in the interior of the rotary kiln ranges from 800 to 1400 °C, with a maximum of up to 1500 °C. The flow-rate of hazardous waste incinerators, depending on system design ranges from 0.5 to 20 tons of

waste per hour. Thus, the statement of the flow-rate makes more sense in mega joules per hour (MJ / h)

The rotary kiln is placed at a slight angle so that a transfer of slag to the discharge can take place easily. The rotational speed is infinitely variable (0.05 to 2 rotations per minute) and can be chosen in order to produce optimal combustion conditions in the interior. The residence time of the solid combustible material is 30 to 90 minutes.

Fig. 60: section through a rotary kiln

The combustion air is added in most plants using direct current which is supplied from the cold front side together with fuel and the waste. On the hot side of the rotary kiln slag and flue gases are leaving the furnace. The exhaust gas can have an oxygen content of 7% to 10% in the case of homogeneous loading. In discontinuous feeding with whole barrels of chunky material excess air has to be increased to prevent CO peaks (O₂ content 10 to 11%)

The construction of an afterburner chamber has proven itself in practice. This chamber serves to mineralize carbonization gas fully. The afterburner is also necessary because the

residence time of gases in a rotary kiln would be too short for a complete combustion. As experience has proven it is effective to construct the afterburner chamber so that gases remain in the chamber with residence time of at least 5 seconds and at least 950 °C. To ensure this temperature in the combustion chamber an auxiliary burner is to be used. In addition tertiary air can be introduced; through a lattice, etc. to achieve adequate mixing of the exhaust gases.

Fig. 61: Scheme of a rotary kiln combined with a secondary combustion chamber and feeding systems. (1100 °C and 2 sec are needed if hazardous wastes with a content of more than 1 % of halogenated organic substances, expressed as chlorine, are incinerated)

The afterburner chamber also has a lining to protect itself. While in the upper part of the chamber the high temperature and corrosion constitute the major stresses of the lining, entrained slag droplets are forcing a chemical attack in the lower part. The operational life span of the afterburner chamber can reach, under correct management, over 25,000 operating hours. The rotary kiln itself provides a short operational life span in comparison (up to 15,000).

The solid slags and ashes fall from the rotating kiln in the inlet region to the afterburner chamber in the deslagger. Although it is possible to perform the slag movement in a dry stage, the wet purification has operational advantages and is particularly necessary when the slag may apply proportionately in liquid form.
Whether the slag is obtained as a liquid depends at what temperature it is being operated in the oven. A higher temperature above 1,000 ° C, as it is customary in Germany for the hazardous waste combustion, improves the combustion and the ash quality (being liquid), but increases the demand for energy and the strain on the lining.

The thermal mode of operation is governed by the legal requirements in each country of the system location. If it is not regulated, it must be decided within the framework of the application and the selection of technology!

10.3.6. Energy production

The exhaust gas leaves the post-combustion chamber (also known as afterburner chamber) with a temperature of about 1000 to 1200 ° C. Before the exhaust gas passes into the flue gas cleaning, it must be cooled down to a temperature of 350 ° C. This reduction of the temperature is required in order to prevent the formation of dioxins. The reduction of the temperature can either be done by using a unit of energy or by spraying water without obtaining further energy. Although the latter is energetically not desirable it was decided to use it in some smaller facilities to save the higher investment costs for energy units.

The energy production is due to the construction of heat exchangers into the exhaust gas flow. The hot exhaust gas submits its energy to a water circuit. The water evaporates and the steam is getting superheated. The energy is stored in the vapor and can be converted subsequently into mechanical energy in a steam turbine. Using a generator it can be transformed into electrical energy. This energy can be used and the surplus can be fed into the national grid. Usually the electric energy can be fed into the grid without any problems. The energy contained in the steam can only be converted into about one third of electrical energy because of physical reasons. Depending on the location of the plant, the steam can be sold to a nearby industrial plant for further use. This energy use results in higher efficiency. It is also possible, if required in the vicinity of a location, to couple the demand of heat or cooling energy with energy production (combined heat and power).

10.3.7. Chimney and flue gas cleaning

The quality of the flue gas cleaning is usually essential for public acceptance of a waste incineration plant. The selection of technology, or more precisely, the selection of the concept for the flue gas cleaning, is very complex. Is a concept set for emission control; there are different modules (filter modules, gas washing, and denitrification) to implement this concept.
Basically the political decision-makers should focus on what can be guaranteed by the technology provider. Considering the values of a guarantee, it is important to regard, what is guaranteed and what restrictive conditions are formulated. Furthermore, it is important to know what financial security is insured with the respective guarantees.

Only individual pollutants related reduction rates can be guaranteed reliably. The expected amount of raw gas is the starting point for all negotiations of guarantees. The following table shows the technique described above for the expected amount of raw gas from the combustion of conventional hazardous waste.

Table 20: Selection of typical pollutant concentrations in the raw gas from hazardous waste incinerators in Europe (EU) and Germany (G) and their clean gas emission threshold

<table>
<thead>
<tr>
<th>Pollutant</th>
<th>Unit</th>
<th>Raw gas hazardous waste incineration</th>
<th>Threshold clean gas (daily average) G/EU</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dust</td>
<td>mg/m³</td>
<td>1 000 – 10 000</td>
<td>10</td>
</tr>
<tr>
<td>Mercury</td>
<td>mg/m³</td>
<td>0,05 – 3</td>
<td>0,03</td>
</tr>
<tr>
<td>Inorganic compounds of chlorine as HCl</td>
<td>mg/m³</td>
<td>3 000 – 10 000</td>
<td>10</td>
</tr>
<tr>
<td>Inorganic fluorine compounds other than HF</td>
<td>mg/m³</td>
<td>50 – 550</td>
<td>1</td>
</tr>
<tr>
<td>Inorganic sulfur compounds as SO₂</td>
<td>mg/m³</td>
<td>1 500 – 5 000</td>
<td>50</td>
</tr>
<tr>
<td>Nitrogen oxides as NO₂</td>
<td>mg/m³</td>
<td>100 – 300</td>
<td>200</td>
</tr>
</tbody>
</table>

Individual streams of waste may have high contaminant levels. This must be determined in the initial identification and analysis by the laboratory. Wastes with excessive levels of pollutants above the conditioning framework are to be dismissed. As part of the composition of the waste menus, combining the waste according to their different heating values is not the only task. When creating the menu it should be ensured that the raw gas is left in the field of emission control warranty. The values of the raw gas may be higher if, instead of using a waste menu, monocharges are burnt over a long period. This would be the case treating streams of higher contaminated wastes (such as chlorinated solvents or mercury-containing
waste). In these cases the guaranteed values of the system provider can no longer be maintained and there is a risk that the emission threshold is exceeded.

Thus, the conditioning frame and the control input constitute the first safety barrier of the system. The compilation of waste incineration by using a waste menu and its timetable provide further assurance not to violate guarantee values conditions.

The mandatory limits listed in Table 20 are short-term limits (daily average). They demonstrate which qualitative service the flue gas cleaning systems perform when cleaning the exhaust gas. Since the limits are to be maintained at all times, operating parameters that are dependent on the pollutant type and concentration profile range from 50% to more than 90% below the respective limit. The reduction of the raw gas by the emission control system therefore exceeds a factor of 1000 in some cases.

The higher the achievable purification factor in emission control is the more expensive is the emission control in total. Therefore, the question from an economic point of view is quite understandable if European limits set as listed in Table 20 should be used as guaranteed values for emission control in a developing country. To get from the listed values of raw gas to the listed European values of clean gas, quite high investment and operating costs must be spent. This usually leads to the fact that - at a European level of costs - the emission control becomes the major investment factor (up to 50% for particular high-quality systems).

The European expense in flue gas cleaning in a hazardous waste incineration is usually lower, around 20% to 30% of the total investment volume. Thus, a waiver of emission control facilities would lead to a decrease of approximately 10% to 15% of combustion costs. Of course, no operator would want or should run a plant operating without emission control. Reduced emission control relative to European standards would reduce the costs of combustion. The reduction in costs depends on the standard of the plant and would range from a few percent up to 15%. However, this data only provides approximate guidelines, which cannot replace a more accurate calculation based on technical data of the proposed plant.

A reduction of the limits below European levels can indeed reduce the investment and operating costs for a hazardous waste incinerator, but there are detriments to consider. The European threshold values ensure that the environmental impacts are minimized and health risks to the neighborhood, even in the immediate vicinity of the plant, are not present. One disadvantage to setting higher threshold values is the resulting potential for conflicts with opponents of such a plant, especially in the context of the planning and approval process. The European standard is known to the environmental protection experts as a high but
manageable standard. A low standard (higher thresholds) will certainly be construed as a lack of environmental and health protection. **For the mentioned reasons it is recommended to implement the European standards.** They are the world's most ambitious air quality standards. However, in case of a hazardous waste incinerator, this standard seems justified.

Unless there are special national standards, these are to be used for hazardous waste incineration.

**10.4. Air Pollution Control**

Among the proven components of the emission of waste incineration plants are dust filters, gas scrubbing process, nitrogen removal and addition of sorbents. These devices and methods are described in detail as follows:

- **(A) dust filter**, included for the deposition of dust particles and heavy metals
  - Cyclone filter
  - Electrostatic precipitators
  - Fabric filters
- **(B) gas scrubbing process** for the separation of $\text{SO}_2/\text{SO}_3$, HCl, HF
  - Gas Drying
  - semi-dry scrubbing
  - wet scrubbing
- **(C) A method for the deposition of dioxins and mercury**
  - air flow method
  - fixed-bed reactor
  - Oxidation
- **(D) A process for reducing nitrogen oxide compounds from the exhaust gas**
  (also called DeNox)
  - Selective catalytic reduction (SCR)
  - Selective non-catalytic reduction (SNCR)

**Dust filter**

Dust separation is the most important component of emission control. The separation can take place by a single filter or in several stages. This depends on the desired performance and the concept of emission control. The concept also includes the definition of the temperature, at what the dust filtration is to be held in. Another conceptual issue is also
whether the temperature window in which the dioxin formation (de novo synthesis of 250 - 400 °C) is taking place should be passed as quickly as possible or not.\textsuperscript{147}

As a dust filter are considered: filter cyclones, electrostatic precipitators and fabric filters. Further, dust in the exhaust system can also be deposited by integrated scrubbing stages if necessary. As scrubbers are not usually used primarily for the deposition of dust, but of dissolved gases, they are discussed below under that heading

10.4.1 Cyclone filter

The cyclone filter for dust separation works as a gravity filter. The exhaust gas that is to be purified is forced into the filter or sucked through the filter. Due to the structural geometry of the filter, the exhaust gas is forced along the filter wall in a helical orbit. This slows the flow velocity. Simultaneously transported dust particles are pressed against the filter wall through the exhaust stream. From there, they slide down and fall to the bottom of the filter, from where they are subsequently removed. The purified exhaust gas leaves the system by a tube outlet at the top of the filter.

\textsuperscript{147} The rapid passing of this temperature window can be achieved through quenching of the exhaust gas. In this case so much water is injected into the exhaust gas at a temperature of for example 500 °, that the temperature is lowered in a few seconds to less than 250 ° C. This allows suppressing the de novo synthesis of dioxins. The disadvantage of this method is that by doing this the energy from the exhaust gas is getting "destroyed", the energy is being reduced. The energy in this temperature window can be used alternatively. In this case already in the economizer (last part of the boiler) (also see 10.4.1.) the de novo synthesis is taking place. The dioxin formation can continue in the ensuing dust filter. This reaction does not lead to increased dioxin emissions when a dust filtration with high efficiency is used. The disadvantage is that the fly ash is contaminated with dioxins and exploitation in the economic cycle is no longer possible. Again, this is only a certain disadvantage, because even without the dioxin contamination the fly ash is already heavily loaded, especially with heavy metals. Read more about de novo synthesis dioxins in William J.: Mechanistic investigation of the influence of intra-and intermolecular oxygen transfer reactions and to strikturell related educational trends in the de novo synthesis of PCDD and PCDF, http://bibliothek.fzk.de/zb/berichte/FZKA6489.pdf
Fig. 62: Air flow profile of a cyclone filter (left taken from\textsuperscript{148}, and right taken from\textsuperscript{149})

Fig 62 shows a section through a standard dust filter. Left, the dark spiral shows the incoming dust-loaded gas stream. The white spiral shows how the purified exhaust gas then exits the filter.

The cyclone filter is very robust and can be used over a wide temperature range up to 450 °C. Its disadvantage is that it cannot deposit fine dust. The potential of the cyclones to deposit often ends with particles in the size of less than 5 microns (µm). Therefore, cyclone filters in the field of hazardous waste incinerations should only be used in pre-dedusting and in combination with other dust filters. Cyclone filters compared with the electrical and fabric filters are a significantly more economic solution, both in the capital cost and in the operation.

10.4.2. Electrostatic precipitator

The electrostatic precipitator is a widely used filtration system, which is also used outside the waste management industry and also in the energy industry. It has also high separation efficiency for particulate matter less than 5 microns (µm).

Figure 63 shows the operating principle of an electrostatic precipitator. A very high electrical voltage is applied between two poles. The negative electrode submits electrons which are deposited on the surface and "pent-up", to flowing gas molecules. This results in ionized gas. The gas molecules continue to submit the electrons to dust particles, so that they become

\textsuperscript{148} http://www.mikropul.de/produkte/zyklone/zyklone.php?gclid=COz20rLZiqqCFdA3wodzmYYyg
\textsuperscript{149} http://www.sohanpalmechanical.com/how%20we%20can%20control.html
charged negatively. The charged dust particles are attracted to the positively charged electrode and are deposited there to the surface. When it reaches a certain thickness, due to gravity the layer of dust falls down to where the dust is collected and discharged.

Fig. 63: Operating principle of an electrostatic precipitator, taken from\(^{150}\).

The falling of the dust is supported technically in the filter system by vibration, hammering or knocking against the electrode. Figure 64 shows how such a filter can be set up technically.

Fig. 64: Structure of an electrostatic precipitator, taken from\(^{151}\)

\(^{150}\) http://www.elexindia.co.in/products.htm
The advantage of the electrostatic precipitator is partly because of its ability to be used in a wide range of temperature (even at higher temperatures up to 450 °C). On the other hand also for fine particles to 1 micron (µm) a good retention rate is given. Electrostatic precipitators if compared to the cyclone filters are more expensive, if compared to the fabric filter, are the cheaper option.

10.4.3. Fabric filters

The operating principle of the fabric filter is the mechanical separation of the dust particles on a tissue. The mesh may vary in size depending on the type of tissue. Particles that are larger than the mesh size remain on the fabric. Thus there is established a dust layer in a relatively short time, which is constantly growing. In this condition the tissue itself no longer has an effect, but the dust layer on the fabric (filter cake) functions as a filter.

Figure 65 shows a schematic diagram of a conventional fabric filter. The tissue is stretched as a bag on a wire rack. The exhaust gas which is to be cleaned flows from the outside on to the filter bags and is getting cleaned. With increase of the layer thickness of the filter cake, pressure loss occurs, so that less and less exhaust gas can be cleaned. Therefore when a defined value is reached the filtering is stopped by an appropriate valve control and a compressed air blast is getting released in the opposite direction from top to bottom. This results in the filter cake being detached and falling downward. The filter bag is clean and can be used again for the filtration of exhaust gas.

The fabric is usually made of a plastic (often perfluorinated polymers). Although usually temperature-resistant plastic is used, a fabric filter is not used in the higher temperature range (above 260 °C). The fabric filter has the highest filtration efficiency and also filters ultrafine particles (about 0.5μm). The disadvantage is that the fabric filter is the most expensive option for dust separation, both with regard to investment and operating costs. The following table summarizes the comparison of the different building modules for dust removal

Table 21: Comparison of three different dust filter systems. Source

152 http://www.mindfully.org/Nucs/Firing-Range-Air-Cleaning1mar85f3.gif
153 http://www.infastaub.de/ and at http://www.infastaub.de/typo3temp/pics/61a167808c.gif
### Characteristics

<table>
<thead>
<tr>
<th></th>
<th>Cyclone filter</th>
<th>Electrostatic precipitator</th>
<th>Fabric filter</th>
</tr>
</thead>
<tbody>
<tr>
<td>Removal efficiencies in the grain size range, in µm</td>
<td>&gt; 10</td>
<td>&gt; 1</td>
<td>&gt; 0.5</td>
</tr>
<tr>
<td>raw gas dust content in g/m³</td>
<td>&lt; 1000</td>
<td>&lt; 50</td>
<td>&lt; 100</td>
</tr>
<tr>
<td>Recoverable clean gas dust content in mg/m³</td>
<td>100 – 200</td>
<td>&lt; 50</td>
<td>&lt; 20</td>
</tr>
<tr>
<td>Maximum gas temperature in °C</td>
<td>450</td>
<td>450</td>
<td>260</td>
</tr>
<tr>
<td>Flow-rate in m³/h</td>
<td>3000 – 200000</td>
<td>10000 - 300000</td>
<td>1000 – 100000</td>
</tr>
<tr>
<td>Pressure loss in Pa</td>
<td>500 – 3000</td>
<td>30 – 400</td>
<td>600 - 20000</td>
</tr>
</tbody>
</table>

**Gas scrubbing process**

Exhaust gases from the waste or hazardous waste incinerators show high concentrations of acidic pollutant gases in the raw gas. Sulfur dioxide (SO₂), especially hydrogen chloride (HCl) and hydrogen fluoride (HF) are important. Among other things the entry of chlorine is due to the plastic PVC, which is contained in many products, and in special waste incineration also enters through chlorinated organic substances such as chlorinated solvents. Fluorine also enters due to plastics (PTFE (polytetrafluoroethylene) - Teflon). Or in some cases due to propellants (e.g. refrigerant from old refrigeration units). Therefore, besides for separating the dust, a component should be present that deposits acidic pollutant gases formed during the combustion (SO₂/SO₃, HCl and HF).

The acidic pollutants in the exhaust gases are distributed finely (solved). Within emission control three process principles were being established to separate these components from the exhaust gas:

- Dry
- Wet
- Semi-dry

All processes use a chemical additive (sorbent), which binds the acids by a chemical reaction. Often, chalk -CaCO₃- or hydrated chalk -Ca (OH)₂- is used. Calcium as an integral
part forms corresponding salts with these acids (e.g. calcium sulphate CaSO₄ and calcium chloride CaCl₂), which can then be deposited.

10.4.4. Dry gas scrubbing

In the dry method, the sorbent with a very fine grain size is sprayed into the exhaust stream and binds the acids. Subsequently, the loaded sorbent powder is to be separated again using a fabric filter. The sorbent can be used multiple times until it is used up chemically.

10.4.5. Wet-gas scrubbing

Using the wet method, the sorbent is dissolved in water. The wash solution is then injected into the exhaust stream, where the fine sorbent droplets can then react with the acids. The wash water can be prepared and circulated. As part of the treatment a wash solution is produced, which must be discarded. This method is most effective when washing liquid is brought into the most possible contact with the exhaust gas. Hence, one can find very different constructions of the scrubber on the market. All these systems have disadvantages and advantages.

In waste incinerator two-stage scrubber systems are not rare. In the first (acidic) stage HCl is deposited in particular, while, in the second alkaline or near neutral level the deposition of SO₂ can take place.

The wet exhaust gas purification generally results in lower residual concentrations in the exhaust gas than the dry gas cleaning method. The heaviest drawback of wet flue gas scrubbing is the production of a highly saline wastewater, which is difficult to dispose (0.2 to 0.5 m³ per ton of burned waste)¹⁵⁴.

10.4.6. Semi-dry scrubbing

Due to the disadvantages of the other methods, semi-dry flue gas cleaning has been developed, a method that combines advantage of the wet method (high separation efficiency) with the advantages of the dry process (no wastewater). After the wet flue gas cleaning the spent washing liquid is dried in the exhaust stream. The droplets turn into small salt crystals, which can then be separated with a dust filter.

Figure 66 shows a possible design of the quasi-dry flue gas cleaning. It is apparent that the scrubber is operating with water in the lower part. The additive lime is dissolved in small water droplets. Over the course of the circulation in the scrubber, the water evaporates and salt crystals are formed which are separated in the fabric filter.

In the exhaust gas treatment of waste incineration plants several filtering elements are combined. The following figure 67 shows which clean gas values can be achieved through combination of filtering elements.

\[\text{http://www.evza.de/__/_images/abgage.jpg}\]
Deposition of dioxins and mercury

Dioxins can be divested either by installed waste gas treatment techniques which had been installed for other purpose (see 10.4.7) or some special filter units can be installed that are exclusively designed for dioxin removal. In the case of the use of sorbents a co-deposition of mercury can also be accomplished.

10.4.7. Activated carbon technology / process air stream

A special feature of emission control using sorbents is the addition of finely powdered activated carbon. The activated carbon acts as a sorbent for Dioxins, but also for Mercury. Activated carbon has a high porosity and a large surface area and is therefore particularly suitable for the adsorption of pollutants.

The injection of sorbents is called entrained flow process (process air stream). Activated carbon can be injected in different elements within the entire process of emission control (e.g. in the dust filters) and in different forms (see Figure 68). In addition to activated carbon, finely ground coke (HOK\textsuperscript{157}) is used. Also inorganic sorbents such as zeolites are used. The use of activated carbon or lignite coke (HOK) is usually combined with the use of calcium hydroxide. With the entrained-flow process separation efficiencies above 99% can be achieved.

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\textsuperscript{157} HOK is produced on the basis of lignite in the so-called rotary hearth furnace process.
Fig. 68: Schematic view of the entrained-phase absorption process before the dust deposition\textsuperscript{158}; HOK = (abbreviation from the German word \textit{Herdöfenkoks})

10.4.8. Activated carbon technology / fixed bed reactor

In practice, activated carbon or activated coke is used as its own filter, the so-called fixed-bed reactor. In this case, the exhaust gas is passed through an (active coke bulk). This process can achieve very high efficiencies of 99.9%. If the filter is depleted, the filter material must be replaced. In this instance the filter has to be taken out of service. This disadvantage is avoided with a so-called moving bed sorbent. A part of the absorber continuously leaves the area where it is traversed by the flue gas, and can therefore be replaced on the other side of the filter with fresh material.

10.4.9. Oxidation

Also, dioxins are removable by oxidation from the exhaust gas. The oxidation can be achieved by post-combustion. But this method is not used in practice of waste incineration.

\textsuperscript{158} Wirling J.: Sicherheitstechnische Aspekte bei der Anwendung von kohlenstoffhaltigen Sorbentien zur Flugstromadsorption. Stahl und Eisen 126, 6, 2006
because the energy required for this purpose would be too high. Another option is a catalytic oxidation (with titanium oxide, tungsten oxide and vanadium pent oxide), this has significant energy-efficient advantages compared to the post-combustion. The catalytic oxidation (159) makes sense when it is combined with the catalytic reduction of NOx (SCR-process, see below), which has been developed in Germany and practiced since the early 90s (160). For this purpose, the SCR catalyst needs a supplementary oxidation layer. With this method, separation efficiencies are possible from 95 to 99%. Table 22 shows a comparison of different process principles for dioxin removal in waste incineration plants (supplemented by161).

<table>
<thead>
<tr>
<th>Dioxin removal principles</th>
<th>Fixed bed reactor</th>
<th>entrained-phase adsorption process</th>
<th>Oxidation catalyst</th>
</tr>
</thead>
<tbody>
<tr>
<td>Potential for separation</td>
<td>Very high</td>
<td>High</td>
<td>High</td>
</tr>
<tr>
<td>Residue use / waste disposal use</td>
<td>Internal combustion</td>
<td>Deposition</td>
<td>None</td>
</tr>
<tr>
<td>Deposition of acids and heavy metals</td>
<td>Very good</td>
<td>Good</td>
<td>None</td>
</tr>
<tr>
<td>Safety requirements</td>
<td>Medium</td>
<td>Medium</td>
<td>Low</td>
</tr>
<tr>
<td>Space requirements</td>
<td>Medium</td>
<td>Medium</td>
<td>Low</td>
</tr>
<tr>
<td>Operational aspects</td>
<td>High effort</td>
<td>Low (less) requirements</td>
<td>Superheat related to CO entry by incomplete combustion possible, Catalyst can be damaged</td>
</tr>
<tr>
<td>Emission</td>
<td>Very good separation of all pollutants</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Technical Data**

- **HOK granules**: 2-4 kg/Mg
- **HOK dust hydrated lime**: 0.4-0.7 kg/Mg 2-3.5 kg/Mg
- **Catalysts**: 0.2-0.7 m³/a/Mg
- **Energy requirements**: 8-12 kWh/Mg 7-10 kWh/Mg 3-5 kWh/Mg
- **Residues**: 2-4 kg/Mg 2 bis 3.5 kg/Mg
- **Investment** (converted): 218.000-400.000 €/(Mg/h) 73.000-182.000 €/(Mg/h) 13-33 €/(Nm³/h) 73.000-109.000 €/(Mg/h) 13-20 €/(Nm³/h)

Table 22: Comparison of different procedural principles for dioxin removal in waste incineration plants (supplemented by163); Mg refers to a ton of waste, Mg / h = Mg per hour, burning waste gases for 1 Mg household waste in 7,000 standard-m³ (norm-m³)

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159 Different oxidation catalysts are available at the market e.g. Johnson & Matthey: [http://www.powerplantcatalysts.com/index.php?id=197&L=1](http://www.powerplantcatalysts.com/index.php?id=197&L=1)


162 This statement of the investment cost in Mg per hour is common. The plant size is measured in Mg / h. In cubic meters, they can be converted by multiplication with approximately 7000. This only applies if the plant does not perform exhaust gas recycling. If it executes exhaust gas recycling the cubic meters per Mg will be less than 7000 (10 to 20% lower, depending on the technology; **Normal cubic meter** within the process industry and in gas engineering is a unit used for a describing gas volumes. The Normal cubic meter describes a gas volume of one cubic meter under specified conditions

276
With all three methods, the current European limit values for dioxins and furans of 0.1 ng TE / m³ can be achieved. In practice, the fixed-bed reactors have not been established because of their high costs and operational risks (such as smoldering fire). The entrained flow process in particular has asserted itself. However, using the entrained flow process with carbonaceous sorbents safety aspects (fire and explosion protection) must be considered.

The technique to remove mercury depends on the selected emission control concept. For example, if a wet scrubber stage is used, mercury deposition may be completed in the scrubber solution by the addition of special chemicals. Common additives are sulfur compounds which form compounds that are difficult to absorb with the oxidized mercury in the combustion chamber, which can then be separated.

In a dry or semi-dry flue gas cleaning activated carbon as used in an entrained flow process can also be used to separate mercury. To increase the deposition, activated carbon impregnated with sulfur compounds may be used.

**Deposition of nitrogen oxides (NOx)**

At high temperatures the nitrogen and the oxygen from the air form nitrogen oxide compounds. Therefore, any combustion is associated with the formation of these compounds. Of the various nitrogen oxides nitric oxide (NO) and nitrogen dioxide (NO₂) are important to consider because of their produced volume. They are collectively known as NOx or nitrogen oxides. The concentrations of these compounds are relatively low at the usual temperatures of 1,000 to 1,500 °C of the hazardous waste incineration. If the combustibles contain organic nitrogen compounds, the concentration of nitrogen oxides in the raw gas increases. Since this is usually the case, it is necessary for waste incineration plants to reduce formed nitrogen oxides. For this purpose two main methods are used in emission control: the SCR and the SNCR process. Both processes operate through a chemical
reaction; an added reducing agent such as ammonia or urea being converted in the form of a redox reaction\textsuperscript{168} so that the nitrogen oxides and the reducing agent react to nitrogen and water, and thus render them harmless. This reaction proceeds very slowly at the prevailing temperatures (200 to 300 °C).

10.4.10. SCR process\textsuperscript{169}

In the SCR process the described reaction is accelerated with the aid of a catalyst. The catalyst consists of a ceramic support material, on which the catalyst (titanium, vanadium or tungsten oxides) is applied. Figure 69 shows the structure of an SCR reactor that is filled with several layers of the catalyst. The exhaust gas is flowing through the reactor. The reducing agent is injected before the gas enters the reactor.

Fig. 69: Schematic structure of a SCR-reactor, taken from\textsuperscript{170}.

Depending on the type of catalyst, an exhaust temperature of 300 to 450 °C must be reached. This temperature is located directly behind the energy extraction and in front of the dust separation (behind the superheater, but if present, possibly even before the economizer). To use the catalyst there (high dust) is energetically advantageous however the

\textsuperscript{168} Redox reaction= Reaction of an oxidizing agent with a reducing agent
\textsuperscript{169} SCR = Selective catalytic reduction
\textsuperscript{170} http://www.lab-stuttgart.de/images/scr.jpg
high dust exposure damages the catalyst mechanically and chemically (poisoning)\textsuperscript{171}

Therefore, this circuit is chosen rarely for the incineration of waste, particularly in case of high concentrations of dust and catalyst poisoning. Frequently used in waste management is the so-called low-dust circuit in which the SCR reactor is located at the end of the flue gas cleaning as the last module before discharge to the chimney. This circuit extends the lifetime of the catalyst, but the exhaust gas needs to be reheated. This is done through use of a heat exchanger. After it has passed through the catalyst, the heated exhaust gas is cooled down by the heat exchanger and this energy is used in order to heat the inflowing exhaust gas which is to be purified. Despite the return of the heat a defined energy loss must be replaced by adjusting the amount of combustibles, which presents the arrangement of the SCR reactor energetically unfavorable.

The advantage of the SCR process is its high reduction success. The exhaust gases can be safely lowered to values below 50 mg NO\textsubscript{x} / m.

\textbf{10.4.11. SNCR process}\textsuperscript{172}

In the SNCR process, the reducing agent - such as ammonia or urea – is injected directly in or after the combustion chamber, because a favorable temperature range 900-1100 °C is given. In this area a sufficiently high reaction rate is given, and therefore the use of a catalyst may be waived. But at the same time the secondary formation of NO\textsubscript{x} from the introduced reducing agent is not substantial. The injection of the reducing agent is implemented by means of lances directly into the zone which is at the corresponding temperature. The injection has to be executed in a manner ensuring the best possible mix.

For hazardous waste incineration, the injection of the reducing agent is not taking place in the combustion chamber itself, as usually the temperatures are too high. At most, there is a possibility for this at the end of the secondary combustion chamber. Sometimes the SNCR is also performed in the upper region of the boiler.

\textsuperscript{171} A catalyst features an active centre that is responsible for the catalytic reaction. In the case of poisoning these centers can be blocked by substances from the exhaust. A heavy metal atom which entered the active center is bound in the active center and no longer available for other reactions.

\textsuperscript{172} SNCR= Selective non-catalytic reduction
10.4.12. Deposition of heavy metals

Usually there are no specific modules in flue gas cleaning for heavy metal deposition (except for mercury). **Heavy metals are mainly bound to dust.** Therefore, they are deposited together with dust and penetrate into the filter dust. Residual amounts of heavy metals are separated via the scrubber stage. The better the filter system for dust removal is, the higher its collection efficiency, and the better this system is for deposition of heavy metals.

10.4.13. Performance of the emission control modules in comparison

The various devices of air emission control have different retention rates, as already shown above by the example of the dust filtering with electrical, cyclone and fabric filters. In general, the better systems have higher costs, so therefore it must be decided in the context of the overall concept for flue gas cleaning which modules are to be used.

For the modules shown different variants are offered which need to be considered when planning the concept of the incineration plant. Among these variants some significant differences remain, such as performance, operational costs and maintenance.

While the selection and combination of components can be included in the planning system, as long as the future operator performs on the basis of a detailed planning, the selection of technical options for the individual modules can only be made in the context of the specific tender.

10.4.14. Combination of modules

As stated, there are very different ways to combine the individual modules into the entire flue gas cleaning system. In addition to the costs, the desired emission limits need to be considered. The required guarantees of reducing the pollution of the raw exhaust gas form an essential part of the conception.

In figure 70, such a concept is exemplified as a process flow diagram. The facility is located in Germany and therefore has to comply with the European and German emission limits\(^\text{173}\).

Fig. 70: Combination of several modules for the purification of exhaust gases for a HWI plant in Germany\textsuperscript{174}, ZWS = Circulating fluidized bed reactor, “Sorbalit” is a sorbent (lime as reagent and carbon as surface-active substance).

\textsuperscript{174} Berzelius/Muldenhütten Recycling und Umwelttechnik GmbH (MRU), Freiberg: A hazardous waste incineration plant is operated in conjunction with a secondary lead smelter. This association may reduce costs because system components (energy, waste residues) are operated together. This is a good example for a site selection in other countries. Read more at: http://www.berzelius.de/berzelius/dokumente/mru_verbrennung.pdf
10.4.15. Flue gas cleaning costs

The exact costing for the described elements of a modern flue gas cleaning is difficult due to several reasons. They can only be made seriously on the basis of a detailed implementation planning of a hazardous waste incinerator. Thus, exact costs can only be identified within a particular project.

Rough cost estimates are possible, but they must be considered with caution because they cannot be exact. Since in recent years few hazardous waste incineration plants were built worldwide, it is also difficult to use actual numbers for a cost estimate. Therefore it is necessary to work with older data, which further limits the significance of the cost data. Table 23 shows investment costs for the components of an emission control system as described above.

Table 23: Investment costs of several system components for the purification of exhaust gases for two lines and 200,000 Mg waste per year (1999)²⁷⁵

<table>
<thead>
<tr>
<th>System components</th>
<th>Investment costs (Mio. €/2 Lines)</th>
</tr>
</thead>
<tbody>
<tr>
<td>3-stepped electrostatic precipitator</td>
<td>2,2</td>
</tr>
<tr>
<td>2-stepped electrostatic precipitator</td>
<td>1,6</td>
</tr>
<tr>
<td>Fabric filter</td>
<td>2,2</td>
</tr>
<tr>
<td>Spray dryer</td>
<td>ca. 1</td>
</tr>
<tr>
<td>2-stepped scrubber</td>
<td>4,6</td>
</tr>
<tr>
<td>3-stepped scrubber</td>
<td>6,6</td>
</tr>
<tr>
<td>Entrained absorber</td>
<td>2,3</td>
</tr>
<tr>
<td>Moving bed absorber</td>
<td>2,3</td>
</tr>
<tr>
<td>External evaporation (no utilization of residues)</td>
<td>&lt; 2</td>
</tr>
<tr>
<td>SNCR</td>
<td>1,0</td>
</tr>
<tr>
<td>SCR</td>
<td>4,3</td>
</tr>
</tbody>
</table>

The data about the investment costs given in Table 23 have been collected more than 12 years ago, so they need to be adjusted in terms of price increase, market trends, etc. They

are limited to the pure fixed capital without construction services, electrical systems, instrumentation and control systems, etc. but they give a good overview of the investment costs that had to be estimated for the individual components of a flue gas cleaning system.

In recent years the flue gas cleaning processes got more efficient and the costs got lower. The following Table 24 shows current cost for different combinations of components for emission of waste incineration plants (in Germany)\textsuperscript{176}. These costs, in addition to the pure technical part, include costs of electrical systems, instrumentation and control systems, etc. (but without the construction service).

Table 24 shows the required specifications for flue gas cleaning. The German Federal Emission Control Ordinance (known in Germany as 17. BImSchV) with its sharp limits must be maintained. The table is based on current guiding price offers of leading manufacturers.

It has been operated with a consistent line of 130,000 m\textsuperscript{3} / h (7000 m\textsuperscript{3}/ Mg comply with 158,000 Mg / yr)\textsuperscript{177}.

Variant V7 consists of a SNCR technology, a spray dryer, a fabric filter with activated carbon dosing and a two-stage scrubber including NH\textsubscript{3} stripping\textsuperscript{178}. V8 variant consists of the SNCR process, spray dryer, a dry scrubbing stage, fabric filter and a two-stage flue gas scrubber including NH\textsubscript{3} stripping. The variant 8.1 is identical to the variant 8 except to the removal of NH\textsubscript{3}. In the case of Variant 8.1 NH\textsubscript{3} is not stripped, but fed through the scrubber water to the SNCR. Variant 9 includes a steam cooler, then a dry scrubbing stage with activated carbon dosing, waste circulation, a fabric filter and an activated carbon fixed-bed filter.

Table 24: Procedural comparison and economic efficiency analysis for the four different options of the purification of exhaust gases of waste incineration plants\textsuperscript{179}. In the table the following abbreviations have been used: RG-condensing = condensation of flue gas; NH3 Stripper = Step that strips surplus ammonia; DaGaVo = prewarming of raw gases with low pressure vapor; Slip= Loss because of the breakthrough into the clean gas.


\textsuperscript{177} A tumb rule: one Mg waste produces 7000 m\textsuperscript{3} exhaust gas

\textsuperscript{178} In this technique, ammonia is expelled from the washing liquid at low pH by injection of air and collected afterwards.

It can be seen from the above table how to make decisions for the concept by analysing the techniques and their respective advantages and disadvantages. The exhaust gas treatment caused in this current analysis costs around 25 € per Mg of waste input.
In case of developing and emerging countries in particular it is important to consider the possibility of finishing the installation engineering at least partly in their own country, as this can reduce costs significantly.

In the end the costs will depend on the competitive situation. Currently, the market situation for the construction of thermal waste treatment plants is positive. It is therefore possible that a high quality emission control system for costs less than 20 € / Mg waste can be purchased for about € 10 million.

10.4.16. Wastewater treatment and discharge

Similar to the emission control, how a hazardous waste incinerator is equipped with wastewater treatment facilities depends on the load of waste. The equipment of wastewater treatment facilities depends on the load of raw wastewater and the effluent values which need to be reached after passing through the clarification plant. The cost side of the water path is not as high, because compared to the air emission control the investment of wastewater treatment is usually lower by more than a factor of 10. The discharge values are often defined in national regulations. If not, the operator has the ability to choose standards given in accordance with the receiving water conditions.

In Germany, the Annex 33 (washing of flue gases from waste incineration)\textsuperscript{180} of the waste water Regulation is relevant regarding the discharge of sewage\textsuperscript{181}.

10.4.17. Temporary storage of ash, slag, etc

In the process of incineration slags, fly ash and flue gas cleaning residues accumulate. When planning a special waste incineration plant interim storage facilities should be considered to provide sufficient capacity for storage. After appropriate mechanical treatment the slag may be recycled, in road construction or as embankment for the construction of walls, etc. The ash and flue gas residues containing pollutants are hazardous wastes that are to be land filled. Delays may occur in the recycling or disposal of waste material. It is also possible that a long-time customers and purchaser of waste material pulls out. For the search and review of a new buyer time should be taken. Therefore, it is useful to have sufficient interim storage facilities available on own premises (at least for 6 months).

\textsuperscript{180} http://www.gesetze-im-internet.de/abwv/anhang_33_39.html
\textsuperscript{181} http://www.bmu.de/files/pdfs/allgemein/application/pdf/wastewater_ordinance.pdf
Fig. 71: Ashes and slags produced from hazardous waste incineration

10.4.18. Infrastructure Facilities

Infrastructure such as roads, and also infrastructure of supply is normally not considered with sufficient intensity in the context of planning. Especially when considering utility installations it is necessary to consider redundancy. If a channel of supply fails, the operator should be able to assure the supply continues through a second option (emergency generators, etc.)

- **10.5. Operational problems**

The most common operational problems occur mostly before the actual combustion of hazardous waste. The composition of the waste in the menus is one of the biggest issues. If high-caloric and the rather low-caloric waste, the solid and liquid wastes, the problematic and the less problematic waste are combined badly with each other, the rotary kiln may have much shorter run times. Or the required use of fossil fuels may increase so much that the economically optimal operation of the plant cannot be assured.

In addition, many small operational and technical difficulties can occur. In older works\(^\text{182}\) there are reports about:

- Incorrect air inlet in the loading area of solid waste

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• Blocking of the valves due to solids and pastes
• Incorrect air inlet in the drum delivery area (jammed drums)
• Corrosion damage to the lower part of the chute
• Poor accessibility of the devices on the front side of the rotary kiln
• Primary air supply insufficiently due to miscalculation
• Caking and clogging in the slag chute (drums, solidified slag)
• Section of the slag pit is too small

Many of these small operational problems can be solved or improved as part of upcoming maintenance. This list also indicates that some of the operational problems would have been avoided by better planning.

A potential investor or operator, before making decisions on a planning or technology provider, should take the time for some study tours to other countries with existing systems. Especially in Europe, there are many independent operators of hazardous waste incineration plants that like to share their knowledge gathered over the years. Responsible management personnel should build an international network for the planning and construction of a HWI plant.

It is also important for the management staff to have an international network of experts from other facilities in case of operational problems, so that they may have an official or unofficial information exchange. To build or to maintain a network, regularly offered professional conferences are a good opportunity to (re)connect, even if the programs themselves are not always entirely convincing. Such a network should be established as early as possible. For the construction and maintenance of the network a budget is to be provided.

10.6. Total costs details

The data about costs for the described technology and the equipment of a special waste incinerator depend primarily on the system size. Rotary kiln incinerators have a limited capacity depending on size for every line. For an average availability of 6500 hours a capacity of 30,000 tons per year is a suitable size for a line.

If possible, single-line systems should be avoided, because the necessary multi-week revision periods can be bridged badly. A configuration of two lines would mean an annual capacity of 60,000 tons.

The investment and operating costs depend on the particular cost level in the country where such a facility should be built. Equipment of the system and the environmental requirements
are also important variables that determine the cost. The costs are subject to the competition, which makes reliable data of costs difficult.

The following is an Outline of European level of costs, since the essential techniques must be purchased in the West. Investment for a double lined system with a capacity of 60,000 tons per year should be in the range of 180 to 190 million € (as per 2011). For this system configuration the processing costs would be, in Europe, above € 500 per tonne. In developing and emerging countries, the costs could be reduced (using local expertise and manpower), so that processing costs would be 300 € and below

10.6.1. Economy of scale

Another aspect is the „economy of scale” effect which refers to reductions in unit cost as the size of a facility, or scale, increases. In case of complex installations such as incinerators with many ancillary facilities, this effect is particularly distinctive. Table 25 presents various financial parameters for hazardous waste incinerators of different capacities ranging from 5,000 to 90,000 t/a. Calculations refer to a rotary kiln including afterburner, Air Pollution Control and ancillary facilities were made during a hazardous waste infrastructure planning project in the Chinese Province Zhejiang as part of the “Environmental Enterprise Consultancy Zhejiang” Program (GTZ). As the table 25 shows, the specific costs per ton of waste to be incinerated drop significantly with increasing capacity of the facilities. Tables 26 and 27 present detailed fixed costs assessment for HWI. The data is from China, 2007. (1RMB = 0.1€)

Table 25 “Economy of Scale” effect for hazardous waste incinerators of different capacities (based on estimated local costs, China, 2007. 1RMB = 0.1€)\(^\text{183}\)

<table>
<thead>
<tr>
<th>Capacity</th>
<th>5,000</th>
<th>6,000</th>
<th>10,000</th>
<th>20,000</th>
<th>25,000</th>
<th>30,000</th>
<th>60,000</th>
<th>35,000</th>
<th>70,000</th>
<th>90,000</th>
<th>2 lines à 30' tons</th>
<th>2 lines à 35' tons</th>
<th>3 lines à 30' tons</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Investment</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Investment incinerator</td>
<td>60</td>
<td>65</td>
<td>75</td>
<td>120</td>
<td>140</td>
<td>150</td>
<td>270</td>
<td>165</td>
<td>300</td>
<td>380</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Investm. tank farm, storage, etc. (15%)</td>
<td>9</td>
<td>10</td>
<td>11</td>
<td>18</td>
<td>21</td>
<td>23</td>
<td>41</td>
<td>25</td>
<td>45</td>
<td>57</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Total investment</strong></td>
<td>69</td>
<td>75</td>
<td>86</td>
<td>138</td>
<td>173</td>
<td>311</td>
<td>311</td>
<td>190</td>
<td>345</td>
<td>437</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Annual costs</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Amortisation (15 years)</td>
<td>4.60</td>
<td>5.00</td>
<td>5.73</td>
<td>9.20</td>
<td>10.73</td>
<td>11.53</td>
<td>20.73</td>
<td>12.67</td>
<td>23.00</td>
<td>29.13</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Interest (8%)</td>
<td>2.76</td>
<td>3.00</td>
<td>3.44</td>
<td>5.52</td>
<td>6.44</td>
<td>6.92</td>
<td>12.44</td>
<td>7.60</td>
<td>13.80</td>
<td>17.48</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Capital costs per year</strong></td>
<td>7.36</td>
<td>8.00</td>
<td>9.17</td>
<td>14.72</td>
<td>17.17</td>
<td>18.45</td>
<td>33.17</td>
<td>20.27</td>
<td>36.90</td>
<td>46.61</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Maintenance (3.5%)</td>
<td>2.10</td>
<td>2.28</td>
<td>2.63</td>
<td>4.20</td>
<td>4.90</td>
<td>5.25</td>
<td>9.45</td>
<td>5.78</td>
<td>10.50</td>
<td>13.30</td>
<td></td>
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</tr>
<tr>
<td>Staff</td>
<td>0.96</td>
<td>0.96</td>
<td>0.96</td>
<td>1.49</td>
<td>1.56</td>
<td>1.82</td>
<td>2.43</td>
<td>1.82</td>
<td>2.43</td>
<td>2.88</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fuel</td>
<td>1.25</td>
<td>1.50</td>
<td>2.00</td>
<td>3.33</td>
<td>3.75</td>
<td>4.00</td>
<td>7.99</td>
<td>4.00</td>
<td>7.99</td>
<td>11.99</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Total fixed operating costs</strong></td>
<td>4.31</td>
<td>4.73</td>
<td>5.58</td>
<td>9.02</td>
<td>10.21</td>
<td>11.07</td>
<td>19.87</td>
<td>11.60</td>
<td>20.92</td>
<td>28.17</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Total fixed costs per year</strong></td>
<td>11.67</td>
<td>12.73</td>
<td>14.76</td>
<td>23.74</td>
<td>27.38</td>
<td>29.52</td>
<td>53.05</td>
<td>31.86</td>
<td>57.72</td>
<td>74.78</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Specific Costs per ton</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Capital costs per ton</td>
<td>1,472</td>
<td>1,333</td>
<td>917</td>
<td>736</td>
<td>687</td>
<td>615</td>
<td>553</td>
<td>579</td>
<td>526</td>
<td>518</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fixed operating costs per ton</td>
<td>862</td>
<td>789</td>
<td>558</td>
<td>451</td>
<td>408</td>
<td>369</td>
<td>331</td>
<td>331</td>
<td>299</td>
<td>313</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Total fixed costs per ton</strong></td>
<td>2,334</td>
<td>2,122</td>
<td>1,476</td>
<td>1,187</td>
<td>1,095</td>
<td>984</td>
<td>884</td>
<td>910</td>
<td>825</td>
<td>831</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Variable operating costs per ton</td>
<td>549</td>
<td>549</td>
<td>549</td>
<td>549</td>
<td>549</td>
<td>549</td>
<td>549</td>
<td>549</td>
<td>549</td>
<td>549</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Tot. op. costs per ton (fixed + var.)</strong></td>
<td>1,411</td>
<td>1,338</td>
<td>1,108</td>
<td>1,001</td>
<td>958</td>
<td>918</td>
<td>881</td>
<td>881</td>
<td>848</td>
<td>862</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Total costs per ton</strong></td>
<td>2,883</td>
<td>2,672</td>
<td>2,025</td>
<td>1,737</td>
<td>1,645</td>
<td>1,534</td>
<td>1,434</td>
<td>1,460</td>
<td>1,374</td>
<td>1,380</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Table 26: Staff costs as part of the fixed operating costs of Incinerators

<table>
<thead>
<tr>
<th>Incineration Staff Costs</th>
<th>No of Staff for</th>
<th>Salary / month (RMB/y)</th>
<th>Salary / year (RMB/y)</th>
<th>Annual Staff Cost per given Capacity (RMB/y)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>10' t/y</td>
<td>20' t/y</td>
<td>25' t/y</td>
<td>30' t/y</td>
</tr>
<tr>
<td>Capacity</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Head</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Secretary</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Department heads</td>
<td>2</td>
<td>4</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>Shift leader</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>Control room</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>Crane operator</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>Furnace operator</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>Operator Flue gas</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>Operator washwater</td>
<td>0</td>
<td>5</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>Operator drum feeding</td>
<td>0</td>
<td>5</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>Boiler operator</td>
<td>0</td>
<td>5</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>Waste acceptance,</td>
<td>4</td>
<td>8</td>
<td>8</td>
<td>8</td>
</tr>
<tr>
<td>Workshop</td>
<td>2</td>
<td>2</td>
<td>3</td>
<td>8</td>
</tr>
<tr>
<td>Laboratory</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>Dispatcher</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Total</td>
<td>60</td>
<td>63</td>
<td>74</td>
<td>99</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>10 (t/y)</th>
<th>20 (t/y)</th>
<th>25 (t/y)</th>
<th>30 (t/y)</th>
<th>60 (t/y)</th>
<th>90 (t/y)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Head</td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Secretary</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Department heads</td>
<td></td>
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<td></td>
<td></td>
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<tr>
<td>Shift leader</td>
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<tr>
<td>Control room</td>
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<tr>
<td>Crane operator</td>
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</tr>
<tr>
<td>Furnace operator</td>
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<tr>
<td>Operator Flue gas</td>
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</tr>
<tr>
<td>Operator washwater</td>
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<td></td>
</tr>
<tr>
<td>Operator drum feeding</td>
<td></td>
<td></td>
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<tr>
<td>Boiler operator</td>
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<td></td>
</tr>
<tr>
<td>Waste acceptance,</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Workshop</td>
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<td></td>
</tr>
<tr>
<td>Laboratory</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dispatcher</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

staff cost / ton 75 63 61 40 32
Table 27: Fuel consumption as part of the fixed operating costs of incinerators

<table>
<thead>
<tr>
<th>Fuel, costs</th>
<th>Fuel oil, energy content = 42 GJ / t</th>
</tr>
</thead>
<tbody>
<tr>
<td>RMB / t</td>
<td></td>
</tr>
</tbody>
</table>

### Fuel oil related data with respect to incinerator capacity

<table>
<thead>
<tr>
<th>Capacity (t/year)</th>
<th>5,000</th>
<th>6,000</th>
<th>10,000</th>
<th>20,000</th>
<th>25,000</th>
<th>30,000</th>
<th>60,000</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operating hours/year</td>
<td>5,000</td>
<td>6,000</td>
<td>6,000</td>
<td>7,500</td>
<td>7,500</td>
<td>7,500</td>
<td>7,500</td>
</tr>
<tr>
<td>Tons/hour</td>
<td>1.00</td>
<td>1.00</td>
<td>1.67</td>
<td>2.67</td>
<td>3.33</td>
<td>4.00</td>
<td>8.00</td>
</tr>
<tr>
<td>Average waste heat content (GJ/t)</td>
<td>14.00</td>
<td>14.00</td>
<td>14.00</td>
<td>14.00</td>
<td>14.00</td>
<td>14.00</td>
<td>14.00</td>
</tr>
<tr>
<td>Gross load (GJ/h)</td>
<td>14.00</td>
<td>14.00</td>
<td>23.33</td>
<td>37.33</td>
<td>46.67</td>
<td>56.00</td>
<td>112.00</td>
</tr>
<tr>
<td>Need &quot;liquid&quot; fuel (waste or fuel oil)</td>
<td>65 %</td>
<td>65 %</td>
<td>60 %</td>
<td>50 %</td>
<td>48 %</td>
<td>44 %</td>
<td>26 %</td>
</tr>
<tr>
<td>&quot;Liquid Gross load&quot; (GJ/h)</td>
<td>9.10</td>
<td>9.10</td>
<td>14.00</td>
<td>18.67</td>
<td>22.40</td>
<td>24.61</td>
<td>29.51</td>
</tr>
<tr>
<td>Percentage of Gross load via fuel oil</td>
<td>15 %</td>
<td>15 %</td>
<td>12 %</td>
<td>10 %</td>
<td>9 %</td>
<td>8 %</td>
<td>4 %</td>
</tr>
<tr>
<td>Fuel oil (tons/year)</td>
<td>250</td>
<td>300</td>
<td>400</td>
<td>667</td>
<td>750</td>
<td>799</td>
<td>831</td>
</tr>
<tr>
<td>Fuel oil costs / ton waste</td>
<td>250.00</td>
<td>250.00</td>
<td>200.00</td>
<td>166.67</td>
<td>150.00</td>
<td>133.21</td>
<td>69.23</td>
</tr>
</tbody>
</table>
Fig. 72: Hazardous Waste Incinerator of HIM GmbH at Biebesheim, Germany (Capacity: 2x 50,000 t/a)
• **10.7 Conclusion HWI**

The hazardous waste incineration using a rotary kiln as described in this module is an established, robust, and reliably functioning technology. The environmental risks during incineration are negligible with appropriate choice of the emission standards. The risks of unforeseen accidents of course exist, as well as for any other technology. They can be reduced with an acceptable level if recommendations on good practice are complied.

In the end the vote for the construction of a hazardous waste incinerator is an outcome of an evaluation of different considerations. The amount and type of disposed hazardous waste will depend on the region's industrial structure and the potential for waste prevention and recycling. If at the end of the regional waste management planning is the need for disposal of hazardous wastes, the combustion may be a technical option. The other option represented is land filling (but only for the solid hazardous wastes). Compared to land filling the incineration option evinces more environmental benefits. From a financial point of view the landfill is cheaper, if the long-term environmental damages involved in landfills are not included. Considering the entire life cycle of a hazardous waste landfill, the cost advantages over combustion are no so significant. This is just not considered on a regular basis, because in terms of costs no one feels responsible for a no longer operated landfill which mutated to become a contaminated site.

**Summary HWI**

<table>
<thead>
<tr>
<th>The rotary kiln with corresponding post-combustion is the classical proven, robust and versatile technique of hazardous waste incineration.</th>
</tr>
</thead>
<tbody>
<tr>
<td>A waste which cannot be land filled or conditioned in a CPT plant, e.g. because of high organic content or exceeding limit values, has to be incinerated.</td>
</tr>
</tbody>
</table>

In general, the main types of waste to which incineration is applied as a treatment are:

- municipal wastes (residual wastes - not pre-treated)
- pre-treated municipal wastes (e.g. selected fractions or Refused Derived Fuel)
- non-hazardous industrial wastes and packaging waste
- hazardous wastes
- effluent treatment sludge
- clinical wastes

Many incineration plants accept several of these waste types, depending on the incineration technology, flue gas cleaning etc. In general, non-hazardous and municipal waste is incinerated in Municipal Waste Incinerators. Municipal Waste incineration (MWI) is carried out at an incineration temperature of minimum 850 °C at a residence time for 2 seconds at least.

For the hazardous waste incineration the principal and ultimate goal is the reduction of the hazardousness of the wastes. During incineration less problematic slages and ashes should result from the partially highly toxic and / or hazardous wastes.

HWI is also referred to as „high temperature incineration“ because temperatures of at least 1100 °C are required to achieve an effective destruction of organic pollutants.

Minimum temperature is 850 °C for municipal waste incineration and 1100°C for hazardous waste incineration both for minimum 2 seconds

Acceptance criteria which can be applied generally for incineration plants do not exist in EU legislation. In order to allocate waste to either MWI or HWI the specific permit conditions of the incineration plant have to be considered. The latter are highly dependent on the incineration technology, the flue gas and waste water cleaning system. Accordingly the input, i.e. type and composition of the waste have to be defined.

Typical wastes sent to HWI are e.g. certain pesticides, halogenated solvents, hazardous hospital waste, infectious waste, combustible liquid wastes including waste oils or plastics contaminated with polychlorinated aromatic hydrocarbons, e.g. polychlorinated biphenyls (PCB) or pentachlorinated phenol (PCP), contaminated dried sludges, contaminated tissues, contaminated wood, etc.

The quality of the air pollution control (APC) system in the incineration plant determines which maximum concentrations of specific hazardous substances e.g. mercury, dioxine, chlorine, sulphur is feasible and acceptable for the incineration plant.

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184 Waste from households and similar waste from institutions and commerce
185 According to the “European Directive of Waste“ waste with halogen content of more than 1 % weight requires flue gas incineration at a temperature of minimum 1100°C at a residence time of 2 seconds in the secondary combustion chamber.
186 If hazardous wastes with a content of more than 1 % of halogenated organic substances, expressed as chlorine, are incinerated,
Fig. 73: Scheme of the hazardous waste incineration plant of AVG, Hamburg (Capacity: 2x 44,000 t/a)
Summary figure from an air pollution control system shown in Fig 74

With an appropriate combination of different elements (filters, scrubbers, sorbens) that are present in an HWI a satisfactory air pollution control can be achieved. The figure 74 shows a combination of four different elements and where hazardous wastes are produced and which final disposal should be undertaken.

The heat content of the combustion gases exiting the secondary combustion chamber is recovered via heat exchangers subsequently cooled down to approx. 600 °C and then to approximately 200 °C. Due to reaction kinetics, the temperature range between 450 and 250 °C has to be passed quickly during cooling down in order to avoid recombination of molecular fragments of combustion products into dioxins and furans. This requires “quenching” by water spraying.

After quenching the combustion gas is passed through two bag filters. The first bag filter precipitates the flue dust however without removing organic contaminants. These are removed in the second bag filter by means of adsorption on a mixture of activated carbon, lime and stone meal in low quantity. After its adsorption capacity is exhausted this material can be incinerated again in the rotary kiln. Thus the quantity of organic materials which has to be disposed in a landfill is very low. This design is also suitable to precipitate Mercury in the acid scrubber, because the HCl concentration is high enough to precipitate Mercury as H₂[HgCl₄].

Fig. 74: Example of a scheme of an air pollution control system Source: K.H.Decker

The Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH was formed on 1 January 2011. It has brought together under one roof the capacities and long-standing experience of three organisations: the Deutscher Entwicklungsdienst (DED) gGmbH (German Development Service), the Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ) GmbH (German technical cooperation) and Inwent – Capacity Building International, Germany. For further information go to www.giz.de.
• Module 6b

• Co-processing: a hazardous waste incineration option
• 10.8. Co-Processing

Inadequate waste management due to lack of infrastructure is a frequent problem in developing countries and in countries in transition. In many of such countries, waste is discharged to sewers, buried or burned on company premises, illegally dumped at unsuitable locations or taken to landfills that fail to meet requirements for the environmentally sound final waste disposal. One possible alternative and possible solution for the poor waste management in many countries is the co-processing of selected waste materials in the cement industry.188

10.8.1 Co-processing in cement industry

Co-processing is the use of waste material as raw materials or as a source of energy, or both, to replace natural mineral resources and fossil fuels such as coal, petroleum and gas in industrial processes. An efficient cement kiln can provide an environmentally sound and cost-effective treatment or recovery option for a number of wastes.189

The high temperatures and residence times in the rotary kiln of a cement plant have a high capacity to destroy persistent organic chemicals, so that they are mineralized. The use of alternative fuels and raw materials (AFR) in cement kilns decrease greenhouse gas emissions, can decrease waste management costs and save money in the cement industry.

Co-processing of waste materials in properly controlled cement kilns provides energy and material recovery while cement is being produced. It offers an environmentally sound recovery option for many waste types. Particularly in developing nations, which may have little or no waste management infrastructure, properly designed and operated cement kilns can provide a practical, cost-effective and environmentally preferable option to landfill and incineration, through the co-processing of waste.

The process itself has some differences from the process of the previously described hazardous waste incineration plant, which limits the application of this technique in certain areas.

Heavy metals, if they are not volatile, are shifted in the product clinker (cement). If the hazardous waste has a high heavy metal contamination, this will lead to contamination of the product.

188 http://www.coprocem.com/holcim-gtz-alliance
189 http://www.coprocem.com/Guidelines
Volatile heavy metals, such as mercury, are not retained, so they are released almost completely into the exhaust gas and are then emitted. Thus, it is to be ensured that only wastes with no or very little content of volatile heavy metals are used in the cement plant.

There are heavy metals, such as thallium, which evaporate in a certain temperature range, so that it leads to an enrichment in the process, which can cause an intermittently emission of the heavy metal.

Chlorine in turn, contained in the PVC plastic in high concentrations and also in chlorinated solvents, accumulates also as a chloride in the product. This chloride has no toxic effect, but it is still very problematic, because it degrades the material properties of the clinker / cement. Cement with high chloride content may lead to corrosion of the concrete and the steel reinforcement, which greatly affects the life of buildings and can even cause damage to buildings.

Further, working staff is exposed to high danger in the context of reception, storage and discharge. This is especially true if hazardous or infectious waste is to be treated.

**These brief examples illustrate the fact that the use of cement kilns for incineration should only be made and can be operational when requirements for co-processing of hazardous waste are clearly defined. These include in particular limits which are to be respected, and of course input monitoring.**
Table 28: Limit emission values in different permits and regulations in Austria, Switzerland and Germany for wastes used for co-processing in cement plants.\(^1\)

The co-incineration of hazardous waste in particular should only be allowed if the following emission limits are observed (table 29):

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\(^{1}\) See annex 7 at: [http://www.coprocem.com/Guidelines/unterordner/guideline_coprocem_v06-06.pdf/view](http://www.coprocem.com/Guidelines/unterordner/guideline_coprocem_v06-06.pdf/view)
Table 29: Limit emission values according to the Directive 2000/76/EC incineration of waste (Daily average 10% O$_2$, all values in mg/m$^3$ dioxins and furans in ng/m$^3$) that have to be observed for waste combustion in cement plants$^{191}$

<table>
<thead>
<tr>
<th>Pollutant</th>
<th>C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total dust</td>
<td>30</td>
</tr>
<tr>
<td>HCl</td>
<td>10</td>
</tr>
<tr>
<td>HF</td>
<td>1</td>
</tr>
<tr>
<td>NO$_x$</td>
<td>500$^1$/800$^2$</td>
</tr>
<tr>
<td>Cd + Tl</td>
<td>0.05</td>
</tr>
<tr>
<td>Hg</td>
<td>0.05</td>
</tr>
<tr>
<td>Sb, As, Pb, Cr, Co, Cu, Mn, Ni, V</td>
<td>0.5</td>
</tr>
<tr>
<td>Dioxins and Furans</td>
<td>0.1</td>
</tr>
<tr>
<td>SO$_2$</td>
<td>50$^3$</td>
</tr>
<tr>
<td>TOC</td>
<td>10$^3$</td>
</tr>
</tbody>
</table>

Dust, HCl, NO$_x$, SO$_2$, and Hg and TOC should be measured continuously; 1) new plants; 2) existing plants; 3) exceptions may be authorized by the competent authority in cases where SO$_2$ and TOC do not result from the incineration of waste

Co-processing should only be applied if not just one but all tangible preconditions and requirements of environmental, health and safety, socio-economic and operational criteria are fulfilled. As a consequence not all waste types are suitable for co-processing. The following negative and positive lists show respectively lists of waste not recommended or allowed for co-processing in cement plants:

**Negative waste list for co-processing in cement plants**

Waste that cannot be disposed in a cement plant form part of a negative list e.g.: nuclear waste; electronic waste; explosives; mineral acids; asbestos waste or wastes containing asbestos; chlorinated solvents; high-concentration cyanide waste; infectious medical waste;

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chemical or biological weapons destined for destruction; entire batteries; unsorted municipal garbage and other waste of unknown composition.

Positive waste list co-processing in cement plants

The positive list specifies which wastes can be disposed of in cement plants. For detailed information see positive lists included in guidelines for co processing at cement plants from the Swiss Federal Office for the Environment (FOEN) for: 1-) alternative fuels, 2-) raw materials, 3-) corrective raw materials, 4-) grinding additives and 5) process materials at: http://www.bafu.admin.ch/publikationen/publikation/00444/index.html?lang=en

Conclusion

The co-incineration of certain hazardous wastes in cement kilns is an option, especially in developing countries where a high-quality waste management structure is not yet available. Because of the risks and possible negative impacts on the environment, and also the health, safety and product quality, this option should only be used with careful planning and monitoring in order to minimize these negative effects. For more information on Co-processing in cement plants use the following link.¹⁹²

Case study Switzerland¹⁹³

In 2008, there were 6 cement plants operating in Switzerland, producing around 4.2 million tons of cement. The production of 1 tone of clinker requires about 135 kg of coal or 86 kg of heavy oil.

In principle, cement plants can use suitable types of waste as an alternative fuel or raw material. However, this must not increase the emission of air pollutants from kilns or reduce the quality of the cement produced. Accordingly, guidelines on waste disposal in cement plants were developed by (FOEN) in close collaboration with the industry and the cantonal authorities. These guidelines prohibit the incineration in cement plants of municipal waste and problematic special wastes (e.g. chlorinated solvents or paint residues with high heavy metal content). However, bulk wastes with a low pollution potential and high calorific value - such as used oil, sewage sludge, animal flour/animal fat, low-chlorinated solvents, plastics, used tires etc. - may be used as alternative fuels. In 2008, the cement works consumed a total of around 270,000 tons of combustible waste.

¹⁹² http://www.coprocem.com/trainingkt/pages/home.html

<table>
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<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>used oils</td>
<td>48.735</td>
<td>45.926</td>
<td>42.276</td>
<td>39.714</td>
<td>36.299</td>
<td>25.247</td>
<td>24.285</td>
</tr>
<tr>
<td>plastics</td>
<td>20.860</td>
<td>20.695</td>
<td>28.791</td>
<td>32.126</td>
<td>40.232</td>
<td>41.905</td>
<td>42.544</td>
</tr>
<tr>
<td>animal fats / animal meal</td>
<td>54.034</td>
<td>63.580</td>
<td>64.906</td>
<td>45.309</td>
<td>42.239</td>
<td>38.974</td>
<td>38.331</td>
</tr>
<tr>
<td>sewage sludge (95% dry weight)</td>
<td>38.296</td>
<td>40.980</td>
<td>39.878</td>
<td>47.920</td>
<td>54.964</td>
<td>57.696</td>
<td>53.152</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td><strong>269.180</strong></td>
</tr>
</tbody>
</table>
The Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH was formed on 1 January 2011. It has brought together under one roof the capacities and long-standing experience of three organisations: the Deutscher Entwicklungsdienst (DED) gGmbH (German Development Service), the Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ) GmbH (German technical cooperation) and Inwent – Capacity Building International, Germany. For further information go to www.giz.de.
• Module 7

• Hazardous waste landfills and underground disposal of HW
• Above-ground Landfill Sites for Hazardous Waste Disposal

The least desirable option of hazardous waste treatment is land filling. Whereas hazardous waste incineration eliminates pollutants (and energy recovery is possible), landfill disposal concentrates and accumulates them only thus building a toxic inventory that poses potential threats for the environment and human health, in particular for future generations. As a result of fast industrialization in many Western countries in the second half of the 20th century, indiscriminate disposal of hazardous waste has caused serious groundwater and soil pollution. This enormous damage was detected only decades later. Very expensive sanitation and recultivation measures became necessary that have required huge efforts and are still ongoing today.

Fig. 75: Discharge of acid resins into a sludge "lagoon" in Germany, 1968

In general, the following systemic risks have to be expected from landfill disposal of hazardous waste:

- Leachate percolation into the subsoil and resulting considerable to very high groundwater and soil pollution
- Leachate discharge into surface water and resulting considerable to very high pollution of surface water and the aquatic environment
- Uncontrolled discharge of landfill gas with resulting considerable to very high air pollution and risks for occupational health and safety
- Air pollution by windblown dust
Nuisance by bad odors

Basel Convention siting characteristics for landfills at: [link]
Basel Convention landfill site selection criteria at: [link]

What is a leachate?
Leachate …

- ... is an aqueous complex mixture of organic and inorganic pollutants
- ...is generated by:
  - Infiltration of precipitation water into the waste body
  - Settling of waste with high water content (e.g. effluent treatment sludge), thus forming “press water”
  - Reaction of water with waste followed by mobilization and uptake of water soluble pollutants
- ...quantity is subject to precipitation rate, waste area exposed to the atmosphere, evaporation rate and retention capacity of the waste
- ...is a threat to ground- and surface water resources, - in case of flaws with regard to site location, design, construction or management of landfill sites
- ...is usually considered as liquid “hazardous waste”, NOT as wastewater!
- Leaching behavior of waste can be simulated and forecasted by suitable elution tests during which waste samples are eluted by aqueous liquids

Fig. 76: Leachate from a landfill containing only mineral wastes (left) and leachate from a landfill containing a high amount of organic wastes
11.1. The Multi barrier Concept

To avoid that today’s landfill sites become tomorrow’s old dump sites, civil engineers have applied the “Multi barrier Concept” to landfill sites at the end of the 1980ies.194 The multi barrier concept is originally a safety philosophy for nuclear technical facilities. It says that several barriers have to be set up independent from one another in order to avoid release of pollutants into the biosphere. The barriers to be considered for landfill sites are as follows (see Fig. 77):

1) **Waste quality**

Waste should be accepted for disposal only if it has a defined content of total as well as water soluble pollutants. Moreover waste should create only insignificant amounts of landfill gas. Compliance with these conditions requires formulation of limit values for acceptance and, in many cases, pre-treatment of the respective waste prior to disposal. According to EU legislation only pre-treated wastes (inert, non-hazardous and hazardous wastes) may be land filled.

2) **Geological barrier**

The site location must be such that it supports the protection of the groundwater and the containment of pollutants. The natural subsoil below the bottom of the site is considered as the geological barrier and should have a low hydraulic conductivity and high adsorption potential for pollutants.

3) **Technical barriers**

For insulating the waste body from the biosphere, the landfill must be equipped with artificial barriers such as surface and bottom liner and leachate drainage & collection system that avoid release of pollutants from the waste body.

4) **Operation technique**

In order to minimize infiltration of rain water into the waste body during the operation period, the active sections where waste is being placed must be kept as small as possible. During placement, the waste should be well compacted in order to reduce settlements.

5) **Monitoring and control**

Monitoring enables detection of potential damages of the landfill and pollutant release in an early stage and taking appropriate counter measures.

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194 Stief, K.: „Das Multibarrierenkonzept als Grundlage von Planung, Bau, Betrieb und Nachsorge von Deponien”, Müll und Abfall, Heft 1, 1986
In order to avoid the release of pollutants from a hazardous waste landfill into the environment, several barriers have to be set up in such a way that the effectiveness of the barriers is independent from one another. This should be combined with appropriate management measures, adequate site management, supervision and aftercare of the landfill.

Meanwhile, as a result of experiences from 20 years of landfill operation and post-closure control (after care), with respect to domestic waste landfills this concept has been modified: It was found that the complete encapsulation of the waste body causes a “dry tomb effect” during the post-closure phase that inhibits anaerobic pollutant degradation of household waste. For hazardous waste landfills, however, the multibarrier concept continues to be followed more or less in all countries where hazardous waste landfill sites are operated.

The barriers are explained in the following sections in detail.

11.2. Quality of hazardous waste to be disposed on landfill sites

Waste quality is an important element of the multi barrier concept. Only waste that emulates a defined level of mineralization or inertness can be disposed on landfill sites. Waste that is
liquid, explosive, corrosive, oxidizing, flammable or infectious must not be disposed of at landfill sites.

Mixing hazardous waste with non-hazardous for joint landfill disposal (= co-disposal) should be avoided as it has proven to create problems with regard to leachate management. Co-disposal is meanwhile banned in Europe and other countries.

Regulators of many countries have formulated allocation criteria for hazardous waste landfill disposal. The EU legislation has defined minimum requirements\textsuperscript{195} for the waste acceptance criteria and procedures at landfills. Member States need to transpose these minimum requirements into national legislation and may define additional and more stringent requirements.

Table 30 shows allocation criteria for hazardous waste landfill disposal with relevant limit values for single substances as applied in German legislation. For comparison, the respective criteria for domestic waste disposal are also shown. The criteria are briefly discussed below.

Table 30: Allocation criteria for municipal and hazardous waste landfill disposal, Germany\textsuperscript{196}

<table>
<thead>
<tr>
<th>No.</th>
<th>Waste Parameter</th>
<th>Limit values</th>
<th>Municipal Waste Landfill</th>
<th>Hazardous Waste Landfill</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Strength</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.01</td>
<td>Vane shear strength</td>
<td>&gt; 25kN/m(^2)</td>
<td>&gt; 25kN/m(^2)</td>
<td></td>
</tr>
<tr>
<td>1.02</td>
<td>Axial deformation</td>
<td>≤ 20%</td>
<td>≤ 20%</td>
<td></td>
</tr>
<tr>
<td>1.03</td>
<td>Uniaxial compressive strength</td>
<td>&gt; 50 kN/m(^2)</td>
<td>&gt; 50 kN/m(^2)</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Organic content of dry residue of the original substance</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.01</td>
<td>Determined as ignition loss</td>
<td>≤ 5 % by weight \textsuperscript{1) }</td>
<td>≤ 10 % by weight \textsuperscript{1) }</td>
<td></td>
</tr>
<tr>
<td>2.02</td>
<td>Determined as TOC (Total Organic Carbon)</td>
<td>≤ 3 % by weight \textsuperscript{1) }</td>
<td>≤ 6 % by weight \textsuperscript{1) }</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Other solid criteria</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3.01</td>
<td>Extractable lipophilic substances in original substance</td>
<td>≤ 0.8 % by weight</td>
<td>≤ 4 % by weight</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Eluate criteria (24 h, 10 parts H(_2)O / 1 part dry solid) \textsuperscript{2) }</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4.01</td>
<td>pH value</td>
<td>5.5 – 13</td>
<td>4 – 13</td>
<td></td>
</tr>
<tr>
<td>4.02</td>
<td>DOC (Dissolved Organic Carbon)</td>
<td>≤ 80 mg/L</td>
<td>≤ 100 mg/L \textsuperscript{3) }</td>
<td></td>
</tr>
<tr>
<td>4.03</td>
<td>Phenols</td>
<td>≤ 50 mg/L</td>
<td>≤ 100 mg/L</td>
<td></td>
</tr>
</tbody>
</table>

\textsuperscript{195} EU Council Decision 2003/33/EC on establishing criteria and procedures for the acceptance of waste at landfills, Annex 2.4
\textsuperscript{196} German Federal Government: “Ordinance simplifying landfill law, Annex 3, Table 2, 2009. In addition to the criteria of Table 2, also the “Strength”-criteria from the previous “Ordinance on Landfills and Long-Term Storage Facilities…”, 2002 have been included.
<table>
<thead>
<tr>
<th>No.</th>
<th>Waste Parameter</th>
<th>Limit values</th>
<th>Municipal Waste Landfill</th>
<th>Hazardous Waste Landfill</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.04</td>
<td>Arsenic</td>
<td>≤ 0.2 mg/L</td>
<td>≤ 2.5 mg/L</td>
<td></td>
</tr>
<tr>
<td>4.05</td>
<td>Lead</td>
<td>≤ 1 mg/L</td>
<td>≤ 5 mg/L</td>
<td></td>
</tr>
<tr>
<td>4.06</td>
<td>Cadmium</td>
<td>≤ 0.1 mg/L</td>
<td>≤ 0.5 mg/L</td>
<td></td>
</tr>
<tr>
<td>4.07</td>
<td>Copper</td>
<td>≤ 5 mg/L</td>
<td>≤ 10 mg/L</td>
<td></td>
</tr>
<tr>
<td>4.08</td>
<td>Nickel</td>
<td>≤ 1 mg/L</td>
<td>≤ 4 mg/L</td>
<td></td>
</tr>
<tr>
<td>4.09</td>
<td>Mercury</td>
<td>≤ 0.02 mg/L</td>
<td>≤ 0.2 mg/L</td>
<td></td>
</tr>
<tr>
<td>4.10</td>
<td>Zinc</td>
<td>≤ 5 mg/L</td>
<td>≤ 20 mg/L</td>
<td></td>
</tr>
<tr>
<td>4.11</td>
<td>Chloride</td>
<td>≤ 1,500 mg/L</td>
<td>≤ 2,500 mg/L</td>
<td></td>
</tr>
<tr>
<td>4.12</td>
<td>Sulphate</td>
<td>≤ 2,000 mg/L</td>
<td>≤ 5,000 mg/L</td>
<td></td>
</tr>
<tr>
<td>4.13</td>
<td>Cyanides, easily released</td>
<td>≤ 0.5 mg/L</td>
<td>≤ 1 mg/L</td>
<td></td>
</tr>
<tr>
<td>4.14</td>
<td>Fluoride</td>
<td>≤ 15 mg/L</td>
<td>≤ 50 mg/L</td>
<td></td>
</tr>
<tr>
<td>4.15</td>
<td>Barium</td>
<td>≤ 10 mg/L</td>
<td>≤ 30 mg/L</td>
<td></td>
</tr>
<tr>
<td>4.16</td>
<td>Chromium, total</td>
<td>≤ 1 mg/L</td>
<td>≤ 7 mg/L</td>
<td></td>
</tr>
<tr>
<td>4.17</td>
<td>Molybdenum</td>
<td>≤ 1 mg/L</td>
<td>≤ 3 mg/L</td>
<td></td>
</tr>
<tr>
<td>4.18a</td>
<td>Antimony</td>
<td>≤ 0.07 mg/L</td>
<td>≤ 0.5 mg/L</td>
<td></td>
</tr>
<tr>
<td>4.18b</td>
<td>Antimony – C0 Value</td>
<td>≤ 0.15 mg/L</td>
<td>≤ 1 mg/L</td>
<td></td>
</tr>
<tr>
<td>4.19</td>
<td>Selenium</td>
<td>≤ 0.05 mg/L</td>
<td>≤ 0.7 mg/L</td>
<td></td>
</tr>
<tr>
<td>4.20</td>
<td>Water-soluble portion (evaporation residue)</td>
<td>≤ 6 % by weight</td>
<td>≤ 10 % by weight</td>
<td></td>
</tr>
</tbody>
</table>

1) 2.01 may be applied in equivalence to 2.02.
2) Eluate to be prepared according to DIN EN 12457-4, “Compliance test for leaching of granular waste materials and sludge - Part 4: One stage batch test at a liquid to solid ratio of 10 l/kg for materials with particle size below 10 mm”
3) With the approval of the competent authority, excessive values of DOC up to 200 mg/l shall be permissible if the public welfare is not impaired and up to max. 300 mg/l if they are based on inorganically bound carbon.

**Strength (Table 30 No.1)**

Physical stability of the waste is an important requirement for building a landfill site from waste and for avoiding landslides. In this regard particular attention has to be paid to the acceptance of slurry waste. It should be noted that referring sludge stability exclusively to the water content or vice versa to the solid content of a waste may not always work. A solid content of e.g. 25 % may be sufficient for specifying the stability of domestic effluent treatment sludge. However in case of industrial slurries this parameter may fail. There are slurries with high specific density of the solid phase e.g. such as barium sulphate from chlorine production. These slurries are nearly liquid at solid contents much higher than 25 %.

A better parameter for measuring sludge stability is the “vane shear strength” (Table 30, No 1.01) which can be established with a testing probe as shown in Fig. 78. For field work also portable devices are available.
Fig. 78: Testing probe for measuring the vane shear strength of sludge

- **Organic content of the waste** (Table 30, No’s 2.01)

  Limitation of the total organic content is required for minimizing landfill gas generation, organic load of the leachate and settlements of the waste body. Waste that exceeds the limit values for ‘ignition loss’ or ’Total Organic Carbon’, No’s 2.01 and 2.02, is usually a case for incineration. The intention of these parameters is to exclude waste with high organic content from landfill disposal and to attract waste that is largely inorganic in nature. Waste with high organic content has to undergo thermal treatment by incineration.

  German legislation sets very stringent limit values difficult to meet. Countries with less experience in this field and only beginning to set up an environmentally sound disposal system, should consider more lenient values for these parameters or introducing some of them at a later stage.

- **Eluate criteria** (Table 30 No 4)

  Eluate criteria are the most important criteria as they enable a forecast of the waste’s contribution to the leachate quality once the waste has been disposed of. With exception of No’s 4.02, and 4.03 all parameters refer to inorganic pollutants. Waste that does not meet these criteria needs appropriate chemical/physical pre-treatment or has to be disposed of elsewhere. Important is No 4.20: the “water-
soluble component” is limited to 10% w/w of the dry residue. It means that solid water-soluble salts, e.g. many filter dusts, are not suitable for landfill disposal because they would be immediately dissolved by water and become part of the leachate (see underground disposal of HW).

Wastes that do not comply with the requirements of column 4 in Table 30 require either pre-treatment by means of chemical/physical treatment, stabilization or solidification or they have to be allocated to another disposal option.

Some selected hazardous waste types suitable for landfill disposal are listed below:

- Ashes and slags from incineration
- Dewatered sludge from industrial wastewater treatment
- Filter cakes from precipitation sludge containing heavy metals
- Tailings from mining
- Construction & demolition waste containing asbestos
- Contaminated soil

11.3. Acceptance Procedures for Hazardous Waste Landfills

The objective of acceptance procedures for waste to be disposed of at hazardous waste landfill sites is to ensure that only waste is accepted that is suitable for landfill disposal. The complete procedure of waste acceptance at a waste disposal unit should comprise the following steps:

1. Defining conditions for acceptance, to be laid down in the landfill’s operational license
2. Basic characterization of HW to be delivered to the landfill in advance of the delivery
3. Compliance testing of key parameters to be defined in accordance with the basic characterization
4. On-site verification of HW at the time of delivery to the landfill including organoleptic control, testing and if available rapid test methods

11.3.1. Defining acceptance criteria

When issuing the operational license for the landfill, the competent waste authority should specify the following items:

- List of wastes NOT to be disposed (Negative List). (These wastes require other treatment and disposal measures such as incineration, underground disposal or
special pre-treatment.)

- List of hazardous waste codes permitted to be disposed of at the respective landfill (Positive List).

- Limit values of relevant parameters (such as pollutant concentrations, stability, etc., see e.g. Table 30) to be met by wastes intended for disposal.

- Mandatory parameters to be analyzed in a representative sample of the waste under consideration prior to the first delivery to the landfill (“Basic characterization” of waste).

- Checking procedure and documentation requirements to be followed by the operator at the time of the delivery of the waste to the landfill (see “step 4, on-site verification of hazardous waste at the time of delivery to the landfill”).

11.3.2. Basic characterization

Basic characterization according to Directive 1999/31/EC is generally required prior to the first delivery of hazardous waste to a waste disposal or recovery plant (not only to a landfill site).

Basic characterization is the most important part of the acceptance procedure and constitutes a full characterization of the waste by gathering all the necessary information for a safe disposal of the waste in the long term. Basic characterization is required for each type of waste. Once it has been established it serves as a passport or a “fingerprint” of the respective waste.

The objective of the basic characterization is:

- To provide basic information on the waste (type and origin, composition, consistency and other characteristic properties)

- To identify the best treatment option

- To assess the permissibility of the intended disposal option by testing a waste sample against respective limit values

- To provide basic information for understanding the behavior of waste during the envisaged treatment

- To determine normal and exceptional deviations of the waste’s characteristics

- To identify key critical parameters for compliance testing and options for simplification of compliance testing (in order to reduce the constituents to be tested, but only after demonstration of relevant information. Characterization may deliver ratios between
formal evaluation test procedures and results of simplified test procedures.)

Information required for the basic characterization of hazardous waste is given in the text box below.

<table>
<thead>
<tr>
<th>Information and data comprising basic characterization of hazardous waste</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Source and origin of the waste</strong></td>
</tr>
<tr>
<td><strong>Information on the process producing the waste (description and characteristics of raw materials and products)</strong></td>
</tr>
<tr>
<td><strong>Description of the waste treatment applied in compliance with Article 6(a) of the Landfill Directive, or a statement of reasons why such treatment is not considered necessary</strong></td>
</tr>
<tr>
<td><strong>Data on the composition of the waste and the leaching behaviour, where relevant</strong></td>
</tr>
<tr>
<td><strong>Appearance of the waste (smell, colour, physical form)</strong></td>
</tr>
<tr>
<td><strong>Code according to the European waste list (Commission Decision 2001/118/EC)</strong></td>
</tr>
<tr>
<td><strong>Information to prove that the waste does not fall under the exclusions of Article 5(3) of the Landfill Directive</strong></td>
</tr>
<tr>
<td><em><em>The landfill class</em> at which the waste may be accepted</em>*</td>
</tr>
<tr>
<td><strong>If necessary, additional precautions to be taken at the landfill</strong></td>
</tr>
<tr>
<td><strong>Check if the waste can be recycled or recovered</strong></td>
</tr>
</tbody>
</table>

*3 landfill classes: a.) for hazardous waste, b) for non hazardous waste and c) for inert waste

Source: Decision 2003/33/EC

11.3.3. Compliance testing

The function of compliance testing is to periodically check regularly arising waste streams.

After a waste has been deemed acceptable for a specific landfill class on the basis of a basic characterization, subsequent deliveries of the waste shall be subjected to periodical compliance testing in order to determine if the waste complies yet with the results of the basic characterization and the relevant acceptance criteria. The competent authority should determine the intervals for compliance testing according to the waste quantity and/or time (e.g. at least once a year).

11.3.4. On-site verification

Each consignment of waste delivered to a landfill should be visually inspected before unloading. The required documentation should be checked. In case the waste does not
comply with the basic characterization and the results of compliance testing, it must not be accepted for disposal. It may be kept at an intermediate storage area until the competent authority has decided on further action.

While the truck is still waiting, two representative samples from each waste type have to be taken at delivery of a waste consignment prior to unloading of the waste (see Fig. 79). Bulk cargo deliveries should be checked at minimum 3 different places of the container or the truck:

- The first sample is for making a quick test (e.g. color, odor, homogeneity, consistence, pH-value and conductivity of a rapid eluate, etc.) to compare the delivered waste with the results of the basic characterization
- The second sample is retained as reference sample (see Fig. 80) of the respective consignment for a period the duration of which is determined by the competent authority197.

Fig. 79: Waste sampling for on-site verification at the delivery station of a

197 This period varies in the EU member States between one month and several years
11.4. Geological Barrier

The geological barrier is of paramount importance for groundwater protection. Site locations that provide effective geological barriers may be found in areas with clayey subsoil. Clay has a low hydraulic conductivity and a high pollutant retention capacity.

According to EU legislation\(^{198}\) requirements for the geological barrier of landfill sites are the following:

- Landfill for hazardous waste:
  - Subsoil must have a hydraulic conductivity of \( k < 1.0 \times 10^{-9} \, \text{m/s} \), thickness \( >5 \, \text{m} \)
- Landfill for non-hazardous waste:
  - Subsoil must have a hydraulic conductivity of \( k < 1.0 \times 10^{-9} \, \text{m/s} \); thickness \( \geq 1 \, \text{m} \)
- Where the geological barrier does not meet above conditions, it should be improved and reinforced by technical measures to provide equivalent protection. Strength of an artificially improved geological barrier must not be less than 0.5 m.
- Distance between the highest groundwater level to be expected and the bottom of the landfill should not be less than 1.5 m.

The low hydraulic conductivity required by EU legislation can be achieved only by clayey soils.\(^{199}\) An insufficient geological barrier, however, is permitted in case it is improved for


\(^{199}\)
example by adding extra layers to the mineral liner that is forming the base of the landfill and next to the geological barrier. For assessing the distance between the highest groundwater level to be expected and the bottom of the site, annual groundwater fluctuations have to be taken into consideration which may amount to several meters in countries with a monsoon season.

**Permeability of soil materials**

Laminar flow of liquids through soil materials is governed by **Darcy’s Law**:

\[ v = k \cdot i \quad [m/s] \]

- \( v \) = velocity of liquid transport \([m/s]\)
- \( k \) = soil-type-specific coefficient \([m/s]\)
- \( i \) = hydraulic gradient = Height / Thickness

Coefficient \( k \) is also called **hydraulic conductivity**. 

\( k \) is subject to the soil characteristics and has the dimension of a velocity:

<table>
<thead>
<tr>
<th>Soil type</th>
<th>( k ) [m/s]</th>
<th>Relative Permeability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gravel</td>
<td>( 10^{-2} - 10^{-4} )</td>
<td>Pervious</td>
</tr>
<tr>
<td>Sand</td>
<td>( 10^{-3} - 10^{-5} )</td>
<td>Pervious to semi-pervious</td>
</tr>
<tr>
<td>Silt</td>
<td>( 10^{-6} - 10^{-8} )</td>
<td>Semi-pervious</td>
</tr>
<tr>
<td>Clay</td>
<td>( 10^{-8} - 10^{-13} )</td>
<td>Impervious</td>
</tr>
</tbody>
</table>

As the \( k \)-values show, flow velocity decreases with decreasing particle size of the mineral aggregates.

---

199 For more information about hydraulic conductivity of soil materials refer to: http://en.wikipedia.org/wiki/Hydraulic_conductivity
11.5. Technical Barriers

11.5.1. Design

An important issue with regard to the effectiveness of the technical barrier is the basic design chosen for the site.

There are three principal design types for landfills, as depicted in Fig. 81. A fourth design type would be a combination of the stockpile and the pit design. Whereas the slope- and the stockpile design enable leachate discharge by gravity, landfills with pit design will always rely on pumping arrangements for leachate removal. Leachate removal by pumping is disadvantageous for obvious reasons. If pumps are not available the landfill pit gets flooded (see Fig. 45). Maintaining pumping during the long aftercare phase is another problem. The pit design should be avoided therefore.

![Diagram of design types](image)

Fig. 81: Principal design types of landfills

Stockpile sites have usually the highest space requirements for a given disposal capacity because slope inclination is limited due to stability reasons. In this regard the pit design is advantageous as it enables implementation of steeper slopes and requires less space. If topographic conditions permit, the most favorable solution to be chosen is a slope design (Fig. 82).
Fig. 82: CAD (Computer-aided design) drawing of longitudinal – and cross sections of a "slope design" landfill

Figure taken from: KfW, ERM GmbH: "Denizli, Solid Waste Management Project, Turkey", Investment Project within the Framework of Turkish-German Financial Cooperation
11.5.2. Liner Systems

Landfill sites should be sealed on the top and at the base to avoid infiltration of rain water and release of pollutants. Particularly during the operation phase leachate generation is high due to open sections of the waste body exposed to the atmosphere. During this phase proper functionality of the bottom liner is required. After sections of the site have been completely filled, it is the function of the cover liner to avoid infiltration of precipitation water into the waste body and subsequent leachate formation. This is particularly important after the closure of the site in the long-term.

Commonly used liner systems are the following:
- Mineral liners (Bentonite enhanced soil)
- Geo-membranes made from ‘High Density Poly-Ethylene’ (HDPE)
- Asphalt concrete
- Geo-synthetic Clay Liners (GCL’s)
- Composite liners (= mineral liner combined with a HDPE- or an asphalt concrete liner)
- Others

When assessing the suitability of a liner system for a landfill project the following criteria should be considered:  

<table>
<thead>
<tr>
<th>Impermeability (hydraulic conductivity)</th>
<th>Resistance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stability</td>
<td>Long-term durability (1) &gt; 100 years</td>
</tr>
<tr>
<td>Mechanical stability on slopes</td>
<td>Long-term durability (2) &gt; 1000 years</td>
</tr>
<tr>
<td>Ductility202 with regard to curvature without enhancing impermeability</td>
<td>Chemical resistance</td>
</tr>
<tr>
<td>Hydraulic stability against erosion</td>
<td>Resistance against landfill gas</td>
</tr>
<tr>
<td>Construction feasibility</td>
<td>Resistance against micro-organisms, mycelia</td>
</tr>
<tr>
<td>On-site construction feasibility</td>
<td>Resistance against roots</td>
</tr>
<tr>
<td>Construction feasibility with respect to climate impacts (frost, rainfall)</td>
<td>Resistance against crack formation in case of water content reduction</td>
</tr>
</tbody>
</table>

---

201 According to ‘Laender ArbeitsGemeinschaft Abfall’ (LAGA is a working group of experts from German States that elaborates standards for waste related issues): „Deponietechnische Vollzugsfragen: Allgemeine Grundsätze für die Eignungsbeurteilung von Abdichtungskomponenten in Deponieoberflächenabdichtungssystemen.”, Germany, 2004

202 Liners must not be stressed below certain curvature radii. As a result of settlements e.g. “dishes” may be formed which can cause cracks or rupture of mineral and asphalt concrete liners. Geo-membranes must not be folded below a certain curvature e.g. when anchoring them on the top of a slope, otherwise they become brittle and permeable.
11.5.3. Mineral Liners

Mineral liners are made from soil with high clay content. In order to construct a mineral liner with defined impermeability, the quality of the clay or the soil available at the site has to be improved by addition of bentonite which is a pure clay mineral with high swelling power. The materials have to be well mixed and the optimum water content adjusted. Subsequently the resulting mixture is placed and compacted by vibratory rollers in 20-25 cm thick layers. The minimum configuration of a mineral liner comprises two compacted layers corresponding to a height of 0.4 – 0.5m. Achievable impermeabilities range between $10^{-9}$ and $10^{-10}$ m/s. Achieving the prescribed impermeability requires high quality of the construction works and thorough implementation of quality assurance measures.\textsuperscript{203, 204}

The surface of finished layers must be covered by a temporary plastic foil in order to avoid drying out and crack formation. In countries with hot climate the adjustment and maintenance of the water content may become difficult. In contrast to other liner materials mineral liners have also adsorptive capacity for leachate pollutants due to their clay content. Mineral liners are deemed to provide long-term durability $> 1000$ years.

11.5.4. Geo-membranes

Geo-membranes are made from ‘High Density Poly-Ethylene’ (HDPE) and are available as sheet ware with lengths up to 150 m and widths up to 20 m and in various thickness degrees. Geo-membranes as supplied by the manufacturer are inherently impermeable (with a hydraulic conductivity of $-\infty$). This is in contrast to mineral liners the impermeability of which is subject to the quality of the construction works during the liner placement. The HDPE sheets are welded together by special welding devices. The material used in Germany has to have a thickness of 2.5 mm and is rather stiff. Wrinkle-free placement of HDPE without voids between the membrane and the underlying sub grade is difficult and must be done by specialized companies.

With regard to the long-term durability of geo-membranes, manufacturers shy away from providing warranties for the functionality of geo-membranes in landfill sites for more than 100 years: At the

\textsuperscript{203} Values for the relevant soil mechanical parameters of mineral liners can be found in: Federal Ministry of the Environment: “Technical Instructions on the Storage, Chemical, Physical and Biological Treatment, Incineration and Storage of Waste requiring Particular Supervision”, (TA Abfall), Annex E, Germany, 1991

\textsuperscript{204} For a comprehensive overview of mineral liners including quality assurance measures refer to: Burkart, G.U., Gartung, E., “Toolkit Landfill Technology, Chapter 2.3, Mineral Liners for Bottom Barrier Systems”; German Geotechnical Society (DGST); Germany, 2009
end, HDPE like other organic materials is subjected to degradation processes under the conditions in the waste body of a landfill site.

11.5.5. Composite Liners

Composite liners consist at least of one mineral liner and one geo-membrane. The geo-membrane is placed on top of a compacted mineral liner without any voids between both (“press-fit”). Composite liners combine the properties of both single liners and are usually considered as a reference sealing system for landfills. They are most widely used for hazardous- but also for domestic waste landfill sealing systems all over the world.

Fig. 83 and Fig. 84 show the structure of a composite sealing system for the base and for the cover liner according to the standards in Germany in compliance with EU legislation. The mineral liner at the base must be 2x 25 cm high. Prior to implementation of the EU Landfill Directive, the mineral liner had to have a height of 1.5 m (6x 25 cm) according to German legislation. Fig. 85 and Fig. 86 show the placement of a mineral base liner and of a geo-membrane liner at a slope during extension works at the Gallenbach hazardous waste landfill site in Germany.

Fig. 83: Composite sealing system: Base- and cover liner, Germany
Fig. 84: Cross section: Base and cover liner
Fig. 85: Placement of a mineral base liner on a slope during extension works at a hazardous waste landfill site in Germany

Fig. 86: Placement of a geo-membrane liner on a slope during extension works at a hazardous waste landfill site in Germany
11.5.6. Asphalt Concrete Liners

In Germany, for the construction of asphalt concrete liners the same technology is used as for road construction from asphalt. The liner consists of a foundation layer (8 cm) and two sealing layers (2x 6 cm) according to German standards.\textsuperscript{206} Materials needed to include graded gravel and bitumen as a binder. To achieve good impermeability (hydraulic conductivity \(\approx -\infty\)), the void content between the gravels of the sealing layer must be minimized to \(\leq 3\ \text{vol}\%\) for which good compaction is needed. Similar to mineral liners, high quality of the construction works and thorough implementation of quality assurance measures is required for achieving the prescribed sealing effect.\textsuperscript{207}

In Germany asphalt concrete lining is permitted to be used for base and cover sealing of domestic waste landfills in combination with a mineral liner (40 cm), with the asphalt concrete liner replacing the geo-membrane of the composite liner. The benefit of asphalt concrete is its higher resistance to perforation and UV radiation compared to geo-membranes and its insensitivity against drying out compared to mineral liners.

In other countries asphalt concrete lining is also used for disposal sites receiving selected hazardous wastes (e.g. Switzerland, see Fig. 87). Since asphalt concrete uses bitumen as a binder, asphalt lining must not be applied for landfill sites that receive wastes containing agents such as oil or certain organic solvents that might dissolve the binder.


\textsuperscript{207} For a comprehensive overview of asphalt concrete liners including quality assurance measures refer to: Burkart, G.U.: "Toolkit Landfill Technology, Chapter 2.5, Asphalt Liners", German Geotechnical Society (DGPT), Germany, 2009.
Fig. 87: Placement of the sealing layer of an asphalt concrete liner during extension works on a hazardous waste landfill in Switzerland: Small picture: Cylindrical core sample drawn from an asphalt concrete liner for quality testing (diameter approx. 12 cm). The foundation- and sealing layers are clearly visible.

11.5.7. Geo-synthetic Clay Liners

In Germany geo-synthetic clay liners (GLC) consist of two geo-textiles sandwiching a few mm thick layer of bentonite. The geo-textiles are connected with each other by needle-punching or stitch bonding.\textsuperscript{208} Swollen with water and under respective compaction load, the thin bentonite layer provides a sealing effect that corresponds approximately to a 0.5 m thick mineral liner.

Compared to mineral liners GCL’s have the following advantages and disadvantages:

<table>
<thead>
<tr>
<th>Advantages of GCLs</th>
<th>Disadvantages of GCLs</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Easier and faster to construct than mineral liners, with lightweight equipment</td>
<td>• Less shear strength</td>
</tr>
<tr>
<td>• Simpler Quality Assurance</td>
<td>• Less adsorption capacity, faster diffusive breakthrough</td>
</tr>
<tr>
<td>• Comparable in cost to mineral liners</td>
<td>• Thin GCL more subject to puncture</td>
</tr>
<tr>
<td></td>
<td>• Unknown long-term durability</td>
</tr>
</tbody>
</table>

Advantages of GCLs

- Small thickness conserves landfill space
- Better freeze-thaw, desiccation resistance

Disadvantages of GCLs

- Limited experience

GCL’s are permitted in Germany to be applied as sealing element in cover liners of domestic landfills, thus replacing the mineral liner. In the USA, EPA has approved application of GCLs also as a liner element for base sealing’s of domestic waste landfills on a case by case basis. However, nowhere in Western countries GCLs have been approved for application as a sealing element in hazardous waste landfill sites, neither for base nor for cover lining. The lack of shear strength and puncture resistance bears unforeseeable risks particularly when GCL’s are used for base lining, given the high load of the overarching waste body. It should be noted that the technical specifications of GCLs such as e.g. strength values and elongations at maximum strength are the results of laboratory tests and do not cover the rough construction and operation conditions on a landfill site.

Despite these considerations it was observed that GCLs are used in developing countries for hazardous waste landfill sealing even at the base. GCLs may provide convenient solutions in the short run; however, there may be risks in the long-term. Landfill planners should seek therefore advice from independent civil engineering experts with practical field experience when choosing a sealing system.

11.6. Leachate Drainage and Collection

The function of the leachate drainage and collection system is to receive leachate trickling down from the waste body and to remove it quickly towards the leachate collection pipes thus minimizing the hydraulic pressure on the liner surface. The leachate collection pipes transfer the leachate further to collection tanks or lagoons outside of the site.

The basic design of the leachate drainage and collection system is depicted in Fig. 88. The base of the landfill has to be profiled according to a roof-shape sequence. On top of the geomembrane a protective layer has to be placed consisting of a geo-textile or a 2 cm sand layer. This is to avoid perforation by the gravels of the subsequent 50 cm high drainage layer which consists of graded gravel material. To ensure best function of the system, relevant parameters are adjusted to each other, such as:

---

- Drainage layer: Range of particle sizes of the gravel: 16-32 mm, graded; \( k > 1 \times 10^{-3} \) m/s
- Height of the drainage layer: 50 cm
- Inclination of the transversal slopes: > 3%
- Length of transversal slopes: < 15 m
- Inclination of the longitudinal slopes: > 1%
- Length of longitudinal slopes: < 200 m

![Diagram of leachate drainage and collection system](image)

Fig. 88: Leachate drainage and collection system: Cross section and perspective view; leachate collection pipe, cross section

Leachate collection pipes are placed into the roof valleys of the leachate drainage and collection system. They are made from HDPE and their upper surface is perforated with a pattern of holes or slots for taking up the leachate (see Fig. 79).

Given that the pipes have to withstand the load of a 30 m high waste body, structural analysis calculations have to be performed on the pipes and wall thickness adequately dimensioned. Also proper pipe bedding support must be provided. The pipes should have an internal diameter of 300 mm to enable pipe inspection with cameras and flushing with high-
pressure cleaning lances. For the same reason lateral pipe connections or branching (herring bone pattern of pipe connections) must be avoided.

11.7. Landfill Gas Drainage

Landfill gas generation from hazardous waste landfills is much less compared to domestic waste landfills due to the smaller portion of organic matter of hazardous waste. Moreover, the toxic nature of the pollutants in hazardous waste inhibits micro-bacterial anaerobic degradation processes from which landfill gas is generated.

During site operation landfill gas generation should be monitored. Gaswells for passive venting may be set up if deemed necessary. Gaswells can be built from cylindrical segments and, filled with coarse gravel, elongated with growing height of the waste body. As shown in Fig 69 a gas drainage layer (sand) may be placed below the mineral liner of the cover sealing, unless this function can be ensured by the underlying compensation layer. A challenge for engineers is to find a technically sound solution for the perforation of the cover sealing required for the venting pipes. It must be avoided that, fostered by settlements during the closedown phase, precipitation water trickles into the waste body at the perforations.

11.8. Reference Design for Sealing and Leachate Collection System

The regulator should specify a reference design for the sealing- and leachate collection system including detailed quantification of relevant dimensions and parameters related to the properties of the materials to be used and the functionality of the system. Also requirements for quality assurance should be specified. Relevant German legislation may serve as a good example [203].

Merely defining liner layers, their sequence and respective thickness as observed is insufficient. Compliance with this reference design should be made mandatory for all landfill project applications. Applicants intending to use alternative designs or modify the reference design should be obliged to provide evidence that functionality and long-term sealing effect of the alternative design is equivalent with that of the reference design.

11.9. Quality Assurance (QA)

Quality Assurance is of paramount importance during landfill construction. Flaws that occur during the construction are difficult to detect after disposal operations have started because relevant elements of the construction are no longer accessible. QA measures have to be specified in the tender documents and adequate financial means for QA have to be considered in the budgeting.
The following refers to the construction of a base sealing composite liner consisting of a mineral liner and a geo-membrane.

Before the construction works start, a quality assurance plan has to be elaborated in order to ensure that the construction quality of the sealing system meets the design specifications. The quality assurance plan includes the following:

(1) Suitability testing (to be conducted prior to the beginning of the construction)

(2) Quality assurance measures during the construction of the sealing system:

- In-house testing by the contractor (= construction company assigned the contract)
- Confirmation testing by an independent 3rd party laboratory as deemed necessary by the competent authority
- Monitoring by the competent authority

11.9.1. Suitability testing prior to the beginning of the construction

Suitability testing is to establish the construction feasibility of the sealing system according to the design specifications. It also serves to establish the contractor’s capability to ensure the required construction quality. Suitability tests are to be performed:

(i) On the materials needed for the construction,
(ii) On the planned construction procedures.

The contractor should conduct the following tests: 210

a) Materials for the mineral liner and the drainage layer:
   determination of relevant soil mechanical parameters as specified in the design and other relevant standards such as particle sizes, axial deformation, unaxial compressive strength, water content, limestone content, proctor density, hydraulic conductivity etc.

b) Material for the geo-membrane:
   For establishing the suitability of the geo-membrane a respective certificate of the manufacturer of the geo-membrane is required. Random checks on the specified thickness, evenness etc. of the sheets has to be conducted.

210 According to Annex E of [209]. Details of all tests can be found there.
c) Construction procedures:
Prior to the beginning of the liner construction, the contractor has to set up a test field (see Fig. 80):

d) To establish relevant parameters for the placement of the mineral liner, such as thickness of layers prior and after compaction, weight and speed of the rollers, number of passes, etc. The test field must consider construction of the mineral liner in the base as well as in the slopes.

e) To establish that the mineral liner meets the relevant requirements specified in the design. Samples have to be taken from compacted mineral liner layers in the test field to compare relevant soil mechanical parameters achieved in the field with the design values.

f) To develop the detailed quality control plan and test program for the mineral liner. According to German legislation, the construction of a test field is mandatory. The test field must not become part of the later sealing system. Fig. 89 shows the minimum dimensions of a test field. Implementation of the test field and accomplishment of the required quality assurance should be examined by the competent authority.

Fig. 89: Test field for suitability testing of the intended placement procedures of the mineral
liner: a) layout view, b) cross section A-A, c) cross section B-B

11.9.2. Quality assurance measures during the construction of the sealing system

After evaluation of the test field results the competent authority and the contractor will agree on the details of the QA plan. The contractor has to conduct his own in-house testing parallel to the construction works. With regard to the mineral liner, for each completed layer field- and laboratory tests on the relevant soil mechanical parameters have to be conducted. The next layer must be placed only on explicit approval of the competent authority. With respect to the geomembrane, the quality of completed welding seams of the HDPE-sheets has to be tested. The competent authority may request an independent 3rd party laboratory to conduct random tests for comparing the results with the in-house testing of the contractor. The competent authority must oversee the entire quality assurance program and confirm the test results.

Final acceptance of the sealing system will be only granted when all tests show satisfactory and conclusive results. All test results have to be well documented for later reference.

Expertise on soil mechanics, which is required for the quality assurance of mineral liners, may be found in civil engineering departments of universities or in companies engaged in earth works such as road-, dam- or tunnel construction.

11.10. Operation

Waste Placement

The placement of the waste should proceed in small compartments or cells (see Fig. 90). This is to minimize leachate generation and to maintain cleanliness of the operation area. The scale and number of the cells depends on local site conditions and on factors such as:

- Quantity of periodic waste delivery
- Consistence of the waste and necessity of separated storage due to different chemical characteristics of the waste
- Maximum possible placement height for specific waste materials. With increasing height, the traffic areas, ramps and turning pads are also growing

For the first layers to be placed on top of the drainage layer only selected fine wastes should be chosen. The waste should be well compacted in layers. This is necessary for reducing later settlements of the waste body. The layer height is subject to the waste materials. Slurry waste may be mixed with structured waste materials to enhance stability. To minimize

211 See also: TA Abfall, Annex E, 2.3, „Eignungsprüfung im Großmaßstab“, 1991
leachate generation and air pollution, the placement area should be covered with a layer of cohesive soil and/or plastic foils at the end of a working day.
Fig. 90: Longitudinal cross section and lay-out views of cell development during landfill disposal [200] (The first cell to be developeds the red-shaded cell, the second cell the brown-shaded-cell, and so on)
11.10.1. Leachate Minimization

Leachate from hazardous waste landfill sites is in most cases liquid hazardous waste and requires expensive treatment. Top priority of leachate management is therefore leachate minimization.

The area exposed to the atmosphere where filling operations are on-going should be kept as small as possible. Sections that are intermittently being operated should be covered during operation off-time with an intermediate cover made from plastic foils weighed down by old tires (see Fig. 91). There are also concepts that provide for a movable roof overarching the section under operation or even for a stationary roof sheltering the entire landfill site (see Fig. 92).

Fig. 91: Intermediate cover and temporary surface liner at hazardous waste landfill site Billigheim in Germany

Fig. 92: Roofing constructions at hazardous waste landfill site Rondershagen,
Germany. Total capacity: 960,000 m$^3$; roofed area = 45,000 m$^2$ (2010)

In countries with a **monsoon season**, it may be advisable to dimension the cells in such a way that the cells can be completely filled every year prior to the beginning of the monsoon season and covered with an intermediate cover (plastic foil) as protection against precipitations. During the monsoon season fill operations may be discontinued and waste delivered to the site stored at an intermediate storage area under roof for later filling.

Sections of the disposal area where waste placement is on-going should be separated from clean sections by means of temporary berms in order to separate non-contaminated storm water from leachate and thus minimizing leachate quantity. To facilitate this separation, waste disposal should always start at the highest point of the landfill or of a cell. Storm water is diverted over a bypass-system to collection ponds outside the landfill area from where it can be discharged to the public sewerage system after absence of pollutants has been confirmed.

Completely filled sections should be covered with a geo-membrane as a temporary cover liner (Fig. 82. The final cover including the mineral liner and the recultivation layer can be applied only after settlements have come to a halt.

### 11.10.2. Leachate Treatment

Leachate collection pipes may get choked by precipitation reactions between pollutants or by infiltration of fine particles. Periodical pipe inspection and pipe flushing with high pressure lances is therefore necessary.

Leachate has to be collected in tanks or lagoons (see Fig. 93). There are two options for leachate treatment:

- **Off-site treatment**  
  if leachate quantities are small, the leachate may be transported by tanker trucks to a domestic ‘Effluent Treatment Plant’ (ETP). From a dedicated storage tank the leachate can be channeled into the input flow of the ETP as a controlled bypass stream so that the degradation capacity of the ETP is not exceeded. Alternatively the leachate may be transported to a chemical-physical treatment plant for treatment. Off-site treatment may be reasonable also at the beginning of the operations when leachate quantities are yet unsure.

- **On-site treatment**  
  in many cases a leachate treatment plant has to be built next to the landfill for on-site treatment. Due to the recalcitrant nature of the pollutants, leachate treatment should be developed and should include a chemical/physical treatment such as precipitation,
ultra-filtration, reverse osmosis, air stripping (for ammonia removal), flocculation and sedimentation, adsorption on activated carbon followed by conventional biological treatment.

Fig. 93: Leachate collection tanks with two-stage reverse osmosis treatment plant

11.11. Monitoring and Control

According to EU legislation\textsuperscript{213} the competent authority of a Member State (or regional administrative entity) shall require the operator to monitor the following data during the operation-, closedown- and aftercare phase:

- Meteorological data (e.g. rates of precipitation and evaporation)
- Emission related data
- Leachate volume and composition
- Storm water volume and composition (upstream and downstream of the site)
- Potential landfill gas emissions

\textsuperscript{212} Figure taken from: Kolboom, F.; (2005). company information, PS Project Systems GmbH & Co. KG, 24539, Neumuenster, Germany

\textsuperscript{213} Directive 1999/31/EC on the landfill of waste, Annex III
Data related to groundwater protection (groundwater level and composition)
- Data related to the topography of the site
- Volume already filled, remaining capacity
- Settling behavior

Meteorological data together with data on leachate volumes enable calculation of the water balance which may be an effective tool for evaluating whether leachate is building up in the landfill body or whether the site is leaking. The water balance also serves to forecast leachate generation.

For establishing reference values for groundwater monitoring, sampling must be carried out in at least three locations before the filling operations start. The measurements must be such as to provide information on groundwater likely to be affected by the discharging of waste, with at least one measuring point in the groundwater inflow region and two in the outflow region. This number can be increased on the basis of a specific hydro-geological survey and the need for an early identification of accidental leachate release in the groundwater.

The parameters to be analyzed in the groundwater samples taken must be derived from the expected composition of the leachate and the groundwater quality in the area. In selecting the parameters for analysis account should be taken of mobility in the groundwater zone. Parameters could include indicator parameters in order to ensure an early recognition of change in water quality e.g. such as pH, TOC, phenols, heavy metals, fluoride, oil/hydrocarbons.

11.11.1. Elements for control and monitoring procedures

Meteorological data
States should supply data on the collection method for meteorological data. The data shown in the table below could be collected from monitoring at the specially engineered landfill or from the nearest meteorological station.

It is recognized that water balances are an effective tool for evaluating whether leachate is building up in the landfill body or whether the site is leaking.

<table>
<thead>
<tr>
<th>Measurement of Operational phase</th>
<th>Aftercare phase</th>
</tr>
</thead>
</table>

http://archive.basel.int/meetings/sbc/workdoc/techdocs.html
### Emission data: water, leachate and gas control

Sampling of leachate and surface water if present must be collected at representative points. Sampling and measuring (volume and composition) of leachate must be performed separately at each point where leachate is discharged from the site.

Monitoring of surface water if present shall be carried out at not less than two points, one upstream from the landfill and one downstream.

Gas monitoring must be representative for each section of the specially engineered landfill.

The table below indicates the frequency of sampling and analysis.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Operational phase</th>
<th>Aftercare phase (3)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Leachate volume</td>
<td>Monthly (1)(3)</td>
<td>Every 6 months</td>
</tr>
<tr>
<td>Leachate composition</td>
<td>Quarterly (3)</td>
<td>Every 6 months</td>
</tr>
<tr>
<td>Volume and composition of surface water (7)</td>
<td>Quarterly (3)</td>
<td>Every 6 months</td>
</tr>
<tr>
<td>Potential gas emissions and atmospheric pressure (4)</td>
<td>Monthly (3) (5)</td>
<td>Every 6 months</td>
</tr>
<tr>
<td>(CH$_4$, CO$_2$, O$_2$, H$_2$S, H$_2$ etc.) (5)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

(1) The frequency of sampling could be adapted on the basis of the morphology of the landfill waste (in tumulus, buried, etc.). This has to be specified in the permit.

(2) The parameters to be measured and the substances to be analyzed vary according to the composition of the waste deposited; they must be laid down in the permit document and reflect the leaching characteristics of the wastes.

(3) If the evaluation of data indicates that longer intervals are equally effective, they may be adapted. For leachates, conductivity must always be measured at least once a year.

(4) The measurements are relevant mainly to landfills receiving large quantities (>25% w/w) of organic waste.

(5) CH$_4$, CO$_2$, O$_2$ regularly, other gases as required, according to the composition of the waste deposited, with a view to reflecting its leaching properties.

(6) Efficiency of the gas extraction system must be checked regularly.

(7) On the basis of the characteristics of the landfill site, the competent authority may determine that these measurements are not required.

Leachate volume and leachate composition apply only where leachate collection takes place.

For leachate and water a sample, representative of the average composition, shall be taken for monitoring.

### Protection of groundwater

**Sampling**
The measurements must be such as to provide information on groundwater likely to be collected by the discharging of waste, with at least one measuring point in the groundwater inflow region and two in the outflow region. This number can be increased on the basis of specific hydrogeological survey and the need for an early identification of accidental leachate in the groundwater.

Sampling must be carried out in at least three locations before the filling operations in order to establish reference values for future sampling.

*Monitoring*

The parameters to be analyzed in the samples taken must be derived from the expected composition of the leachate and the groundwater quality in the area. In selecting the parameters for analysis account should be taken of mobility in the groundwater zone. Parameters could include indicator parameters in order to ensure an early recognition of change in water quality.215

The table below provides information on the selection of parameters.

<table>
<thead>
<tr>
<th>Operational phase</th>
<th>Aftercare phase</th>
</tr>
</thead>
<tbody>
<tr>
<td>Level of groundwater</td>
<td>Every 6 months (^{(1)})</td>
</tr>
<tr>
<td>Groundwater composition</td>
<td>Site-specific frequency (^{(2) (3)})</td>
</tr>
</tbody>
</table>

\(^{(1)}\) If there are fluctuating groundwater levels, the frequency must be increased.

\(^{(2)}\) The frequency must be based on possibility for remedial actions between two samplings if a trigger level is reached, i.e. the frequency must be determined on the basis of knowledge and the evaluation of the velocity of groundwater flow.

\(^{(3)}\) When a trigger level is reached (see C), verification is necessary by repeating the sampling. When the level has been confirmed, a contingency plan (laid down in the permit) must be followed.

*Trigger levels*

Significant adverse environmental effects should be considered to have occurred in the case of groundwater, when an analysis of a groundwater sample shows a significant change in water quality. A trigger level must be determined taking account of the specific hydrogeological formations in the location of the landfill and the groundwater quality. The trigger level must be laid down in the permit whenever possible.

The observations must be evaluated by means of control charts with established control rules and levels for each down gradient well. The control levels must be determined from local variations in groundwater quality.

*Topography of the site*

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215 Recommended parameters: pH, TOC, phenols, heavy metals, fluoride, As, oil/hydrocarbons.
Data on the specially engineered landfill body should be collected as indicated in the below table.

<table>
<thead>
<tr>
<th>Operational phase</th>
<th>Aftercare phase</th>
</tr>
</thead>
<tbody>
<tr>
<td>Structure and composition of landfill body (1)</td>
<td>Yearly</td>
</tr>
<tr>
<td>Setting behavior of the level of the landfill body</td>
<td>Yearly</td>
</tr>
</tbody>
</table>

(1) Data for the status plan of the concerned landfill: surface occupied by waste, volume and composition of waste, methods of depositing, time and duration of depositing, calculation of the remaining capacity still available at the landfill.

11.12. Life Phases of a Landfill Site

Fig. 94 shows the different phases of the lifetime of a landfill. Due to a significant “economy-of-scale” effect landfill sites are usually planned as centralized facilities with sufficient capacity to enable active operation and waste disposal up to 30 years.

![Fig. 94: Life phases of a landfill site](image)

The construction phase continues actually during the disposal phase because landfill sites are developed in phases. Completion of the entire construction prior to the beginning of disposal operations is neither technically nor economically sensible. During and after termination of the disposal phase temporary cover, liners are applied on top of the waste body. The final cover liner and the re-cultivation layer can be placed only after settlements of the waste body have come to a halt which takes between 2-5 years.
During the post-closure period (aftercare phase) the pollutant containment has to be ensured mainly by the effectiveness of the cover liner: Less precipitation water percolates into the site, less leachate will be generated and carried out. However, leachate generation will still continue during this phase and leachate needs to be collected and treated accordingly.

According to EU legislation the site operator is responsible for monitoring and analyzing leachate, landfill gas and the groundwater regime in the vicinity of the site for: “…as long as may be required by the competent authority taking into account the time which the landfill could present hazards.”

Responsibilities of the operator include also site maintenance, i.e. leachate- and landfill gas collection and treatment during the post-closure phase.

This means, operators have to set aside money during the disposal phase in order to cover costs for the placement of the final cover liner and the recultivation layer as well as costs for monitoring and maintenance of the site during the post-closure phase. The minimum period to be considered is 30 years in accordance with relevant EU legislation.

These costs have to be included into the disposal costs charged to the clients. It has to be highlighted that the cost share of the post-closure phase expenses including cover liner, recultivation layer, leachate treatment, maintenance and monitoring, is approximately 50 % of the entire lifetime costs of the landfill site.

11.13. Economical Aspects

Landfill sites are subjected to a significant ‘economy of scale’ effect.

The total investment of a landfill site consists of the development costs and the infrastructure costs (See Table 31)

Whereas the development costs are subject to the scale of the project (i.e. the site capacity), the infrastructure costs are nearly independent from the scale.

Table 31: Cost items for landfill development

---

### Development Costs
(dependant on the scale of the site)
- Preparation of land for construction
- Construction of ring road
- Leveling and profiling of subsoil (cut and fill)
- Construction of liner and leachate drainage & collection system including costs for quality assurance

### Infrastructure Costs
(relatively independent from the scale of the site)
- Access road
- Fence
- Electricity and water supply
- Leachate treatment plant
- Groundwater monitoring wells
- Machine park (wheel loader, compactor, bulldozers, trucks)
- Weigh Bridge
- Office building and equipment
- Laboratory for testing of incoming waste

Development costs of the landfill can be kept at bay by stepwise development based on the actual need for fill capacity. Only one cell, i.e. one drainage section should be provided in advance. This avoids binding financial means for constructions which are actually needed only years later and reduces the initial investment required. Stepwise development reduces therefore the annual amortization costs and thus the disposal costs.

On top of the infrastructure costs also other factors contribute to the ‘economy of scale’ effect:

- Bigger and subsequently higher landfill sites lead to a minimization of specific area demand and to considerably reduced costs for the costly sealing and leachate collection system (on one m² of lined bottom area a higher waste column can be piled up);
- The percentage of sloped areas in relation to the total landfill volume of a bigger landfill is usually smaller than that of several smaller landfills totaling the same volume. It should be noted that the placement of the liner and leachate collection system on sloped areas is significantly more expensive than on flat leveled areas;
- Landfill operation can be organized much more cost effective in bigger landfills, as the equipment can be used more efficiently (from only 1-2 hours a day up to 8 hour a day or even 2 or three shift operation);
- On big landfill sites with a high annual disposal capacity the landfill sections under operation which are exposed to the atmosphere can be kept relatively small. This reduces leachate generation and costs for expensive leachate treatment.
Fig. 95: Hazardous Waste Landfill Site Billigheim in Germany (Total capacity: 930,000 m$^3$, delivery: 20-40,000 t/a, tentative end of disposal phase: 2025)

For estimating the ‘economy of scale’ effect the “Environmental Enterprise Consultancy Zhejiang” Program (GTZ) had elaborated rough cost estimations based on actual investment and operation costs for two existing landfill sites in the Chinese Province Zhejiang in the cities Hangzhou and Ningbo. This was part of a hazardous waste infrastructure disposal planning project. For the annual average disposal capacity of both sites 30,000 t/a has been assumed. This leads to average specific investment costs of 130 RMB/t and to specific operation costs of 800 RMB/t. Based on an evaluation of comparable projects and the principles of balance of scale, the resulting costs for landfills with other capacities have been estimated and are listed in Table 32. As the data show, total specific costs decrease significantly with increasing lifetime capacity.

Table 32: Estimation of “Economy of Scale” effect for hazardous waste landfill disposal (based on actual local costs, China, 2007. 1RMB $\approx$ 0.1€)\(^{219}\)

\(^{218}\) 1 RMB (= Renminbi, Chinese currency unit) equals approx. 0.1 Euro (2008)

Landfill Investment and Operation Cost

<table>
<thead>
<tr>
<th>Landfill Investment and Operation Cost</th>
<th>Average annual capacity usage (t/a)</th>
<th>Lifetime Capacity (t)</th>
<th>Investment Costs (RMB)</th>
<th>Specific Investment Costs (RMB/t)</th>
<th>Operating Costs (RMB/t)</th>
<th>Total specific costs (RMB/t)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average investment &amp; operation costs based on existing examples in Hangzhou / Ningbo</td>
<td>30,000 *)</td>
<td>600,000</td>
<td>78,000,000</td>
<td>130</td>
<td>800</td>
<td>930</td>
</tr>
<tr>
<td>Estimated Total and Specific Landfill Costs</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Assumption: 1/6 capacity, investment cost * 0.5</td>
<td>5,000</td>
<td>100,000</td>
<td>39,000,000</td>
<td>390</td>
<td>1,200</td>
<td>1,690</td>
</tr>
<tr>
<td>Assumption: 1/3 capacity, investment cost * 0.6</td>
<td>10,000</td>
<td>200,000</td>
<td>46,800,000</td>
<td>234</td>
<td>1,200</td>
<td>1,434</td>
</tr>
<tr>
<td>Assumption: 1/2 capacity, investment cost * 0.75</td>
<td>15,000</td>
<td>300,000</td>
<td>56,250,000</td>
<td>188</td>
<td>1,200</td>
<td>1,188</td>
</tr>
<tr>
<td>Assumption: 2x capacity, investment cost * 1.5</td>
<td>60,000</td>
<td>1,200,000</td>
<td>117,000,000</td>
<td>98</td>
<td>700</td>
<td>798</td>
</tr>
<tr>
<td>Assumption: 3x capacity, investment cost * 1.8</td>
<td>90,000</td>
<td>1,800,000</td>
<td>140,400,000</td>
<td>78</td>
<td>600</td>
<td>678</td>
</tr>
<tr>
<td>Assumption: 4x capacity, investment cost * 2</td>
<td>120,000</td>
<td>2,400,000</td>
<td>156,000,000</td>
<td>65</td>
<td>500</td>
<td>565</td>
</tr>
<tr>
<td>Assumption: 5x capacity, investment cost * 2.15</td>
<td>150,000</td>
<td>3,000,000</td>
<td>167,700,000</td>
<td>56</td>
<td>450</td>
<td>506</td>
</tr>
</tbody>
</table>

*) assuming a period of 20 years for the disposal phase

(It should be noted that the total specific costs for the existing sites in Hangzhou and Ningbo in Table 32 are not the disposal rates charged to the waste producers. These costs are decided by the Chinese City Level Price Bureaus and include also cost provisions for the aftercare phase.

Costs charged to waste producers are exceptionally high with prices ranging between 1,500 -2,000 RMB/t.)

Landfill sites should be planned and operated as centralized facilities, possibly with capacities that enable disposal operation for 20 to 30 years. This ensures that disposal costs can be kept at levels acceptable for waste producers. A centralized approach is beneficial also from an environmental point of view. Experience has shown that centralized landfills can be operated more effectively with regard to environmental standards. Moreover, potential risks are restricted to a limited number of objects. A decentralized approach for hazardous waste landfill disposal on the other hand might evolve into a hot spot pattern of small sites with each one presenting potential risks that would not easily be manageable for the competent authorities.


The Sino-German bilateral “Environmental Enterprise Consultancy Zhejiang” Program was implemented in the Chinese Province of Zhejiang from 2003 to 2008. The objective of the hazardous waste management component of this program was to assist Zhejiang in building a hazardous waste management system. Zhejiang has one of the highest GDP’s from all
Chinese provinces. It is also considered as China’s pilot province for hazardous waste management.

Though landfill design and development was not one of the focal areas of the program, the Chinese cooperation partner, the “Solid Waste Management and Supervision Center” of the “Zhejiang Environmental Protection Bureau” requested the program to conduct a survey among four landfill site projects in Zhejiang with regard to design, construction and operation of these sites. The landfill sites have been developed by Chinese stakeholders independently from the Sino-German Program.

It may be noted that it is a major trend among China’s administrative city districts to follow a decentralized approach for developing a hazardous waste disposal infrastructure. Each of Zhejiang’s eleven cities seeks to develop its own facilities such as landfill sites and incinerators.

Usage of the facilities is permitted only to those waste producers located in the respective city region. Hazardous waste transfer from one city to another is banned. Due to the mountainous profile and the high population density of Zhejiang site identification for landfills is extremely difficult. In 2008 Zhejiang had four landfill site projects in different stages of implementation, ranging from site identification to operation. The sites are relatively small in size with total capacities from 180,000 to 650,000 m$^3$. Disposal costs are high, as a result of transfer limitations and the small scale of the facilities.

Fig. 96: Hazardous waste landfill site in Ningbo. Since landfill disposal is more expensive than incineration, the landfill does not receive much hazardous waste
for disposal

Fig. 97: Hazardous waste landfill site in Taizhou. Initial development of the entire site area requires higher investment and increases disposal costs, compared to progressive site development.

Two experts of the program conducted a survey among these four sites during which technical discussions were held with the respective stakeholders of each site. After conclusion of the survey, a workshop was convened with all stakeholders for discussing observations and for making recommendations for future landfill projects. The observations and recommendations were later also conveyed to the competent department of the central government.

The box below provides excerpts of the executive summary of the final report.  

**Regulatory issues**

Observations and recommendations with regard to regulation refer to the “Chinese Standard for Pollution Control on the Security Landfill Site for Hazardous Wastes GB 18598-2001”.

- It was observed that the responsibilities for development, construction, operation and post-closure monitoring of a landfill site are not clearly defined with regard to the involved parties such as the approval authority, the supervising authorities, the landfill owner, the contractor and the operator. Chinese standard GB 18598-2001 should be

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revised in this regard

- The Chinese standard should determine the “Composite Liner System” as a standard design for the base sealing.

- Design specifications laid down in the standard should be supplemented and standardized. This refers particularly to important design items such as slopes, dimensions, materials and construction details. It should become mandatory that designs submitted by applicants for HW landfill sites comply with the standard design thus defined.

- The Chinese Standard should define minimum requirements of a quality assurance programme to be followed during the construction works and specify the responsibility for its supervision.

- The Chinese standard should detail a procedure to be followed for allocating HW to a landfill site starting from the transfer plan application to the final acceptance of the waste at the landfill site. The list specifying the “entrance criteria” for landfill disposal in chapter 5 of the Chinese standard should be supplemented.

For revision of the Chinese standard reference may be made to the “Technical Instructions on the Storage, Chemical, Physical and Biological Treatment, Incineration and Storage of Waste requiring Particular Supervision”, Germany 1991.[99]

- **Design Issues**

  - Despite availability of large gravel quarries and abundant clay quantities in the vicinity of all sites it was observed that ‘Geosynthetic Clay Liners’ (GCL’s) and geomembrane drainage grids are excessively being used for base/slope sealings and drainage respectively rather than making use of naturally occurring materials for implementing clay layers for sealing and gravel layers for drainage.

  - Not only are geo-synthetic materials expensive to purchase but clay liners with appropriate thickness are considered to provide the most reliable sealing, and gravel layers with a minimum thickness of 30 cm are considered as the best standard solution for drainage of groundwater, leachate and as a control drainage. It is recommended therefore to use clay- and gravel layers for sealing and drainage rather than GCL liners and geo-membranes drainage grids.

  - ‘Geosynthetic Clay Liners’ should not be placed directly on top of a geo-membranes drainage grid as executed in the Zhejiang landfill designs. The risk is high that bentonite from the GCL infiltrates into the voids of the drainage grid thus clogging it. It may be noted that application of GCL’s in base sealings of hazardous waste landfill sites does
not comply with international practice.

- In order to enable clay liner compaction on sloped areas, slope inclination should not be steeper than 1:3. Terraces in slope sealing layers should be avoided as they cannot be sealed properly.

- Complicated sealing structures like double geo-membrane liners sandwiching compacted clay liner should be avoided. There is a risk that the first geo-membrane liner gets damaged when installing the compacted clay liner on top.

- Manufacturer’s rules for placement of geo-synthetic materials must be followed to avoid damages. This concerns particularly the allowed installation radiiuses.

- Sufficient distance between the base of the landfill and the highest groundwater level to be expected should be always considered.

- The design of the leachate drainage and collection system should consider cell-wise operation of the landfill and enable leachate minimisation measures.

- With regard to the leachate collection pipes, the design should consider appropriate pipe support to avoid irregular settlements and leachate backlog.

- Leachate collection pipes laterally connected to a collection pipe inside a landfill (= herringbone pattern) must be avoided. These pipelines can hardly be inspected and maintained.

• **Construction**

- Construction quality should be verified by implementation of a quality assurance programme. This includes set-up of a test-field, prior to the beginning of the construction works.

- Construction of the landfill should be performed progressively, step by step, cell by cell, in accordance with the actual need for fill capacity. This avoids binding investment for landfill sections required later and reduces amortization- and disposal costs.

• **Operation**

- The competent authority that issues the operational license for the site should specify an acceptance procedure for waste delivery to the site. This procedure has to be followed by the operator and supervised by the authority.

- For leachate minimization, leachate should be separated from storm water by appropriate measures such as temporary coverage of open waste piles and separation of cells under operation from “clean” areas.

- Geo-membrane sealing layers of landfill sections which are yet uncovered from waste
should be protected against climatic impacts (UV radiation) by means of a temporary plastic liner.

- **Economical Aspects**
  - The key issue to enable economical viability of landfill site operation is, on top of enforcing HWM related regulation, to abandon the traditional planning approach “one city – one landfill’ and to plan centralized facilities. Catchment areas of HW landfill sites should be determined by waste generation, size and spatial distribution of waste generating industrial areas rather than by city borders.
  - Developers of landfill sites should consider the ‘economy of scale’ effect; i.e. the bigger the total and the annual capacity of a landfill site, the lower the specific disposal costs and, as a consequence, the higher the acceptance of HW landfill disposal among the regulated community. Financial benefits due to the economy of scale effect outweigh usually additional transport costs.
  - Construction of the landfill should be performed progressively, step by step, cell by cell, in accordance with the actual need to fill capacity. This avoids binding investment for landfill sections required later and reduces amortization and disposal costs.

- **Underground Disposal of Hazardous Waste**

There is an array of hazardous waste types that can neither be pre-treated appropriately for safe landfill disposal nor allocated to other disposal options such as incineration. In order to enable landfill disposal of those wastes, other barriers of the multi-barrier concept must be enhanced accordingly for compensating respective shortfalls in waste quality.

In countries with suitable geological formations such wastes are preferably disposed in underground disposal facilities. In Germany\(^{221}\), they are disposed in inactive mining fields of potash and salt mines which are situated below the water-bearing strata, at depths of 500 to 800 meters. Underground waste disposal in rock salt is considered to be a safe solution for the disposal of hazardous waste. The geological conditions within the gastight rock salt have been stable for millions of years. Rock salt reacts with plastic deformations to forces moving the earth crust; thus the formation of open crevices is not possible. These conditions are considered as an effective geological barrier for the permanent and maintenance-free

\(^{221}\) The German underground waste disposal plants also receive toxic wastes from all over Europe and from international hazardous waste generators
removal of those hazardous wastes from the biosphere that do not meet the waste quality criteria required for above-ground landfill disposal (see Fig. 98).

Fig. 98: Geological barrier of an underground disposal facility in Germany

A waste type that may exemplify the characteristic nature of wastes to be disposed in an underground disposal facility is e.g.:

Contaminated cyanide salts from case hardening

This toxic waste is generated from case hardening of steel during which steel parts are dipped into a liquid melt of an alkali cyanide salt. The waste is listed in the EWL in chapter 11 03, “Sludges and solids from tempering processes”:

| 11 03 01* | Wastes containing cyanide |

Landfill disposal of this highly water-soluble waste is impossible because of non-compliance with parameters No 4.13 and 4.20 in Table 30. Chemical/physical treatment is technically feasible (dissolving in water, oxidation of cyanide with suitable agents) however not advisable (generation of large wastewater quantities, costs). Stabilization and solidification of inorganic salts is not possible and incineration is no option either (generation of vast NOx quantities, damage of the refractory material of the rotary kiln’s liner due to the alkaline nature of this waste). Hence, underground disposal is the best option for this waste type.

222 Figure taken from a technical information brochure of K+S Entsorgung GmbH, http://www.ks-entsorgung.com/en/home/
Characteristic wastes that are disposed of in underground disposal facilities are the following:

- Polluted water-soluble solid salts
- Heat transfer salts
- Filter dusts and flue gas purification residues from waste incineration and other thermal processes
- Wastes containing mercury, arsenic, cyanides
- Alkaline wastes, moisture-sensitive
- Acid wastes, moisture-sensitive
- Halogenated organic waste (HCH, PCB etc.)
- Capacitors containing PCB’s
- Parts of transformers contaminated with PCB’s
- Expired pesticides
- Lab chemicals
- Galvanic residues

For an overview of recommendable acceptance criteria of hazardous waste for underground disposal, see Table 33 including criteria as applied for an underground storage facility in Germany.
Table 33: Acceptance criteria for hazardous waste in an underground disposal facility\textsuperscript{223}

- To be accepted for underground waste disposal, wastes shall not be
  - Radioactive,
  - Explosive,
  - Highly flammable,
  - Liquid,
  - Infectious,
  - Malodorous or
  - Under deposit conditions easily flammable

- Under deposit conditions there shall be no reactions of the waste with itself or with the rock that cause
  - An expansion of the volume,
  - Formation of auto-flammable, toxic or explosive substances or gases or
  - Other dangerous reactions.

- For underground disposal the wastes heating value (H\textsubscript{o}) shall not exceed 6,000 kJ/kg\textsuperscript{224} dry mass and the waste shall not be biodegradable.

How to deal with the disposal of hazardous waste with insufficient waste quality in countries that do not (yet) have an underground disposal facility?

- The suitability of candidate sites for underground disposal should be assessed within the framework of an environmental impact assessment and the most appropriate site chosen for developing a facility. It may be noted that also consolidated rock strata can serve as effective geological barrier for underground hazardous waste disposal. An important selection criterion is the exclusion of groundwater intrusion.

- If development of an underground disposal facility is not an option, other barriers have to be created for compensating deficiencies in waste quality for above-ground disposal. This could be e.g.

\textsuperscript{223} These criteria apply for the German underground disposal facility Herla-Neurode

\textsuperscript{224} Or the competent authority allows a higher H\textsubscript{o} value because

a) they can be produced and detected in elementary carbon, inorganic substances or process related reactions or distillation residues with a component of more than 10 % by weight, or not other technical treatment is possible or economical reasonable,

b) they are either ion exchange resins with heavy metals contaminations from water treatment facilities or mercury containing wastes or

c) the underground disposal is the best available environmental alternative, see German Deponieverordnung from 2011 at: http://www.karlsruhe.ihk.de/innovation/umwelt/Abfall/Aktuelle Informationen/1658108/Neue_Deponieverordnung_DepV_am_12_2011_in_Kraft_getreten.html?sessionsid=CADB3472747099990714041462DA2BP9D.repl1
- Stabilization and solidification wherever possible (as mentioned earlier, this may not work with inorganic solid water-soluble salts)
- Development of dedicated cement concrete cells within a landfill site for the disposal of special waste types. Incompatible waste types have to be kept in separate cells. Extra packaging and lining may serve as additional barrier. It should be clear however that such solution requires permanent supervision.
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• Module 8

• Waste Management Planning
• Waste Management Plans

In the following, the most important elements of waste management planning will be explained. In this context, the requirements defined in EU waste legislation are briefly presented taking into account priority actions for low and middle income economies in relation to hazardous waste management.

WMP should be designed in a way so as to prioritize prevention, general reduction and recovery of hazardous wastes where possible. Given the continuous increase in demand for resources due to economic growth in developing countries and the scarcity of natural resources, the environmental as well as economic rationale for acquiring recyclable resources from wastes has increased. The waste management industry can generate jobs and elevate the standard of living.

WMP needs to take into consideration the challenges that small and/or geographically isolated countries face. Some wastes may be best managed globally as disposal may be challenging or require large economies of scale in order to be effective. Product stewardship schemes for hazardous waste (e.g. waste electrical and electronic equipment) should be promoted.

General aspects of WMP

Political support and understanding of the need to draw up a waste management plan is crucial. If a plan already exists, this plan may have to be revised. If, on the other hand, the first waste management plan has yet to be worked out, it is very important that the political level should have accepted the need for a plan and allocated sufficient resources to its execution. Hence, it is recommended to create a political starting point in order to carry out the foundation work for a waste management plan.

A political starting point should include a decision on the following questions:

− Who will be involved in the preparation of the hazardous waste management plan?
− What is the time frame for the finalisation of the waste management plan?
− What is the relationship to other existing plans?

Footnote:
225 Some elements and basic pieces of advice are taken from the Methodological guidance on preparing of waste management plans and waste prevention programmes that is currently reviewed and updated on behalf of the European Commission. (Being in draft status these elements may not be cited or publicly used at the moment, the publication is envisaged to be available in the first half of 2011)
EU waste legislation, namely the Waste Framework Directive 2008/98/EC (Art 28), requires competent authorities to draw up waste management plans. The competent authorities comprise national administrations and environmental protection agencies as well as local and regional authorities. In addition, the planning process involves politicians, administrative staff and planners, contractors, various public organizations, NGOs and stakeholders.

Waste management planning is an important implementation and enforcement instrument of waste legislation and has become a permanent element of public planning efforts in all EU Member States. Waste management plans play a key role in achieving sustainable waste management.

The main purpose of WMPs is to provide an inventory of current waste streams and treatment options and to outline needs for action and future developments.

**Checklist before starting planning**

It is recommended to check if the aspects listed below have been considered and clarified before starting the actual planning. This can be done with the help of the following checklist:

<table>
<thead>
<tr>
<th>Checklist</th>
</tr>
</thead>
<tbody>
<tr>
<td>It is recommended to set up a task force with clear responsibilities for the work to be carried out.</td>
</tr>
<tr>
<td>1. Are political understanding and support for the waste management planning process present?</td>
</tr>
<tr>
<td>2. Have sufficient resources been allocated to the process?</td>
</tr>
<tr>
<td>3. Scope of the waste management plan:</td>
</tr>
<tr>
<td>3.1. What is the geographical coverage of the plan? National, regional or local level?</td>
</tr>
<tr>
<td>3.2. What is the time horizon of the plan? E.g. 3, 5 or 10 years?</td>
</tr>
<tr>
<td>4. Have the participants in the planning process been identified? Do they include government departments, local authorities, waste experts, representatives of the waste management sector and the waste generating industry, and NGOs?</td>
</tr>
<tr>
<td>5. Has the time frame for the preparation of the waste management plan been set? Time estimates for the project should be realistic.</td>
</tr>
</tbody>
</table>
6. Have any relationships between the waste management plan and other plans (e.g. spatial planning, energy planning, etc.) been identified? Do they influence elements in the waste management plan?

### Involvement of third parties in the planning process

Participants in the waste planning process should include a wide range of stakeholders in order to cover all the important aspects. They may include:

- representatives from the political and the administrative level (government departments, regional authorities, municipalities)
- hazardous and other waste experts
- representatives from the waste management sector (collection, recycling, incineration and landfill)
- industry, industrial and commercial organisations
- consumer councils/associations
- NGOs.

Other parties may be involved in the planning process as well.

Participation of stakeholders and the general public can be assured by means of working groups, round tables, public information, hearings, workshops, seminars, or other means to disseminate information and to compile and collect proposals, concerns and comments.

### Consultation

All parties involved in hazardous waste management should be involved in the determination of the future hazardous waste management system and a consultation phase must be included in the planning process before adopting the final waste management plan and its initiatives.

Public consultations may take place at various stages in the planning process. Thus, a public consultation may take place as a kick-off meeting before the status part, allowing the competent authority to collect ideas and input from selected stakeholders. Alternatively,

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226 Waste management service providers (including collectors, transporters, plant operators and the corresponding associations), scientist, other competent stakeholders including representatives from specialized NGOs
consultations may be placed just before the planning part when the problems and possible solutions have been identified.

In practice however, in the preparation of a national waste management plan the industrial stakeholders are often involved in a consultation round when the first draft of the plan is available. The consultation round may be very limited – the draft plan is sent for written comments to

selected stakeholders (political parties, industrial organizations in the waste management sector, consumer and environmental organizations, NGOs etc.).

The preparation of a regional/local waste management plan often includes a more extensive consultation phase, for example with public meetings, distribution of information brochures and information about the plan on the internet.

**Dealing with social protests / Acceptance**

Four basic principles of dealing with social protests towards hazardous waste management when planning or building a hazardous waste facility:

1. Understanding that there will be opposition and resistance towards a hazardous waste project and that this can lead to the failure, even of a good and well-planned project. One mistake that has to be avoided is to underestimate the political potential of the project’s opponents.

2. Understanding and analysing the arguments of the project’s critics and opponents. The general ethical or legal right of critics and protesters to be against a project for personal reasons has to be accepted. If this is not accepted first, cooperation and adjustment to the critics’ ideas and needs are made impossible.

3. Understanding that creating acceptance is a long and arduous process. In doing so the basis of all public relations work has to be the principle of trying to convince with adequate and factual information. This leads to:

4. The willingness and motivation to inform and include the public – especially neighbours and critics of the process. **Transparent and continued communication with the community must form the priority.**

**Analysis of the conflict’s different levels by project´s opponents**

The motives of the oppositional attitude towards a project in waste management can come from different levels of conflict. In a specific analysis of project opponents, especially in hazardous waste sector, one is faced with a wide range of motives which have,
depending on the individuals, a different meaning within the opposition. In the case of an evolving resistance, it is therefore useful, to carry out a motive analysis, preferably supported by external experts. To understand which mixture of motifs is present within the opposition and on which level of information it is based on, a motive analysis can be very helpful.

Motifs based on blind conservatism against such projects are observable in the first place: New things on the location are rejected, familiar things should be preserved. Changes are perceived as a threat.

An entirely different level of conflict is the subject of justice. Sites for hazardous waste facilities are often planned in rural, scarcely populated areas, while money is being earned in other regions, for example, on industry and commerce influenced sites. In these regions the hazardous waste is created and often not disposed there, but in poorer, rural regions. This situation is perceived as unjust. Of course there are technical reasons why potentially hazardous facilities are realized in scarcely populated areas. Sometimes decisions about the location are motivated by the fact that lower resistance is to be expected within a rural region. But facilities of that kind should be anyway designed technically in a way that potential risks are minimized. If this argumentation comes more to the foreground (in case of no or a negligible low risk), the need for site's placement in lowly populated areas is eliminated.

Other motifs emerge from interests of neighbours to a proposed hazardous waste facility. There are concerns about noises, dirt and emissions of odours and pollutants. Often the conflict consists of the project's sponsor claiming the insignificance of the emissions. This insignificance is denied by objectors, who might present their own, more negative sceptical notion. Also decreasing land prices and consequently losses in property value can be reason for concerns or protests. Site assessment should always include an analysis of the ownership structure of the neighbourhood.

The scientifically measureable emissions are easier to predict. In addition these effects are not willingly discussed in public. Difficult to grasp, but not less infective, are diffuse fears: fears of elusive environmental toxins, unknown pollutants or carcinogenic effects. Especially cancer and cancer-causing substances, ingested in small amounts over a long period of time, are reason for diffuse fear. These emissions are never completely reducible to zero, so that it is difficult for project sponsors or project managers to argument clearly against these risks. Even if the most technical and scientific experts cannot understand diffuse fears, they should remember that for inhabitants of the site or project opponents "environmental toxins" are very relevant, and sometimes may even be a priority. Therefore, it is generally useful and also reducing weaknesses in the argumentation, when the decision of the location
for a hazardous waste treatment plant is made on the basis of a site search process in accordance with scientifically plausible criteria. But even a technically sound and precise search associated with a transparent presentation of the criteria and the relevant trade-offs may cause conflicts (especially if the opponent is against the use of the site). In these cases often the criteria and the validity or the tradeoffs are attacked. Other motifs against projects or special location decisions in the waste sector can be of idealistic nature, such as ideals of nature and natural resources; certain technologies are rejected, for example, large-scale technologies like large landfills or incinerators that would generate the need for hazardous waste to operate on full capacity. Waste avoidance is part of this pattern of argument.

This argument can lead to a fundamental consumer-critical approach. The criticism is directed against the current high level of production and consumption - especially in Western countries. Humanity and its ecological footprint exceed the natural capacities of the earth. Following this argumentation, one should not create a waste management, which primarily exists to absorb the surplus of a consumer society and which is keeping such a wasteful and destructive system alive. The answer would be to provide a more sustainable development, so that the plant would no longer be required in the proposed form.

Of course, the argument usually is not stated that simplified as in the example above. But it is not a matter the quality of the arguments presentation; the problem in dealing with this argument is that its basic truth is undeniable. It would have little credibility to euphemise the role of waste management. It is necessary to promote understanding for the fact that due to reality of today's production and consumption patterns a disposal site is needed. It is important to show, that you work for a better future. A highly technical and environmentally-friendly standard that can only be purchased at an adequate price is a good starting point.

The motivation of the project's opposition is usually associated with their personal interests. Quite often the opponents own interests are regarded as prior to the arguments like the idealistic ones. Here the driving forces are for example the conservation of the life situation. In this way the project's opponents are following the local existing power structures. And eventually diffuse fears intensify the conflict situation.

Similar to the levels of conflict also the procedure or escalation of a conflict can be analysed.

**Control circuit of resistance**

- Small group of local objectors or protesters get active
- Growing number of locals get involved, local groups form or get involved, protests intensify
- Local intelligentsia (doctors, teachers, lawyers) get involved
- Local church representatives or authorities get involved
- Project critics win local authorities or people in power for their cause
- Conflict reaches supraregional media or even the national level

Fig. 100 Steps of escalation)

A conflict about a proposed site in waste management begins with a "disquieting feeling" within the neighbourhood as the project and/or its planning is being announced. This basic feeling has especially a negative impact, when the first information is not communicated directly, but spread as rumour instead of a regular process.

Important in this initial phase is the active involvement of groups or individuals of the neighbourhood in planning (local activist). Without the commitment of one or more citizens to act as driving force of resistance, there is no resistance.

Possible structures of resistance

Activists often try to establish their approach through self-organized structures and link themselves to other opponents of the project. For short-term conflicts they organize through meetings, etc. For longer-lasting conflicts also fixed binding structures can be established, such as associations or foundations with professional guidance.

The activists are trying to look for allies and supporters. Since many conflicts over the localisation of the site have a large environmental focus, environmental groups offer themselves as a supporter of regional or even international action. Often an escalation of the conflict occurs, if competent environmental groups enter the local conflict. As environmental groups are very limited in their capacity of personnel, they cannot accept all local conflicts and they make decisions according to certain criteria and priorities. The best way is to prevent the occurrence of these groups in the first place.

At the local level also alliance partners are being searched. Church representatives and religious leaders are important contacts for local activists as well as representatives of the local "intelligence" (teachers, lawyers or doctors). Especially the medical community can play a big role in conflict over positioning of waste treatment plants and their emissions. Here a further step to escalation is reached (fig. 100). Activists often succeed in involving the media. Sometimes during this step, important business companies enter the conflict and take position against the planning. Those cases are of course motivated by the companies’ own interests. For example, a food company could have a significant objection to their headquarters being associated with the site of a controversial hazardous waste landfill. At the last step of escalation, it is possible that project opponents will also find allies among the
local or national leaders. Finally, the support for a project which originally existed is cancelled through political decisions. Once at this step, a guilty party is being searched and the developer will need to defend himself against accusations.

**Ways of promoting acceptance**

How does a strategy look like that not only deals with all the technical aspects described in this manual, but also with social aspects of the site planning? The answers may be very different. But some important aspects can be mentioned at this point and the most important aspect has already been mentioned: Site concepts are regularly executed by technical experts and engineers. These experts have a very high level of technical knowledge, but in most cases there is a complete lack of expertise in dealing with social questions. Therefore, the project sponsor must develop an acceptance - especially regarding infrastructure facilities of the hazardous waste sector - that incorporates **social site planning** with the same priority as the **technical site planning**. After convincing the technical site planners, the details of social site planning can be examined.

Before you look at the actual or potential levels of conflict and the relevant actors, a critical analysis of site selection makes sense. You are in a comfortable position, because site selection has taken place under objective criteria. A transparent selection of particularly suitable locations facilitates the legitimacy of the choice of location. But in any case it should be clear why the chosen location is suitable and this **argumentation** should be supported by all the participants. The technical experts tend to start communicating usually by the time a project has an adequate technical clarity and the regulatory approvals, its planning is almost completed and construction is scheduled. At this point in time it is too late.

The art of a transparent work in public relations is to inform as soon as possible and without damaging the project itself. In the beginning you cannot answer all the questions about technical issues and citizens’ concerns towards a project, because the plans are not finalized yet. However, it is possible to represent the actual situation, especially with regard to the location decisions, but without publishing detailed plant design information. Maybe it is best to go public after the preplanning phase, so at least some answers to fundamental questions can be given. The first step in going public, though not easy, should always be made on purpose and not imposed by the unplanned leakage of information.

After the initial information of the public, it is important to observe the neighbourhood’s behaviour. Sometimes the environment remains passive. In this case you should continue public information. But regularly in this early phase questions and concerns occur. These should be answered as good as possible and as fast as possible, maybe even in personal conversations with affected persons. At an early stage, it is also possible to start planning to utilise a **coordination of interests**. Sometimes there are only small requests concerning the
technical planning, that may satisfy a potential activist or can be understood as a fair compromise.

But especially in the hazardous waste sector, one will not always succeed to satisfy the whole neighbourhood. Therefore, it should not be surprising if resistance is rising in this early phase, despite all great efforts that have been made to avoid it. This resistance will grow, depending on the potential of conflict and the objectors within the stages of escalation. **The promoter at this stage should under any circumstances continue to share transparent information with the public.** The realisation of this advice is sometimes not easy; the project opponents can work with the given information about the project and try to generate counterarguments from this information. If these counterarguments are solid, the developer should react to them and possibly even adjust the concept. If the arguments are not persuasive, or if they are even polemical, the project sponsor should dispel the concerns in an objective way. A common mistake in the context of conflict escalation is that the attention too much focused on the projects’ opponents and activists. **The main task of an acceptance strategy is to reach the wider public.** Especially when the project opponents are looking for alliance partners in the local structures, it is necessary that there is good and positive information available about the project and that these are possible to be communicated. Without adequate testing and expert reviews it is unlikely to occur convincing. Without adequate information, neutral persons can be lost in this conflict or even can get involved in the opponents work against the project.

If the escalation proceeds in the described manner, it is necessary for the promoter to follow the discussion very closely and to analyze it. The activities regarding information and explanation of the project have to be intensified and information has to be reprocessed fitting to the specific addressee (for example an ordinary citizen would be overwhelmed by too much technical detail).

From a certain stage of escalation of the location conflict it is to decide if to process social questions with the help of professional support.

**The analysis of motivation,** which should be an essential condition of a social site planning, shows the promoter, which interests push this conflict. It is not recommendable to have too high expectations regarding the projects' acceptance. Those who expect a smooth approval for the construction of a hazardous waste treatment plant will always be disappointed. Those who want to convince the activists completely will fail. But if some understanding of the promoter’s arguments is the goal, it can be successful and the conditions for project approval are given.

**Specific characteristics of the hazardous waste sector**
In the waste sector - in particular in the hazardous waste sector – one of the most challenging parts is the decision about site localisation, because a negative image sticks to it and it is often associated with hazardous emissions, even from scientific perspectives.

Terms such as "hazardous waste" cause concerns among the population, which for that reason assume also high risks associated with the plant. A main issue for the promoters is to deal communicatively with this line of arguments to gain support and social acceptance. Promoters should also keep in mind that this contains the strongest argument for the site at the same time: it must be dealt with this kind of waste in a special way, just because of the fact that it is a hazardous substance.

One way to resolve the dilemma is to clarify the situation without euphemisms and to convey the safety of the techniques in dealing with these substances. Of course people who fear emotionally diffuse risks cannot be completely convinced by technical arguments. Perhaps this is more successful if you can show that there are other people living in comparable locations and that they are not exposed to risks or hazards.

### 13.1. Planning Principles and Procedures

In order to build a hazardous waste management infrastructure on a national, regional or local level, the respective tasks and activities to be tackled have to be based on effective and systematic planning. A waste management plan has to be elaborated that sets out an analysis of the current waste management situation in the geographical entity concerned, as well as the measures to be taken to improve environmentally sound preparing for re-use, recycling, recovery and disposal of hazardous waste.

**Content of a waste management plan**

According to EU legislation, the following mandatory elements have to be included in a national or regional WMP are briefly presented in the box:

The **obligation for Member States to establish a waste management plan** is laid down in Waste Framework Directive 2008/98/EC.

According to Article 28, the competent authorities of the Member States are to establish a waste management plan that relates in particular to the following elements which must mandatorily be addressed in each waste management plan:

(a) the type, quantity and source of waste generated within the territory, the waste likely to be shipped from or to the national territory, and an **evaluation of the development of waste streams in the future**

(b) **existing waste collection schemes and major disposal and recovery**
installations, including any special arrangements for waste oils, hazardous waste or waste streams addressed by specific community legislation

(c) an assessment of the need for new collection schemes, the closure of existing waste installations, additional waste installation infrastructure in accordance with Article 16, and, if necessary, the investments related thereto

(d) sufficient information on the location criteria for site identification and on the capacity for future disposal or major recovery installations, if necessary

(e) General waste management policies, including planned waste management technologies and methods, or policies for waste posing specific management problems

Structure of a typical waste management plan

There is no rigid pattern for how to structure a waste management plan or strategy. However, considering the main contents to be included, a recommended simple structure may look as follows:

- Assessment of the status quo (inventory)
- Identification of deficits and needs
- Establishment of an appropriate infrastructure
- Financial aspects, calculation of investments and costs
- Allocation of wastes to appropriate treatment methods

In order to make the waste management plan easily readable and highly applicable for the different parties involved, it is recommended to keep its content as short and concise as possible.

Fig. 101 depicts the sequence of planning. In the following relevant planning steps are discussed in detail.
13.2. **Assessment of Current Hazardous Waste Generation**

Establishing an inventory of current hazardous waste generation is an important milestone of hazardous waste management planning. It is the reference for the extrapolation of future hazardous waste generation and the subsequent determination of types, capacities and locations of disposal and recovery installations required in the future. Though a data accuracy of ± 20% is sufficient for planning purposes, estimation of hazardous waste generation may become difficult subject to the availability of base data. In principle hazardous waste generation can be assessed from:
o Direct data related to the waste streams, available from governmental sources
o Secondary data
o Conduction of own surveys

In order to get more reliable data it is recommended to always use more than only one method and to crosscheck the results against one another.

13.2.1. Information collection

At the outset information about the key conditions of hazardous waste management in the planning area should be collected, as far as available:

o Information on hazardous waste management from governmental sources with regard to generation, storage, treatment and disposal of hazardous waste as well as types, quantities and classification
o Priority waste types with regard to quantity and toxicity
o Industry structure, main industrial sectors generating hazardous waste
  - Main products
  - Supply chains
  - Number of enterprises and employees in each sector
  - Stratification of industrial sectors in terms of large-, medium- and small scale enterprises as well as state owned – private owned enterprises, if applicable
o Structure of the waste management sector with relation to types, capacities and locations of treatment and disposal installations, disposal fees, collection systems

13.2.2. Estimation of Hazardous Waste Generation from Direct Data

13.2.2.1. Types of direct data

“Direct data” can be obtained as a by-product of waste legislation to control hazardous wastes. They should be readily available from government records and may serve for a first estimation of waste generation.

There are at least three types of direct data:

(1) **Consignment note data**

Depending on the implementation status of hazardous waste legislation, data on hazardous waste generation quantities, types, origins and temporary storage can be
compiled from consignment notes (see chapter 7). These data, however, do not include hazardous wastes recovered or disposed of internally within the premises of the waste producer. In Germany, where the utilization of external recovery and disposal facilities is largely mandatory, consignment note data provide a quite accurate picture of hazardous waste generation.

(2) **Reports of hazardous waste producers**

The most comprehensive source of waste generation data is in general reports on waste generation which form part of a registration scheme in a number of countries and are usually published annually. Hazardous waste producers are generally required to submit a regular report to the competent authorities on waste quantities, composition, and treatment and disposal methods.

(3) **Reports of waste recovery and disposal facilities**

(Annual) reports by treatment and disposal facility operators may also be required as part of a registration or licensing scheme. Compared to similar information reported by waste producers, data from treatment and disposal facilities give however less insight into the origin of the waste.

13.2.2.2. **Quality of direct data**

In countries where implementation and practical enforcement of hazardous waste legislation including notification procedures are still in the beginning, above data are often not available and therefore hazardous waste generation is often underestimated. The reasons are the following:

- Omission of wastes in reports or consignment notes due to low awareness or fraudulent intent of hazardous waste producers
- Recognition of hazardous wastes as “commercial goods” (see section 7.3.)
- Inadequate waste classification (e.g. hazardous waste is classified as non-hazardous waste which can be caused by unavailability of a self-explanatory user-friendly hazardous waste list
- Insufficient separation of hazardous waste at the source of generation
- Inadequate verification of waste producer’s and facility operator’s data by the competent authorities due to lack of resources and/or insufficient capability of the authorities
Insufficient practical enforcement of hazardous waste legislation in the small scale sector. Whereas waste producer data and consignment notes may be available from large and medium scale enterprises, they are rarely provided by the small companies. However, this sector may have a high share in total hazardous waste generation (see also “White Book” on Current Situation and course of action for sound chemical Management in SMEs in India, 2008).\(^{228}\)

These effects have to be taken into consideration when direct data are being used for estimating hazardous waste generation. Plausibility of direct data should always be cross-checked by alternative assessments based on other information.

13.2.3. Estimation of Hazardous Waste Generation from Secondary Data

Estimating hazardous waste generation from secondary data is a rapid assessment method which is chosen when time and financial constraints do not permit more detailed investigation. Secondary data are usually calibrated waste generation data obtained from countries where such data are available. Calibration refers waste generation to a second parameter such as product quantity of a production process from where both products and wastes are generated, turnover, GDP, inhabitants or the number of employees of an industrial sector of which the waste generation has to be estimated. In this way specific waste generation coefficients are created. They are increasingly important for monitoring changes, showing trends and developing projections of quantitative and qualitative waste generation.

Waste generation coefficients can be also applied for estimating waste generation in developing countries. Waste generation is then simply calculated by multiplying the coefficient established in the reference country with the respective parameter sourced from the developing country. However, this simplified approach is based on the assumption that waste generation coefficients have equal values in both countries which may be questionable due to:

- Differences in industry structure (e.g. employment, supply chain mechanism)
- Differences in production efficiency or waste generation intensity
- Different waste classification systems

\(^{228}\) http://srmc-ehe.org.in/8_publications.php
Different air pollution control- or waste water discharge standards (which influences generation of wastes such as effluent treatment sludge, filter dusts, etc.)

Much expertise is required therefore for selecting appropriate waste generation coefficients, making necessary adjustments and interpreting the results.

13.2.3.1. The most important indicators for waste generation are:

- **Waste generation per product quantity**

  Main application of this coefficient is at the enterprise level for benchmarking production efficiency of companies that manufacture similar products. For broad waste generation estimation this coefficient is of limited use as industry statistics use different units for indicating production output, such as metric tons for bulk products and various other units (e.g. cars in the automobile sector, meter for textile cloth etc.).

  With regard to waste generation estimation, the coefficient may be applied for surveying selected industrial sectors in which production output is referred to the same unit in the reference country as well as in the target country. However, not many reference data are available for this coefficient.

- **Waste generation per capita and year /waste generation per value added (e.g. kg / 1000 EUR)** (see Fig. 102)

  These coefficients are applied at a national or regional level as an informative tool which integrates environmental data with demographic and economic aspects, compares efficiency of countries or regions in minimizing waste generation and supports the authorities in drawing up their national or regional waste-management plans. For comparing hazardous waste generation of different countries a coefficient “waste generation per value added” is better suited than “waste generation per capita” given that economic activities have the highest impact on hazardous waste generation.
Fig. 102: Hazardous waste generation in Europe in kg per capita

- **Waste generation per year and number of employees in the respective industrial sector**

  This coefficient is most widely used for estimating hazardous waste generation in developing countries from secondary data. Reference coefficients are available for a number of countries and industrial sectors (see Table 34). Employment data in developing countries can be sourced usually from ministries of industry or statistical agencies.

  Interpretation of the results has to consider differences between the reference- and the target country with regard to industrial structures, production efficiency, supply chain mechanism etc.

  The statistical office of the EU, Eurostat, provides access to databases that permits compilation of tailor made coefficients for individual industry sectors, waste types and EU member countries (see Table 35). Consistency of these data is satisfying as all
EU countries are using the same waste codes (EWL) - and industry catalogue (NACE) codes\textsuperscript{229}.

Table 34: Waste generation coefficients in selected manufacturing industry sectors (kg / employee / year)\textsuperscript{230}

<table>
<thead>
<tr>
<th>Waste Types</th>
<th>32</th>
<th>35</th>
<th>36</th>
<th>37</th>
<th>38(a)</th>
<th>38(c)</th>
<th>39</th>
</tr>
</thead>
<tbody>
<tr>
<td>Textiles, Clothing,</td>
<td>1.0</td>
<td>50.2</td>
<td>5.1</td>
<td>401.7</td>
<td>50</td>
<td>100</td>
<td>50</td>
</tr>
<tr>
<td>Footwear</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chemicals, Petroleum,</td>
<td>1.4</td>
<td>200.6</td>
<td>50.2</td>
<td>100.4</td>
<td>50</td>
<td>20</td>
<td>30</td>
</tr>
<tr>
<td>Coal</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Non-metallic Products</td>
<td>3.4</td>
<td>40.1</td>
<td>80.3</td>
<td>40.2</td>
<td>8</td>
<td>8</td>
<td>6</td>
</tr>
<tr>
<td>Basic Metal Products</td>
<td>0</td>
<td>8</td>
<td>0</td>
<td>2</td>
<td>2</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td>Fabricated Metal</td>
<td>8.6</td>
<td>20.1</td>
<td>10</td>
<td>0</td>
<td>20</td>
<td>20</td>
<td>100.1</td>
</tr>
<tr>
<td>Products</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Other Machinery</td>
<td>2.3</td>
<td>7</td>
<td>0.1</td>
<td>1</td>
<td>5</td>
<td>1</td>
<td>6</td>
</tr>
<tr>
<td>etc.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Reactive wastes</td>
<td>5</td>
<td>10</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>5</td>
<td>10</td>
</tr>
<tr>
<td>Paints / resins etc.</td>
<td>69.2</td>
<td>10</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>15</td>
</tr>
<tr>
<td>Organic Solvents</td>
<td>38.2</td>
<td>80.2</td>
<td>10</td>
<td>60.2</td>
<td>30</td>
<td>30</td>
<td>30</td>
</tr>
<tr>
<td>Putrescible wastes</td>
<td>1.3</td>
<td>20.1</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>Textile wastes</td>
<td>17.3</td>
<td>200.6</td>
<td>401.8</td>
<td>200.9</td>
<td>40</td>
<td>40</td>
<td>30</td>
</tr>
<tr>
<td>Oils / oily wastes</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Contaminated containers</td>
<td>0.1</td>
<td>2</td>
<td>0</td>
<td>0</td>
<td>0.1</td>
<td>0.1</td>
<td>0.2</td>
</tr>
<tr>
<td>Inert wastes</td>
<td>0</td>
<td>10</td>
<td>0</td>
<td>0</td>
<td>0.1</td>
<td>1</td>
<td>0.1</td>
</tr>
<tr>
<td>Organic chemicals</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pesticides</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 35: EUROSTAT data explorer for compilation of sector specific hazardous waste generation coefficients

\textsuperscript{229} In the EU, the common classification for economic activity is NACE (general industrial classification of economic activities within the European Communities). The amounts of hazardous waste generation will therefore be related, where possible, to NACE codes. \url{http://ec.europa.eu/competition/mergers/cases/index/nace_all.html}

\textsuperscript{230} Reid & Crowther & Partners Ltd.: “Hazardous waste in Northern and Western Canada”, Vol. 1, Assessment of Need; Environment Canada; Ottawa, 1980
Experience from detailed waste surveys has shown wide variations in waste-per-employee coefficients even within narrowly defined industry sectors. In most cases however costs and time scale is likely to prohibit conduction of a comprehensive survey which would render more reliable results. A compromise between costs and accuracy is a representative survey of statistically selected waste producers belonging to the relevant hazardous waste generating sectors of the planning area. This will enable the use of locally derived waste generation coefficients.

Enterprises to be surveyed should be selected from industrial sectors with significant contribution to hazardous waste generation. Selection of enterprises should also consider stratification of the industry with respect to large-, medium- and small scale enterprises.

For conducting the survey on-site visits and interviews with the responsible staff have shown to yield better results compared to results obtain by sending postal questionnaires to companies. On-site visits have to be conducted by qualified experts (see section 5.1.). With the results from the sample surveys local sector-specific waste generation coefficients (waste
quantity per employee and year) can be established for further extrapolation.


13.3. Forecast of Future Hazardous Waste Generation

13.3.1. Factors influencing Hazardous Waste Generation

Hazardous waste generation is subject to many impacts which are interconnected and affect each other. The impacts can be broadly grouped into the following categories:

(1) Economic development and trends
(2) Hazardous waste related policy and legal framework conditions
(3) Technological process and new production processes
(4) Population growth
(5) Others

Economic activities have the highest impact on hazardous waste generation. For each of above named categories “influencing factors” can be defined (see Table 36). These factors enable quantification of the assumed impact on future hazardous waste generation.

Table 36: Effects that influence future hazardous waste generation

<table>
<thead>
<tr>
<th>Category of Impact</th>
<th>Influencing Factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1) Economic development, trends and instruments</td>
<td>• Growth of GDP&lt;br&gt;• Change of manufacturing- to service-oriented economy&lt;br&gt;• Raw material- and energy costs&lt;br&gt;• Economic instruments: Levies/taxes, disposal fees, recycling fees, implementation cost of clean technology; etc.&lt;br&gt;• Persuasive instruments: Voluntary agreements, information availability (minimization, disposal); promotion/support of innovative technologies; etc.</td>
</tr>
<tr>
<td>(2) Hazardous waste related policy and legal framework conditions</td>
<td>• Regulation / laws&lt;br&gt;• Hazardous waste classification/definition&lt;br&gt;• Additive environmental protection measures (waste water and air emission treatment; pre-treatment of waste)&lt;br&gt;• Enforcement of regulation: Control of emissions, waste flows, reporting, improved compliance of the regulated community&lt;br&gt;• Consideration of small scale sector&lt;br&gt;• Taxes, tax incentives</td>
</tr>
<tr>
<td>(3) Technological process and new production processes, new products</td>
<td>• Process integrated measures (cleaner production, waste minimization)&lt;br&gt;• Enhanced product quality standards&lt;br&gt;• Product design (life cycle assessment), durability of products, ease of recycling&lt;br&gt;• Material input substitution (reduces toxicity of waste)</td>
</tr>
<tr>
<td>(4) Availability of hazardous waste management services</td>
<td>• Waste collection systems (techniques/ownership/ management), infrastructure, sorting/pre-treatment; etc.&lt;br&gt;• Infrastructure, techniques (availability, capacity,…), ownership, costs of recovery and disposal installations</td>
</tr>
<tr>
<td>(5) Population growth</td>
<td></td>
</tr>
<tr>
<td>Category of Impact</td>
<td>Influencing Factor</td>
</tr>
<tr>
<td>--------------------</td>
<td>-------------------</td>
</tr>
<tr>
<td>(6) Others</td>
<td>Consumer/client demand, marketing, market conditions/competition, ISO 14001, neighborhood complaints; etc.</td>
</tr>
</tbody>
</table>

In a first step, the “influencing factors” have to be identified which are supposed to be relevant for future hazardous waste generation in the respective planning area. In a second step, the assumed impact on future waste generation has to be quantified. In a third step, the factors are applied to calculate the waste quantity, which – based on the assumptions – will be generated in the prognosis period. Depending on the overall duration, the prognosis period may be broken into sub-periods and a set of influencing factors specified for each sub-period. Starting point for the prognosis is the estimation of current hazardous waste generation.

Sudden changes in a hazardous waste management system are rare. However, the forecast should consider that changes might occur gradually. The impact of the influencing conditions and circumstances is – in general – confined to a certain period of time. Changes in waste generation data are not caused by one individual factor but by interaction of several factors. In general, changes will influence specific waste categories rather than entire waste generation.

It should be noted that the uncertainty of forecast results will grow with the length of the prognosis period. In general, the element of uncertainty in waste prognosis amounts to 0.5 to 1.5 %/a. The uncertainty is expressed by means of variance ranges for the prognosis results.

13.3.2. Prognosis of Actual and Reported Future Hazardous Waste Generation

An important aspect to be clarified before undertaking the forecast is to determine if the prognosis should focus either on actual or on officially reported hazardous waste generation. The difference between both can be significant. In fact, actual hazardous waste generation will be always higher than what hazardous waste producers report to the competent authorities and can be difficult to determine. However, taking into consideration the legal framework conditions, only the reported quantities will be visible and available to the “waste market”, i.e. available to future installations for hazardous waste recovery, treatment and disposal. When the forecast shall consider officially reported hazardous waste generation, it is recommendable to assume a narrowing of the gap between actual and officially reported hazardous waste generation with the time passing as a result of improved compliance with hazardous waste legislation during the forecast period. This leads to higher (reported) waste
generation and can be considered in the prognosis by selecting and quantifying suitable influencing factors.

13.4. Determination of the Future Disposal Capacity

When determining the future disposal capacity the following must be taken into account:

- **Internal recovery- and disposal facilities operated by waste producers**
  - In some industrial sectors such as the chemical sector it is common practice that the industries operate their own disposal facilities. Treatment capacity of those facilities has to be considered for further calculations.

- **Existing external recovery and disposal facilities have to be assessed as to which extent they can be integrated into the future infrastructure.**
  - Treatment capacity e.g. of cement kilns for co-processing hazardous waste as AFR's may be considered.

In general, two major waste streams have to be considered for the planning of the future hazardous waste management infrastructure: waste from primary sources and waste from secondary sources.

- **Waste from primary sources** is waste generated e.g. from the manufacturing sector. This can be waste generated for example during extraction of raw materials and further processing to intermediate and final products, during the consumption of final products, and during cleaning operations.

- **Waste from secondary sources** is defined as waste originating from recovery as well as disposal operations applied to primary source wastes, such as chemical-physical-treatment, incineration, landfill and mechanical treatment (e.g. shredding) (see Fig. 103). Waste from secondary sources plays a vital role in a national/regional waste management system. Amount and type of secondary waste depend on the treatment technology used.
For the determination of the required future disposal capacity first of all the various disposal capacities for primary wastes has to be established. Subsequently the disposal capacity for secondary wastes is estimated and finally both values have to be totaled. This assessment is to be performed on the forecasted values for future primary waste quantities at different points during the prognosis period.

13.4.1. Estimation of Recovery and Disposal Capacity Required for Primary Wastes

13.4.1.1. Categorization of forecasted hazardous waste quantities

The waste streams that have resulted from the forecast have to be differentiated according to their chemical/physical properties into the following categories and, based on the specific waste profiles of the respective industrial sectors, their percentages roughly quantified (see Fig 95)

- Inorganic solid waste with low organic content
  which requires landfill disposal or, subject to the characteristics of the individual waste type, can be considered for material recovery. This is waste such as e.g. residues
from flue-gas cleaning containing hazardous substances, sludge from treatment of inorganic industrial waste water and effluents, adsorbents and filter materials, casting cores, slag and ashes containing dangerous substances, spent lining and refractory material, metal sludge etc.

- **Inorganic liquid or slurry waste**
  which requires pre-treatment in a chemical-physical treatment (CPT) plant or, subject to the characteristics of the individual waste type, can be considered for material recovery. This is waste such as e.g. spent acids, spent alkaline solutions, pickling acids or bases, aqueous rinsing liquids etc. From the pre-treatment of this waste stream secondary waste will be generated that is usually solid and has to be disposed on a landfill.

- **Organic liquid or slurry waste**
  which requires pre-treatment in a chemical-physical treatment (CPT) plant. The organic phase separated by means of pre-treatment has to be incinerated or, subject to the characteristics of the individual waste type, can be considered for energy recovery. This is waste such as e.g. degreasing waste, waste oil, contents of oil traps, spent solvents, machining emulsions, aqueous rinsing liquids etc.

- **Organic solid, liquid or slurry waste**
  which requires incineration or, subject to the characteristics of the individual waste type, can be considered for energy recovery. This is waste such as e.g. sludge or solid waste containing waste oil or organic solvents, oil contaminated solid material, spent catalysts contaminated with dangerous substances, machining oil sludge etc. From this waste stream there may be secondary waste generation (e.g. residues from flue-gas cleaning, incineration slag and ashes) that requires landfill disposal or can be considered for material utilization.
13.4.1.2. Estimating the share of future hazardous waste recovery

For further allocating hazardous waste quantities of the four categories to recovery and disposal options it is necessary to define the status of hazardous waste recovery in the future hazardous waste management system. Recovery in this context means material and energy recovery excluding internal utilization measures that industries perform within their premises.

Planning concrete future recovery measures is difficult because it is to a large extent market driven and therefore not under the control of the regulator. Rather than planning recovery facilities that may not be realized later, it is advisable to assume that a certain percentage of hazardous waste generated in the future will be absorbed by material and energy recovery (e.g. co-processing in cement kilns). The future share of recovery can be estimated similarly like future hazardous waste generation. Starting from the current recovery rate, future recovery is estimated by identifying and applying relevant influencing factors. Fig.97 shows for information hazardous waste recovery rates of EU Member States.

With regard to recovery, the regulator may limit his role to ensure protection of environment and human health by providing and enforcing appropriate standards related to hazardous waste recovery. Detailed planning of recovery may become an issue wherever there are e.g. state owned recovery installations in the planning area such as cement kilns that the government can instruct to recover hazardous waste.
It should be noted that the procedure lined out above for the determination of the primary waste disposal capacity is a rough estimation only. For in-depth planning the respective waste streams and local conditions have to be analyzed in greater detail.

Fig. 105: Recycling, incineration and landfilling of MSW in EU Member States and other European countries, 2007

Example for allocating primary hazardous waste to recovery and disposal options

Planning experts have elaborated a hazardous waste inventory of a planning area. The waste prognosis undertaken subsequently forecasts hazardous waste generation of 1,000,000 t/a at a time = t. The capacity required for the disposal of primary hazardous waste at this time has to be estimated.

After analyzing the profiles of the characteristic wastes generated in the industrial sectors surveyed the percentage of the four main waste categories has been assessed as to:

1. Inorganic solid waste (landfill or material recovery) = 30% = 300,000 t/a
2. Inorganic liquid and slurry waste (chem./phys. treatment) = 10% = 100,000 t/a
3. Organic liquid and slurry waste (chem./phys. treatment) = 20% = 200,000 t/a
4. Organic solid, liquid & slurry waste (incineration or energy recovery) = 40% = 400,000 t/a

It was further assumed that the waste portion absorbed by recovery at the time t is 35% and

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231 European Environment Agency 2007
that 50 % of (1) and (4) each can be allocated to material- and energy recovery respectively. In due consideration of waste category allocations to recovery and disposal options as depicted in Fig. 104, the required recovery and disposal capacities are:

(A) Waste for material or energy recovery = 0.5 * (1) + 0.5 * (4) = 350,000 t/a
(B) Waste for landfill disposal = 0.5 * (1) = 150,000 t/a *
(C) Waste for chemical/phys. treatment = (2) + (3) = 300,000 t/a
(D) Waste for incineration = 0.5 * (4) = 200,000 t/a

For calculating the final recovery and disposal capacities generation of secondary hazardous waste has yet to be considered.

The procedure lined out above for the determination of the primary waste disposal capacity is a rough estimation. For in-depth planning the respective waste streams and local conditions have to be analyzed in greater detail.

*) including 2 % anticipated for underground / high safety disposal

13.4.2. Estimation of Secondary Waste Generation

**Waste from secondary sources** is defined as waste originating from recovery as well as from disposal operations, such as chemical-physical-treatment, incineration, landfill and mechanical treatment (e. g. shredding)\(^ {232} \). Waste from secondary sources plays a vital role in a national/regional waste management system. The EWL specifies secondary waste types in chapter 19.

Amount and type of secondary waste depend on the type of treatment technology used. From experience in industrialized countries the percentage of secondary waste generation in relation to source and the input quantity can be roughly estimated, as given below:

- **From material and energy recovery:**
  - Approx. 5 % hazardous organic waste
    Option for further treatment: Incineration
  - Approx. 20 to 30 % hazardous inorganic waste
    Option for further treatment: Hazardous waste landfill

- **From chemical-physical treatment:**

\(^ {232} \) The fine dust fraction that arises from shredding is in many cases contaminated with toxic substances and must be disposed of as hazardous waste
- Hazardous organic waste such as separated oil: 25 to 35 % organic waste
  Option for further treatment: Hazardous waste incineration or energy recovery
- Hazardous inorganic waste such as filter cake from dewatering of neutralization & precipitation sludge: 15 to 25 % inorganic waste
  Option for further treatment & disposal: Hazardous waste landfill
- 40 to 60 % pre-treated waste water that can be discharged to the public sewage system connected to a municipal effluent treatment plant for final treatment. Because this is waste water, it has not further been considered as a waste stream.
  o From incineration:
    Solid inorganic waste: 25 to 35 % inorganic waste
    Option: Hazardous waste landfill or material recovery.
  o From landfill sites:
    Due to its hazardous nature leachate from hazardous- as well as from municipal waste landfill sites is internationally usually considered as liquid hazardous waste, not as waste water. In most cases leachate is treated in special leachate treatment plants directly attached to the landfill sites. Leachate is therefore not further considered as a waste stream.

Above mentioned secondary wastes have to be taken into account when determining the total disposal capacity. As an example Fig. 96 shows forecasted quantities and material flows of primary and secondary hazardous wastes as well as the required disposal capacities from a GTZ planning study in China.\textsuperscript{233} Whereas primary hazardous waste generation is in this case only 980,000 t/a, the total recovery and disposal capacity required is 1,222,000 t/a, with 45 % of primary hazardous waste generation anticipated to be absorbed by material and energy recovery in 2020.

It should be noted that the procedure lined out above provides only a rough estimation. For in-depth planning the respective waste streams and local conditions have to be analyzed in greater detail.

Fig. 106: Sankey diagram showing quantities and flow of primary and secondary hazardous wastes of a hazardous waste management scenario (secondary wastes shaded red)

13.5. Options for the Future Hazardous Waste Management Infrastructure

12.5.1. Considerations with regard to Scale, Capacity and Location of the Disposal Facilities

Scale and capacity of the facilities

From an economical point of view, incinerators and landfill sites should be planned as centralized facilities, in order to make use of the ‘economy of scale’ effect of these facilities (see chapters 10.1.2. and 11.13.). This is beneficial also from an environmental point of view as a smaller number of facilities reduce the pollution risks involved. A smaller number of facilities draw moreover less on resources of the competent authorities with regard to control and supervision.

Due to its minor ‘economy of scale’ effect chemical/physical treatment plants can be planned as decentralized facilities, e.g. for a group of companies forming an industrial park or located in a cluster. Decentralization of chemical/physical treatment plants enables pre-treatment of...
wastes geographically close to the source of generation. Separation of water from liquid or slurry wastes or from oil/water mixtures reduces the waste quantities that need to be transported to distant centralized facilities such as incinerators and landfill sites for final disposal. Chemical/physical treatment plants can be preferably combined with transfer stations where wastes collected in the vicinity are sorted and assembled for further transport (see Fig. 107).

![Image of waste transfer station]

Fig. 107 upper: Hazardous waste transfer station (capacity = 20,000 t/a), bottom: HW transfer station combined with chemical/physical treatment plant (capacity = 30,000 t/a), both in Bavaria, Germany.

Capacities of chemical/physical treatment plants can be kept flexible within a wide range by adjusting the operation mode (e.g. number of shifts). Incinerators which require round the clock operation (for minimizing start-up and close-down operation phases) are usually planned in such a way that a second kiln line can be supplemented at a later time, thus doubling capacity. Landfill site capacities are lifetime capacities. Annual disposal capacities can be kept flexible since deviations from the targeted annual disposal quantities effect only the duration of the active disposal phase. As rule of thumb however, in view of the difficulties
of site identification, landfill capacities should not be less than 10 years, considering potential fluctuations in annual disposal quantities.

For reducing overall transport distances, the disposal facilities should be ideally located in the center of gravity of the entity of waste producers to which they cater. Savings resulting from the economy of scale effects of centralized disposal installations outweigh in general the costs resulting from additional transport distance caused by centralization. This has to be checked however in each individual case. Moreover, there may be conditions such as traffic infrastructure status or topography of the planning area (e.g. islands, mountains) that require a decentralized planning approach.

The charging scheme for waste collection and transport depends on the specific situation in the planning area such as e.g. the spatial distribution of hazardous waste producers. Charging transport costs according to the distance between the waste generating entities and the respective disposal installations would be the most logical approach. However, this favors companies that are located near the disposal facilities and “punishes” companies that are located at a greater distance. A solution to overcome this problem might be cross subsidies and a flat rate charged to all waste producers.

13.5.2. Evaluation of Infrastructure Options

After having estimated the future capacities required for recovery, landfill disposal, incineration and chemical physical treatment, the planning experts will have to elaborate patterns for the potential future infrastructure in due consideration of the scope of the plan and the frame conditions defined by the planning area. Options may address e.g. alternative locations for the disposal facilities (particularly locations for landfill sites are by experience difficult to identify) or different levels of centralization.

Subsequently, the elaborated options have to be evaluated and rated according to environmental and economical criteria such as:

- Environmental risks:
  - Risks from material and energy recovery (if foreseeable)
  - Risks from landfill disposal
  - Risks from incineration
  - Risks from chemical/physical treatment
  - Risks from transport of hazardous waste from the waste generating entities to the disposal installations
o Investment costs required for the facilities and the equipment of the respective options

o Total specific costs per ton of waste of the respective options including capital-, variable and fixed operating costs for:
  - Incineration
  - Chemical/physical treatment
  - Landfill disposal

o Total annual costs of the respective options including capital-, variable and fixed operating- and additional transport costs for:
  - Incineration
  - Chemical/physical treatment
  - Landfill disposal

An economical analysis of the options is indicative for the affordability of the future waste management system for the waste producers and is of paramount importance. Initial calculations may be rough estimations only and need to be refined by subsequent iterative steps. A sensitivity analysis may be performed in order to assess how minor changes of the raw data affect economical viability and ranking of the plan alternatives.

13.5.3. Ownership / Operator Models for the Future Hazardous Waste Management System

Operation of the future collection systems, treatment and disposal installations should be organized in such a way that:

o Protection of the environment and occupational health and safety is ensured
o Economical viability, affordable disposal rates and good service quality are ensured, in line with the ‘polluter pays’ principle

To this end different operator models have evolved which are given below:

- Facilities operated by the public sector
- Facilities operated by the private sector
- Facilities operated by a cooperative association of industries that are generating hazardous waste which is disposed by the facilities
- Facilities operated by a cooperative association of regional governmental bodies situated in the respective area
- Facilities operated by a combination of public- and private sector entities
Private sector operation may take different forms:

- **Build Own and Operate (BOO)** – the private sector party (e.g. company) finances the establishment of the waste management facility and operates.

- **Build Own Operate and Transfer (BOOT)** – the private sector party (e.g. company) finances the establishment of the waste management facility, operates it and transfers it to a public sector entity after an agreed period, usually after 15 to 25 years.

- **Build Own and Transfer (BOT)** – the private sector party (e.g. company) finances the establishment of the waste management facility; the ownership is transferred to a public sector entity on an agreed date.

In the case of BOO and BOOT ownerships, it is important for the government to provide an incentive to private investors to build the facility. This incentive may be in the form of guaranteed fees and quantities for the treatment of hazardous waste, which are sufficient to cover repayment to lenders and investors, as well as the costs of operation.

In many countries hazardous waste management is organized according to market economy principles and is run by the private sector. Also in Germany this organizational form is used in some regions. In addition, also mixed organizational forms – public commitment in combination with private enterprises - are used. In the German State North Rhine-Westphalia, private sector BOO schemes have proven successful, while in Bavaria, most of the facilities are operated by a public-private entity in which industries of the manufacturing sector hold a minor share of 15%.

![Fig. 108: Views of the hazardous waste treatment plant of the GSB in Ebenhausen (Germany), where around 85% of the stockholders are public, while around 15% are private](image)

**13.6. Advanced Waste Management Planning**

**13.6.1 Decoupling Waste Growth from Economic Growth**

Waste management planning covers usually all waste types such as municipal-, production & commercial-, construction & demolition- and hazardous waste. The first and paramount
The objective of waste management planning is the development and execution of a master plan for the future infrastructure of the planning region with regard to waste collection, treatment and disposal. Once such infrastructure is available, waste management planning may focus on other issues. The plan should define objectives and specify actions to be taken in order to fulfill the set out requirements in this context. Differentiated indicators and strategies for each waste type should be stipulated.

In the following, a few topics of current waste management planning and corresponding results achieved in Germany are briefly discussed.

A key challenge for implementing sustainable development and growth is the decoupling of waste generation from economic growth. In order to break this link, strategies must be put in place that foster resource conservation and waste prevention as well as re-use, recycling and recovery of waste materials.

As Fig. 109 illustrates, Germany could reduce total waste generation for 15% between 2002 and 2008 while in the same period the price-cleared GDP rose for 12%. The depicted decrease in waste generation is also resulting from the legal framework in place, financial incentives and information campaigns. However, this is due to a large extent also resulting from the development of an industry society to a service society and a shift of the largest part of manufacturing into foreign countries.

Fig. 110 shows recovery rates of different waste types. Between 2002 and 2007, particularly hazardous waste recovery but also recovery of municipal-, production and commercial waste has improved significantly.
Fig. 109: Decoupling waste growth and economic growth, Germany, 2002-2008 (Source: German Federal Statistical Office, 2009)

Fig. 110: Recovery rates of main waste fractions, Germany, 2000-2007 (Source: German Federal Statistical Office, 2009)
13.6.2 Curbing Greenhouse Emissions Arising from Waste Management

Another issue in current waste management planning is curbing waste management’s share in greenhouse gas emissions. Waste management can have a significant greenhouse effect and implies huge potential to contribute to climate protection. It should be noted that the size of the CO₂ equivalent recognized for reduction (= CO₂ credits) depends on the baseline scenario chosen. According to the Kyoto Protocol, baseline scenarios refer to the emission situation of the signatory states in 1990. Since having signed the Kyoto Protocol, in the area of waste management, Germany has implemented effective climate protection measures that are tailored to the specific conditions in Germany. The most important measures are listed below.

- Discontinuing landfill disposal of biodegradable untreated waste:
  Under the anaerobic conditions prevailing in the waste body of a landfill site, over a period of many years, biodegradable waste generates methane gas which has a greenhouse gas equivalence factor 21 times higher than CO₂. If the landfill is an uncontrolled dump site, the methane is released to the atmosphere via diffuse emissions.

  - Short- and medium-term measures: Engineered landfill disposal with encapsulation of the waste body and active landfill gas collection by pumping, followed by flaring off the landfill gas or, better, using the landfill gas as fuel for gas engines for electricity generation (Fig. 111). (Such measures had been implemented in Germany already in the past and therefore are part of the baseline scenario.)

  - Long-term measures: Discontinuing landfill disposal of biodegradable waste.
    With effect of 2005, Germany has limited rigorously the content of organic matter in waste allowed for landfill disposal, thus enforcing a landfill ban for untreated waste (See Table 30, parameters 2.01 and 2.02). Stakeholders were given a 15 year notice period. By 2004 Germany had reduced greenhouse gas emissions from landfill sites already for 23 Million tons CO₂ equivalents, compared to the baseline scenario in 1990. After 2005 there are nearly no greenhouse emissions from landfill disposal in Germany.

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234 German Federal Environmental Agency (comm.): Env. Study “Waste Sector's Contribution to Climate Protection”,
http://www.google.com/url?q=http://www.umweltdaten.de/publikationen/fpdf-I/4062.pdf&sa=U&ei=IjGOT7mWCgoXr8OGq3ey-Cw&ved=0CAYQFjAB&client=internal-uds-cse&usg=AFQjCNFiNhXHyte4ZqWxp0zXWGSJYN64A

235 Source: German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety
- Enhancing energy efficiency of waste incineration:
  If a waste incineration plant produces power, this energy no longer has to be produced by other power plants and the resulting emission savings are credited to the waste incineration plant. Thus the choice of power plants to be replaced by waste incineration power has a crucial influence on the size of this CO$_2$ credit and hence on the final result.

- Increasing co-incineration of waste:
  Co-incineration of waste in conventional thermal power plants and production facilities such as cement kilns enables savings of primary fuels. Quantity and type of the primary fuels replaced determine the size of the CO$_2$ credits.

- Increasing material recovery of ferrous and non-ferrous metals:
  Recycling of scrap materials containing metals that require high energy input for primary production such as iron or aluminum enables savings of primary energy. The size of the CO$_2$ credits is subject to the mix of primary energy sources in the baseline scenario.

The waste management sector in Germany has contributed significantly to climate protection. Between 1990 and 2006 this relatively small sector has contributed CO$_2$ equivalent emission savings of 56 million tons which is nearly 25% of the total CO$_2$ equivalent emission savings of 235 million tons that Germany has achieved during this period. The reasons behind this success are essentially the landfill ban for untreated waste in 2005 and moreover an efficient system for material and energy recovery from waste.  

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236 Bundesverband der Deutschen Entsorgungs-, Wasser- und Rohstoffwirtschaft e.V.: "BDE-Positionspapier zur Studie 'Klimaschutzpotenziale der Abfallwirtschaft'", Berlin, 2010
For the planning of hazardous waste management facilities, it is essential to know which types of waste are generated in which quantities in the country or region in question, and where exactly. The plausibility of the data collected must be verified by comparisons with similar manufacturing plants in other countries; and predictions for the future development of hazardous waste quantities must be made, taking into account developments in the economy and waste legislation.

Drawing up a hazardous waste management plan requires information on legislation, administration, hazardous waste generation, as well as on the geological and geographical conditions for sites suitable for hazardous waste management facilities.

Existing factory-owned hazardous waste management facilities must be taken into account. Contractual and financial models for planned hazardous waste facilities with participation of private and/or public investors or owners –BOO, BOOT, BOT models- must be evaluated and determined.

Important issues in advanced waste management planning are decoupling economic growth and waste growth and curbing the share of greenhouse gas emissions from waste management.

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Source: GE Jenbacher
Consult also supplement 3 to learn more about planning.

13.7. Case Study, Example from China: Developing a Hazardous Waste Management Infrastructure Plan (HWMIP) for the Province Zhejiang

During 2006 - 2007 the Sino-German Collaboration Program ‘Environmental Enterprise Consultancy Zhejiang’ (EECZ) has elaborated, on request and in collaboration with its Chinese counterparts, a ‘Hazardous Waste Management Infrastructure Plan’ (HWMIP) for the Chinese Province Zhejiang (See Fig. 112. For the situation of Zhejiang Province in China refer to Fig. 42). Planning work was executed at the ‘Zhejiang Environmental Protection Bureau’ (ZEPB) in cooperation with the Zhejiang Solid Waste Management Department. The plan provides a compilation of information for decision makers to set the course for the development of the future infrastructure required for managing industrial hazardous waste in Zhejiang.

The planning work can be divided into four phases:

(1) Taking stock of the present situation with regard to industrial hazardous waste in Zhejiang
(2) Estimating future hazardous waste generation and corresponding treatment- and disposal capacity requirements
(3) Developing options for the potential future infrastructure
(4) Evaluating the options with regard to environmental impact and economical viability
13.7.1. Taking stock of the present situation

At the outset, the current inventory with regard to hazardous waste generation, recovery and disposal in Zhejiang had to be established. At the time when the planning work was undertaken, the official assessment of HW generation was based on the so-called HW declaration data. Registered HW generators are obliged to report annually their hazardous waste generation, recovery and disposal to the competent authorities who use these data subsequently for their statistics. However, these data are not further verified. Only medium and large scale entities are registered for HW generation. Hazardous waste generation from small and micro scale establishments, though having a major share in overall HW generation, is not considered.

Arriving at realistic data for the hazardous waste inventory proved to be extremely difficult under these circumstances. After many discussions it was decided to refer the inventory not to actual hazardous waste generation, but to hazardous waste declaration (which would be significantly lower than actual HW generation). Taking note of the fact that only officially declared waste is “visible” and can be subjected to HW legislation and is available for recovery and disposal. Similarly the hazardous waste forecast would be based

\[ \text{238} \] Zhejiang Environmental Protection Bureau, 2006
on HW declaration rather than on actual generation while assuming that the gap between declared and actually generated hazardous waste would gradually narrow with the time passing due to improved regulatory tools and practical enforcement skills of the competent authorities.

Table 37 shows a summary of the waste declaration data from 2004 on which the inventory is based. The data are differentiated according to the 11 cities in Zhejiang. Thereafter, 2,950 registered waste procures have declared a total HW amount of 378,000 t/a. However, an analysis of the characteristic economic data of Zhejiang’s industrial sectors over the last year’s leads to the conclusion that the HW quantities declared by the waste procures are too low. Actual hazardous waste generation is probably 80 % higher and closer to 680,000 t/a.

The gap results from incorrect classification, non-reported waste types, and non-registered waste producers. Another important reason for lack of notification of hazardous waste is that, as discussed in chapter 4.2.3. Classification of Hazardous Waste, many hazardous waste producers consider their hazardous residues as commercial goods rather than as hazardous waste when selling such waste to third parties for recovery, thus bypassing hazardous waste legislation.

Table 37: Generation, recycling/recovery, disposal, discharge and storage of HW in Zhejiang’s 11 Cities according to HW declaration data 2004

<table>
<thead>
<tr>
<th>City</th>
<th>Generation [t/a]</th>
<th>Utiliz. &amp; Recovery [%]</th>
<th>Disposal [t/a]</th>
<th>Discharge [t/a]</th>
<th>Storage [t/a]</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Generation</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>[t/a]</td>
<td>[%]</td>
<td>[t/a]</td>
<td>[%]</td>
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<td>72,271</td>
<td>19</td>
<td>4,586</td>
</tr>
</tbody>
</table>

As can be seen from

239 Only hazardous waste from primary sources; the estimation does not include waste from secondary sources, waste from remediation of contaminated sites and waste from spent/discharded products (e.g. WEEE)
Table 37, the HW recovery rate is extremely high with 77 %. However, this figure does not comply with the installed licensed capacity of facilities for recycling/recovery in Zhejiang. Moreover, in relation to the Chinese average recycling/recovery rate and to data from comparable states, this recycling/recovery rate is very high and uncharacteristic for regions undergoing fast economic growth. Therefore, the indication of 77% value is highly doubtful.240

The disposal situation is determined by an insufficient capacity of treatment facilities. The installations presently in place are predominantly small-scale incinerators which do not meet modern state-of-the-art requirements. New facilities – landfills and incinerators with small capacities – are already in the planning and construction stage.

13.7.2. Prognosis of Future HW Generation

By applying the concept of “influencing factors” (Ref. chapter 13.3.1), the 2004 waste declaration data have been extrapolated to 2010, 2015 and eventually 2020 (See Table 38). The influencing factors reflect and differentiate a variety of complex impacts that are known to affect HW generation.

Table 38: Influencing factors affecting hazardous waste declaration in Zhejiang

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Law enforcement</td>
<td>1.04</td>
<td>1.05</td>
<td>1.02</td>
</tr>
<tr>
<td>Categorization/classification</td>
<td>1.09</td>
<td>1.05</td>
<td>1.00</td>
</tr>
<tr>
<td>Prevention/minimization</td>
<td>1.00</td>
<td>0.96</td>
<td>0.90</td>
</tr>
<tr>
<td>Knowledge/awareness</td>
<td>1.025</td>
<td>1.03</td>
<td>1.01</td>
</tr>
<tr>
<td>Consideration of SSE</td>
<td>1.10</td>
<td>1.07</td>
<td>1.02</td>
</tr>
<tr>
<td>Economic development</td>
<td>1.19</td>
<td>1.15</td>
<td>1.12</td>
</tr>
<tr>
<td>Specific industrial impacts</td>
<td>1.04</td>
<td>1.02</td>
<td>1.01</td>
</tr>
<tr>
<td>Secondary environmental measures</td>
<td>1.07</td>
<td>1.04</td>
<td>1.02</td>
</tr>
<tr>
<td>Quality standards</td>
<td>1.03</td>
<td>1.02</td>
<td>1.00</td>
</tr>
<tr>
<td>Disposal options</td>
<td>1.02</td>
<td>1.04</td>
<td>1.03</td>
</tr>
<tr>
<td><strong>Resulting overall factor</strong></td>
<td><strong>1.605</strong></td>
<td><strong>1.43</strong></td>
<td><strong>1.13</strong></td>
</tr>
<tr>
<td><strong>Variance</strong></td>
<td>+/- 12 %</td>
<td>+/- 12.5 %</td>
<td>+/- 15 %</td>
</tr>
</tbody>
</table>

Fig. 113 shows the forecasted generation of primary industrial hazardous waste in Zhejiang until 2020. HW generation (precisely: HW declaration) from primary sources is estimated to grow from 378,000 t/a in 2004 to 607,000 t/a in 2010 to 868,000 t/a in 2015 to 980,000 t/a in

240 In 2006 the average utilization rate of hazardous waste amongst the EU-15 Member States approximated only 28%
2020. Error bars give an indication of the precision range. Main driver of the forecasted rise in HW generation is Zhejiang’s anticipated strong economic growth.

![Prognosis of future hazardous waste declaration](image)

**Fig. 113:** Prognosis of future HW Declaration in Zhejiang Province

### 13.7.3 Assessment of Future Treatment and Disposal Capacity Needs

With regard to waste treatment and disposal the following options have been considered in the plan:

- Recycling/Recovery
- Treatment
  - Chemical / physical treatment (CPT)
  - Incineration
  - Landfill

It is understood that “recycling and recovery” comprises material recovery (recycling) and energy recovery (recovery) from waste with sufficiently high calorific value (e.g. co-processing in cement kilns).

Further to recycling/recovery it has been assumed that, with on-going plan implementation, the dubiously high recycling/recovery rate of 77% from 2004 will converge to a more reasonable and realistic value of 50% by 2010 and 45% by 2020. Though the recycling/recovery rate would decrease in this case, recycling/recovery quantities in absolute numbers increases actually, based on the prognosis data (See Fig. 114). Details for
recycling/recovery have not been further elaborated. The assumption is that recycling/recovery will be market driven while the regulator limits his role to ensure protection of environment and human health by providing and enforcing appropriate standards related to recycling/recovery (Ref. chapter 13.4.1.2).

Fig. 114: Shares of hazardous waste recycling/recovery in percent of total primary hazardous waste generation (left figure) and in absolute numbers (right figure) for 2004 (baseline scenario) and for 2010 and 2020 (anticipated)
In order to quantify the waste streams that have to be allocated to the various disposal options such as chemical/physical treatment, incineration and landfill, the forecasted HW declaration data for generation have been further detailed with regard to the originating industrial sectors in Zhejiang, categorized into three classes "inorganic/organic", ‘inorganic’ and ‘organic’ and eventually allocated to the different disposal options. This was done by referring to a special version of the European Waste List that specifies options for CPT, incineration and landfill (See annex 11) for the waste types generated by the different industrial sectors.

Declaration data consider only primary wastes, i.e. production process related waste. On top of the primary wastes, however, also secondary waste generation has to be considered in the future infrastructure. Waste from secondary sources is defined as waste originating from recycling/recovery as well as from disposal operations, such as chemical/physical treatment, incineration, and landfill. Secondary waste generation was estimated (Ref. chapter 13.4.2) and considered for the assessment of the disposal capacities.

Fig. 106 is a Sankey diagram and depicts the material flow of the estimated future primary and secondary HW streams with regard to recycling/recovery, chemical/physical treatment, incineration and landfill in 2020. Table 39 gives a summary of the estimated disposal capacities and other relevant data for 2010 and 2020.

Table 39: Estimated capacities for chemical/physical treatment, incineration and landfill of primary and secondary hazardous waste required in Zhejiang in 2010 and 2020 (Assumption: 50% and 45% of primary hazardous waste generated will be absorbed by recycling & recovery in 2010 and 2020 respectively)

<table>
<thead>
<tr>
<th></th>
<th>2004 (baseline) [t / year]</th>
<th>2010 [t / year]</th>
<th>2020 [t / year]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Primary hazardous waste generation</td>
<td>378,000</td>
<td>607,000</td>
<td>980,000</td>
</tr>
<tr>
<td>Total primary &amp; secondary HW generation</td>
<td>- not available -</td>
<td>776,000</td>
<td>1,222,000</td>
</tr>
<tr>
<td>Disposal, total</td>
<td>87,000</td>
<td>465,000</td>
<td>771,000</td>
</tr>
<tr>
<td>Chem. / phys. Treatment</td>
<td>152,000</td>
<td>196,000</td>
<td></td>
</tr>
<tr>
<td>Incineration</td>
<td>122,000</td>
<td>189,000</td>
<td></td>
</tr>
<tr>
<td>Landfill</td>
<td>191,000</td>
<td>386,000</td>
<td></td>
</tr>
<tr>
<td>Absorbed by recycling &amp; recovery</td>
<td>291,000</td>
<td>311,000</td>
<td>451,000</td>
</tr>
</tbody>
</table>
The procedure described above was repeated for every city, using the declaration data for hazardous waste generation of the respective cities of 2004 as a baseline. At this planning stage, as a first approximation, identical influencing factors and shares for recycling and recovery were assumed for all cities.

13.7.4. Four Alternatives for the Potential Future Infrastructure for HW Treatment & Disposal in Zhejiang Province

The need for ecological as well as economical viability of the future HWM infrastructure would call for joint action of all stakeholders. However, the situation in Zhejiang Province was in strong contradiction to a coordinated planning approach: There was neither co-operation nor even an understanding between the cities with regard to joint operation of waste management facilities. Each city strived to set up its own small-scale incinerator, landfill site and other treatment facilities.

In order to illustrate this situation and to quantify its repercussions, four alternative approaches have been developed where each alternative stands for a specific spatial pattern of grouping cities to clusters with regard to waste generation with each alternative representing therefore a different level of centralization for the future infrastructure.

Centralization in this context means providing the required waste treatment capacity by a small number of large-scale facilities rather than by a large number of small-scale facilities. Pollution control and economical viability of incinerators and landfill sites become usually more favorable with increasing scale of such units. Particularly the ‘economy of scale’ effect of expensive incinerators and landfill sites plays an important role in this context (Ref. chapters 9.1.2, 10.2 and 11.13). A disadvantage of a centralized infrastructure is the higher overall transport distance, compared to a decentralized infrastructure, due to the larger catchment area for waste collection and transport. Environmental and economical implications for hazardous waste transport have to be taken into consideration therefore when comparing centralized and decentralized solutions. In view of the excellent road infrastructure of Zhejiang Province however (all cities and major towns are interlinked by a toll-based 4-6 lane highway system), it was assumed that differences of the environmental impact of hazardous waste transport with regard to centralization are negligible at this stage and have not been further investigated.

Alternative 1 represents a completely decentralized approach in which each of the 11 Cities would get a complete set of treatment & disposal facilities consisting of a chemical physical treatment (CPT) plant, an incinerator and a landfill (See Fig. 115). This alternative
corresponds best to the ideas of many of Zhejiang’s city-level planners. At the other end, alternative 4 marks the highest level of centralization and provides expensive incinerators and landfills only to three main clusters where HW generation is concentrated (CPT plants still in each City). The fourth alternative must be seen as an “ideal” solution because it was not in line with the status of ongoing facility development. It is used therefore only as a baseline and serves as a reference for the highest level of centralization.

The other two alternatives that have been elaborated are intermediates between the first and the fourth one. They take account of the actual status of facility development as well as of the presetting given by the National Hazardous Waste Management Plan of China’s then ‘State Environmental Protection Agency’ (SEPA). Alternative 2 represents a “moderately centralized” infrastructure; alternative 3 is “more centralized”. The alternatives 1-4 are arranged in such a way that their sequence presents an increasing level of centralization.

Fig. 115: Alternative 1 (Decentralized infrastructure: All 11 cities equipped with one CPT plant, incinerator and landfill site)
Alternative 4 (Centralized infrastructure: All 11 cities grouped into 3 clusters and each cluster equipped with one centralized landfill site and incinerator, while every city has yet one CPT plant)
13.7.5. Results

13.7.5.1. Economical ranking of alternatives

The investment requirements have been calculated for the four alternatives taking into account the respective numbers and capacities of CPT plants, incinerators and landfill sites\textsuperscript{241} for each alternative (Table 40).

As the data clearly show, the total investment costs of all three centralized alternatives are significantly lower than the costs of the decentralized alternative 1. This is caused by substantial “economy of scale” effects particularly in case of incinerators but also landfill sites.

Table 41 shows the total annual operation costs of the four alternatives including capital-, variable and fixed operating costs as well as additional transport costs for 2010 and 2020. The annual capital costs are based on an amortization period of 15 years and interest rates of 8 %/a.

Regarding total annual operation costs the advantage of the centralized alternatives is less obvious than in case of the investment costs shown in the previous table. This is because additional transport costs reduce the benefit of centralization to a certain extent: With rising centralization level additional transport distances increase and so do transport costs. However, the total annual costs of a completely decentralized solution (A1) would be still significantly higher than the costs of the centralized scenarios.

Table 40  Investment requirements for the four alternatives

<table>
<thead>
<tr>
<th>Alternative</th>
<th>Chem./Phys. Treatm.</th>
<th>Incineration</th>
<th>Landfill</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No of CPTP’s</td>
<td>Total [Mio RMB\textsuperscript{242}]</td>
<td>No of Inciner.</td>
<td>Total [Mio RMB]</td>
</tr>
<tr>
<td>A 1 (decentralized)</td>
<td>11</td>
<td>285</td>
<td>11</td>
<td>2,087</td>
</tr>
<tr>
<td>A 2 (moder. central.)</td>
<td>11</td>
<td>285</td>
<td>5</td>
<td>1,180</td>
</tr>
<tr>
<td>A 3 (more central.)</td>
<td>11</td>
<td>285</td>
<td>4</td>
<td>1,067</td>
</tr>
<tr>
<td>A 4 (centralized)</td>
<td>11</td>
<td>285</td>
<td>3</td>
<td>1,004</td>
</tr>
</tbody>
</table>

Given the present status of facility development it appears that alternatives 2 and 3 have a realistic chance for implementation. However coordinated planning should be initiated soon,

\textsuperscript{241} For landfill sites an operation period of 20 years is adopted, calculations assume that construction would be completed latest by 2010

\textsuperscript{242} RMB = Renminbi is the currency in China, the abbreviation is CNY, but in China is used the abbreviation RMB , the symbol is ¥. The units of the currency are the Yuán.
otherwise more cities may start planning according to their own requirements and realization of a centralized approach becomes more difficult.

Table 41  Total annual operation costs for the four alternatives including capital-, variable & fixed operating- and additional transport costs in 2010 and 2020

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>A 1 (decentralized)</td>
<td>575</td>
<td>127 %</td>
<td>1,000</td>
<td>138 %</td>
</tr>
<tr>
<td>A 2 (moder. central.)</td>
<td>496</td>
<td>110 %</td>
<td>773</td>
<td>106 %</td>
</tr>
<tr>
<td>A 3 (more central.)</td>
<td>483</td>
<td>107 %</td>
<td>725</td>
<td>99.9 %</td>
</tr>
<tr>
<td>A 4 (centralized)</td>
<td>452</td>
<td>100 %</td>
<td>726</td>
<td>100 %</td>
</tr>
</tbody>
</table>

13.7.5.2. Conclusion related to chemical/physical treatment

Most HW types to be allocated to chemical/physical treatment have a high average water content which can be separated by treatment. This reduces significantly the quantity of the remaining secondary waste for further transport, utilization and treatment (e.g. incineration) or final disposal at a landfill. Moreover, CPT plants are important links in the HW logistics chain and can serve as collection points and temporary-storage facilities for other waste types that do not require CPT. At CPT plants, such waste types can be collected, packed and prepared for transport to centralized incinerators and landfill sites located elsewhere.

CPT plants are relatively low in investment; there is no “economy of scale” effect and economically viable operation of small scale installations is feasible.

CPT facilities should be planned therefore for every city.

13.7.5.3. Conclusion related to incineration

Based on the assessment of the alternatives and in due consideration of the transportation costs, it is recommended to implement initially a system with centralized incinerators. At a later stage it has to be decided if the expected future capacity requirements will be met by either developing additional incinerators or by enhancing the capacities of existing incinerators. When making a choice between these two options it should be considered that adding another incineration line to an existing incinerator has the benefit that the infrastructure already available can be used without high additional investments.
With regard to site selection, it is recommended to locate the incinerators near to the industrial zones and close to the waste generating industry, if possible. Existing infrastructure can be used.

The steam produced by energy recovery from the incinerator can be directly utilized as process steam in the adjacent industries. Electricity generation is also possible; however this is less economical than the direct use of steam.

To optimize HW transport to the centralized incinerators, it is recommended to install in each city HW collection points/transfer stations. These collection points might be combined with CPT facilities which are recommended for each city.

The HW incinerators may also serve for healthcare waste disposal. Creating a synergistic effect of integrated waste management, the infrastructure for industrial HW disposal can be combined with the infrastructure for healthcare waste disposal.

13.7.5.3. Conclusion related to landfill disposal

The total capacity of landfills presently earmarked for the project region is completely insufficient compared to the expected future HW quantities that have to be allocated to landfill disposal.

Based on the assessment of the alternatives and in due consideration of the transportation costs it is recommended to implement a system with initially four centralized landfills. In addition to the three landfill sites in Hangzhou, Ningbo and Taizhou, that are presently under construction, commissioning and planning respectively, a fourth centralized landfill site may cater to the needs of Wenzhou, Quzhou, Jinhua and Lishui.

With regard to site selection it is generally recommended to locate the landfills close to the waste generating industry. However based on the availability of sites and considering the currently relatively low transportation costs, landfill site locations can be also identified outside the centers of waste generation. Further development of landfill facilities after exhausting the capacities of the first sites depends primarily on the availability of site locations with sufficient capacity.

To optimize the transport to the installations it is recommended to install collection points / transfer stations for small quantities. These collection points may be combined with CPT facilities which are recommended for every city.
13.7.6 Impact

The planning report elaborated under the EECZ-Program has served as a valuable resource of information and data for the Chinese planners of the ‘Zhejiang Provincial Development, Planning & Research Institute’ which is in charge for the development of the official Chinese infrastructure plan. The Planning Institute had submitted the Chinese plan to the “Zhejiang Development and Reform Commission” for approval.

Chinese planners have embraced EECZ’s major concern to plan a centralized HWM infrastructure in Zhejiang. The formulation in the official Chinese text however is a recommendation rather than an advice. It was learnt that the ‘Zhejiang Development and Reform Commission’ (ZDRC) did not find itself in a position to approve a more stringent formulation. Advising the cities to undertake facility development jointly would interfere with the Chinese hierarchy principle and violate the autonomous rights of the cities. At the time when the EECZ Program was terminated, the plan had been approved by the ZDRC; however it was not clear as to which extent the concerned Cities would follow the recommendations made.

Taking joint action and crossing city borders in provincial infrastructure development is a rather new concept for Chinese planners. However during the elaboration of the EECZ plan which involved many discussions between Chinese counterparts and German experts, the competent departments in Zhejiang, at the provincial as well at the city level, took on board the concept of a centralized infrastructure for HWM. The EECZ plan was also appreciated by the competent authority at the national level who had forwarded the plan to other Chinese provinces for consideration as an example to follow.

Supplement 3 gives further information on other planning aspects.
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Module 9

Factors contributing for a success of a HWM system, a summary
**Factors Contributing to the Success of Hazardous Waste Management in a Country**

Successful set-up and implementation of a hazardous waste management system requires concerted efforts and intervention in different strategic areas and at different levels (see Fig. 116). The strategic areas are partially interdependent and complementary to each other. Applying the tools of project planning, the strategic areas can be understood as elements of a project planning matrix: For each strategic area objectives, adequate action plans and indicators have to be defined. Achieving the objectives will eventually enable the successful implementation of a hazardous waste management system. An overall goal can be formulated which might be phrased:

*To eliminate the adverse effects of Hazardous Waste by ensuring safe, efficient and economical collection, treatment, recovery and disposal of wastes and to ensure that the system is reliable now and for the foreseeable future.*

![Fig. 116: Successful implementation of a hazardous waste management plan requires simultaneous action of the stakeholders in different strategic areas](image)

The strategic areas, relevant objectives and a few keywords are discussed below.
14.1 Strategic Area “Regulation and Planning”

Objective with regard to “Regulation”:

- *Hazardous waste related legislation has been notified or supplemented where necessary and technical standards for sustainable HWM according to the International State-of-the Art have been developed and are being implemented.*

  Legislation should include all required definitions and standards. It should also clarify responsibilities of the regulated community and of the government. Minimum requirements to be covered by regulation are:

  Definition of hazardous waste and differentiation of hazardous waste from non-hazardous waste
  Definition and differentiation of hazardous waste for recovery (commercial goods) and for disposal
  Consistent, logical and user-friendly system of waste classification
  Obligations of hazardous waste producers to report on hazardous waste generation and management
  Definition of a hierarchy of hazardous waste management measures with regard to minimization of adverse impacts to the environment and human health and with regard to resource conservation
  Mechanism enabling the competent authorities to approve hazardous waste disposal- or recovery operations intended by the waste owner
  Mechanism for tracking transfer of hazardous waste
  Definition of minimum standards for treatment and disposal of hazardous waste (e.g. landfill disposal, incineration)
  Detailing licensing procedures for hazardous waste treatment, recovery and disposal facilities
  Requirements for elaborating and implementing waste management plans

  Regulators of emerging economies who are in the process of shaping HW related regulation in their countries might seek orientation from international HW regulation. The European Union has developed a comprehensive package of latest legal provisions in HWM[^243] which might serve as guidance.

With regard to “Planning” the following objectives have to be fulfilled:

[^243]: Source: [http://ec.europa.eu/environment/waste/hazardous_index.htm](http://ec.europa.eu/environment/waste/hazardous_index.htm)
An overall planning mechanism for HWM infrastructure is established that is instrumental in coordinating planning activities on a National-, State/Provincial, and City/District-level.

The planning mechanism must consider the different planning levels: National/Central – State/Provincial – City/District. The planning process produces a National/Central plan and a plan for every State/Province which includes details from the Cities/Districts. The main planning work is usually done on a State/Provincial level. HWM planning is an interdisciplinary activity and requires cooperation of different government departments and experts from different areas.

The competent authorities at the different levels and the relevant stakeholders have recognized the need for coordinated planning of a HWM infrastructure and have agreed to it.

Planners should be aware that HWM infrastructure planning is not only a technical but also a political issue. Planning must win active support from the stakeholders for ensuring plan implementation. This may not always be easy. HWM infrastructure requires a certain ‘economy of scale’ for enabling economically viable operation of centralized facilities such as landfill sites and incinerators. Hence, planning might face stiff protest from neighborhoods, counties, districts and cities who object the erection of centralized facilities within their premises, particularly when waste also coming from outside of the own area is intended for disposal. To overcome this hurdle, public consultations have to be convened. Subject to the specific conditions planners may also ally themselves with high-level charismatic government bureaucrats who are in a position to reach out to the concerned municipalities for appealing to their consideration of the common welfare.

A HWM plan compliant with national and international requirements and standards, comprising National-, State/Provincial- as well as City/District-level planning, has been approved, is being implemented, monitored, evaluated and regularly updated.

Plans and regulations on hazardous waste management have to contain all relevant objectives, activities, responsibilities to facilitate the further development and implementation of a fully integrated and cost-effective waste management system;

244 “NIMBY” phenomenon (Not In My Backyard)
Comply with National, State/Provincial, as well as international standards and requirements;
Be comprehensive and address all key areas/aspects of hazardous waste management performance on National, State/Provincial, city and institutional level;
To be based on the Cooperative Principle (Chapter 2), especially the inter-regional approach, which is indispensable for implementing an efficient hazardous waste management system;
Comprise “Priority Waste Lists” which define individual waste types occurring in the respective planning area with great (potential) environmental risk and to focus resources and activities on a) minimization of waste quantities, b) minimization of environmental impact, or c) improvement of treatment or disposal;
Provide provisions and specifications on the management of special hazardous waste streams such as waste oil, health care waste, waste electrical and electronic equipment, end of life vehicles, PCB containing wastes and high-volume low-toxicity wastes (e.g. fly ash)
Introduce “Extended Producer Responsibility” (Ref. chapter 2) for relevant categories and types of waste/spent products, or encourage a stronger involvement of stakeholders, particularly polluters, with the aim of improving pollution prevention and sustainable waste management performance by implementation and/or use of ‘Best Available Technology’ BAT, environmental management, voluntary agreements, etc.;
Define appropriate instruments to support sustainable waste management,
   – Regulatory instruments, e. g. extended producer responsibility, disposal ban, facility standards,
   – Economic instruments, e. g. fees, advance treatment/disposal fee, landfill tax,
   – Persuasive instruments, e. g. voluntary agreements, waste prevention targets, eco-labeling, etc.
Establish and maintain waste management quality standards, criteria, benchmarks for a) preventing or minimizing waste amounts arising, b) minimizing the environmental impact related to waste generation, management, and disposal, c) promoting the efficient use of resources;
Set up or amend the monitoring/reporting system on generation and flow of hazardous waste;
Set up a communication system to improve public participation and to encourage stakeholders of all sectors of the society to become involved in partnerships, voluntary agreements, etc. for contributing to the overall goal of the plan.
14.2 Strategic Area “Effective Enforcement, Education and Training”

Objectives include:

- **Enforcement of national and lower level legislation, regulations and standards related to hazardous waste management is effective**
  
  Achieving a high compliance level with existing regulation is a key priority in HWM for minimizing adverse effects of hazardous waste on human health and environment. However the approach taken for enforcement may change over time. Whereas at the outset the competent authorities may have to adopt a “watchdog” role towards the regulated community, with increasing education success their role may gradually change into that of a partner who provides guidance, advice and smooth regulatory services.

  Enforcement of legislation shall:
  
  Be carried out by competent and trained personnel
  Be supported by sufficient (financial, technical, personal) resources and procedures to fulfill the task appropriately,
  Result in the establishment of integrated systems and procedures for licensing, monitoring and inspection (e.g. determination of “enforcement priority tasks”, elaboration of administrative inspection guidelines), taking stock of the HW inventory

- **Self-regulatory initiatives of hazardous waste generating enterprises have improved hazardous waste management significantly**
  
  Under the umbrella of ‘Corporate Social Responsibility’ (CSR) particularly multi-national enterprises have concluded voluntary agreements and developed their own strategies for environmental management including hazardous waste. These internal arrangements go usually beyond of what is required by legal standards. Such enterprises may educate their supply chain companies to do better in hazardous waste management by suggesting minimum standards for their environmental performance. Measures to be considered are e.g.:

  Reducing waste generation, enhancing waste recycling and recovery
  Improving hazardous waste segregation, collection, storage and transport
  Taking responsibility for hazardous waste transferred to third parties for the purpose of recovery or disposal (“Duty of Care”)

- **Data and information on waste management are sufficient to support planning, monitoring and enforcement**

  Data and information have to
Be accurate and reliable to meet all requirements of waste monitoring, waste inspection, and adjustment of waste planning;
Cover the sources, type, quantities, recycling, recovery, treatment/disposal, facilities of waste management;
Be based on a comprehensive National system for classifying waste types, e.g. “Comprehensive Waste List”;
Be based on a National system for compilation, processing, analyzing, evaluation, and documentation of data and information, e.g. “Hazardous Waste Inventory”;
Be updated and analyzed periodically and documented, e.g. “Annual Waste Reports”;
Meet the requirements for planning, monitoring and reporting of waste management activities and performances;
Meet the requirements of law enforcement and control of both waste management activities and facilities;
Comply with national classification and reporting system.

- **Human resources and capacity for hazardous waste management are appropriate**
  
  (See section 14.3)

14.3 Institutional and Organizational Set-up

This strategic area refers to the institutional and organizational set-up of the main stakeholders in HWM such as competent authorities, HWM service providers and HW generators. Objectives in this area are the following:

- **Institutional and organizational arrangements for hazardous waste management are sufficiently developed and implemented**

  Institutional and organizational arrangements have to suit the requirements on National, State/Provincial and City/District level with regard to regulation and planning, administration, enforcement and operational functions. The arrangements may need to be strengthened for gaining more efficiency and competency with regard to:

  Clarifying responsibilities and scope of duties of stakeholders (public sector administrations, HW service providers) with regard to hazardous waste management, “Horizontal” co-operation of competent authorities and HW service providers with respect to planning, building and operating disposal facilities, and recovering and disposing HW
(Competent Authorities) Compiling, assessing and disseminating information related to HWM and advising the Government, lower level competent Authorities, Cities, industrial associations, chambers and HW generators accordingly.

Improving licensing, HW transfer, on-site inspections, monitoring of organizations/enterprises and activities related to HWM.

Institutional and Organizational Set-up,
Waste Authorities: Formation of a Working Group on Waste

It was noticed that legislators at the National/Central/Federal level in low- and middle income countries are sometimes lacking practice related experience when framing waste regulation. As a result, legislative procedures emulate laws and regulation that are often falling short in practicability and of meeting real regulatory requirements. Moreover it was found that competent authorities at the State/Province level, without precise guidance how to implement National/Central/Federal regulation, may arrive at their own interpretation of the National laws. As a result, at the State/Province level inconsistent enforcement procedures may spread.

It is highly recommendable therefore to form a working group on waste, with equal representation from the competent authorities at the National/Central/Federal level and the State/Province levels in order to create a broader base for law making and to ensure uniform execution of waste related regulation in the entire administrational area of the country. This working group should fulfill the following tasks:

- Ensuring information and experience exchange between the States/Provinces and with the National/Central/Federal regulator
- Elaborating legislative proposals
- Clarifying legal issues related to waste law. This might require the formation of a sub-working group.
- Clarifying technical issues e.g. with respect to disposal technology, allocation of waste to recovery/disposal options, waste analysis etc. and elaborating proposals for solution. This might require the formation of a sub-working group.
- Reviewing the adequacy of the regulatory tools presently in use; modification and supplementation if necessary.
- Elaborating administrative instructions and practice related provisions for implementing waste regulation
- Interacting with industrial associations, NGO’s and other relevant bodies
- Publishing guidelines, bulletins, standard procedures, codes of practice etc. for dissemination or sale among the stakeholders including the regulated community

In Germany the foundation of the ‘Working Group of the Federal States on Waste’ (LAGA) in 1963 has proven to be highly successful in this regard.

**Human resources’ capacities with regard to HWM are appropriate**

The improvement of human resources and capacity shall

Be related to the institutional and organizational set-up
Consider all stakeholders at all levels
Be supported by sufficient budget allocation
Be based on training needs analysis and targeted programs/curricula in which the relevant topics and issues are sufficiently addressed, and
Convey the relevant subject matter to the training target groups by appropriate tools such as e.g. interactive workshops, lectures, talks, tests (Q&A), on-the-job training, internships
Compile and disseminate information on ‘Best Available Technology’ (BAT), (international) best practice standards and in-depth issues of HWM
Implement appropriate pilot projects.

**Institutional and Organizational Set-up,**

**Hazardous Waste Generating Enterprises, HW treatment and disposal facilities:**

**Appointment of a ‘Waste Management Officer’**

All enterprises in Germany generating hazardous waste in regular intervals are required by law to appoint a ‘Waste Management Officer’ (WMO) who takes care of waste related issues within the company. This has proven successful for improving internal waste management.

The following are the responsibilities and functions of a WMO:

1) To advise the top management in all waste related issues and to inform about shortfalls in WM observed

2) To assess, organize & review internal waste management (e.g. establishing the waste inventory; setting up waste segregation, reduction, collection, storage, treatment, transport, utilization and disposal, elaborating ‘Standard Operation Procedures’ (SOP’s) and checklists)
3) To oversee all waste streams from “cradle to grave” (Duty of Care)

4) To oversee compliance with waste related and associated regulation, e.g.:
   - Record of proper waste management procedure and manifest
   - Occupational Health & Safety issues with regard to HW,
   - Road transport of HW according to dangerous goods regulation

5) To support the Admin. Dep’t. in tendering & signing contracts with disposal and utilization entities

6) To train staff with regard to the following:
   - Hazards from wastes arising in their respective working areas as well as adequate protective measures
   - Proper management procedures for hazardous wastes

7) To determine goals for waste avoidance, reduction, segregation, for enhancing/upgrading comprehensive utilization, for improving disposal and to monitor the implementation of those goals

8) To document & report all activities and to submit an annual report on No’s 1-7 to the top management

It is important to note that a ‘Waste Management Officer’ does not automatically become legally responsible for the company’s waste management. The WMO is responsible for providing all the information required to the top management which has to decide on the necessary action.

In Germany the competent authorities offer 4-day training programs for WMO candidates for acquiring the required qualification. Being a WMO is not a full time job. The staff who executes the WMO function will usually have also other tasks in the company. The company may also outsource the function of a WMO to an external expert.

**International cooperation is effectively developed**

Stakeholders such as:

Managers and staff of the competent authorities can get deputed from their organizations for taking part in international exchange programs hosted by authorities in countries with advanced HWM systems and accumulated experience. Also participation in international development projects pursuing HWM related themes provides opportunities for enhancing knowledge and experience.
Indigenous HWM service providers and HW generating enterprises may enter into joint ventures with investors from abroad. Such cooperation offers potentials for know-how and technology transfer in the area of HWM.

14.4 Strategic Area “Prevention, Recycling and Recovery”

Waste prevention and recycling activities have to be considered in the HWM Plan as top priority. Objectives to be formulated for this strategic area:

- **The playing field is leveled with regard to hazardous waste prevention, recycling and recovery**

  Planning has to consider the setting of framework conditions for hazardous waste prevention, recycling and recovery by:

  - Reviewing the legal differentiation between ‘waste’ and ‘commercial goods’ and regulation for sale and/or use of hazardous materials as commercial goods
  - Creating conditions in the entire planning area for establishing a transparent uniform tariff system for disposal costs so that disposal charges act as incentive to implement prevention, recycling and recovery
  - Supporting the set-up of an infrastructure and market place for exchange of secondary raw materials
  - Granting operational licenses for future installations in the manufacturing sector only when applicants consider ‘Best Available Technologies’ (BAT) with regard to emission control including hazardous waste minimization.  
  
  - Elaborating reference material for waste prevention, recycling and recovery
  - Selection of Best Practices in waste prevention, recycling and recovery
  - Preparation of waste prevention, recycling, and recovery guidelines
  - Development of waste prevention, recycling and recovery indicators
  - Conducting advanced training and pilot projects

- **The potential of waste prevention and reduction at the source is being exploited.**

  Activities should focus on “Priority Waste Types”, which are characterized by hazardous potential, quantity and/or potential of prevention, (see strategic areas “Legal framework and enforcement”): Activities should consider the major aspects of prevention and reduction:

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245 See Annex 7 for a list of all reference documents on BAT published by the European IPPC Bureau
Improvement of waste composition; i.e. avoiding unfavorable constituents by substituting them against less hazardous raw materials or additives during the production process. This facilitates later utilization.

Improvement of on-site segregation and pre-treatment of wastes


Moreover, activities should consider that waste prevention:

Requires sometimes complex modifications within the production process and is not directly within the purview of "classic" waste management;

Must be initiated within the production process early enough before products or materials become waste;

Is potentially diverse in its effects on materials and products: It may affect the quantity, hazard, and energy content of materials and products that are converted into waste.

The potential of environmental sound waste recycling and recovery is realized.

Activities should focus on “Priority Waste Types”, which are characterized by hazardous potential, quantity and/or potential of prevention, (see strategic area “Legal framework and enforcement”): Activities should consider the major aspects of recycling and recovery:

Improvement of waste composition; i.e. avoiding unfavorable constituents by substituting them against less hazardous raw materials or additives during the production process. This facilitates later utilization.

Improvement of on-site segregation and pre-treatment of wastes


Activities have moreover to consider that waste recycling and recovery:

Should make use of ‘Best Available Technologies’ as far as possible in order to minimize risks to the environment and to human health.\(^{246}\)

May generate waste water, emissions to air and secondary hazardous wastes that require proper treatment and disposal

\(^{246}\) See ‘Reference Document on Best Available Technologies for the Waste Treatment Industries’, published by the European IPPC Bureau)
Is frequently considered as profitable business by operators because the competent authorities do not require them to ensure proper management of secondary pollutants generated. High recycling- and recovery rates do not automatically indicate a State-of-the-Art circular economy; recycling and recovery may be based on low-technologies which cause uncontrolled dissipation of dangerous substances (emission to air, water, and soil, but also products) and leads to high environmental and health risks; such problems need to be identified and resolved.

14.5 Strategic Area “Treatment and Disposal”

- **Consistent minimum acceptance criteria, licensing procedures and operation conditions for treatment and disposal facilities are developed and implemented.**
  
  With respect to landfill sites, the following has to be regulated:
  
  Licensing procedures
  Acceptance criteria
  Design criteria of construction elements essential for pollutant retention
  Quality control measures during construction
  Emission control and monitoring
  Requirements during the operational and post-operational phase
  Disposal of secondary pollutants generated (leachate)
  
  With respect to CPT plants, the following has to be regulated:
  
  Licensing procedures
  Acceptance criteria
  Emission control and monitoring
  Operation conditions
  Disposal of secondary pollutants generated (e.g. waste water, filter cakes and oil)
  
  With respect to incinerators, the following has to be regulated:
  
  Licensing procedures
  Acceptance criteria
  Incineration conditions (temperature, subject to presence of halogenated organic pollutants, retentions time etc.)
  Emission control and monitoring
  Disposal of secondary pollutants generated (e.g. slag, fly ash, waste water, filter cakes)
Feasibility studies for HW treatment & disposal facilities for the individual facilities specified in the HWM plan have been completed.

Feasibility studies for the envisaged treatment and disposal facilities have to be conducted on a City/District level. This requires a more detailed re-examination of hazardous waste generation data which may lead to modifications of the initial planning concept. Quality standards and acceptance criteria for the design, construction and operation of chemical/physical treatment plants, landfill sites and incinerators have to be defined. Planners, regulators, contractors and operators need to be trained accordingly.

Feasibility studies should provide information with regard to the following:

- Catchment area, types and quantities of hazardous waste to be treated / disposed
- A shortlist of maximum 5 options for the potential site location
- Rapid Environmental Impact Assessments of the installations under consideration (at each of the shortlisted respective locations) and suggested measures for minimizing and compensating such impacts
- Detailed design specifications for the installation under consideration, as far as possible according to ‘Best Available Technology’ (BAT), including measures for emission monitoring and pollution control
- Specification of ancillary facilities such as laboratory, water & electricity supply, weigh bridge, fence, access road, storage area, workshops, trucks, compactor, garages etc.
- Requirements for quality control during the construction period (important e.g. for landfill sites);
- Specification of the required staff and capabilities;
- Treatment and disposal of secondary pollutants generated
- Post-closure measures after the active lifetime of the facility (important e.g. for landfill sites);
- Options for the operator model;
- Financial requirements, including costs for site development, quality control, access road, fixed capital costs for main- and ancillary facilities, operation costs, salaries for staff, etc.;
- Options for structuring and calculating the fees to be charged to waste producers, particularly with regard to additional transport costs
Suitable State of the Art facilities including physical chemical treatment plants, incinerators and landfills for the effective treatment and disposal of organic and inorganic hazardous waste are available and provide sufficient capacities.

Detailed planning and construction of the hazardous waste treatment and disposal facilities resulting from the feasibility studies must be initiated. Based on the feasibility studies, design standards should be elaborated. Subsequently tender documents have to be developed and tendering undertaken. The contractor finally identified may yet require training.

Adverse effects on the environment from the treatment and disposal of hazardous waste are minimized as far as possible.

Emissions resulting from operation are controlled and secondary pollutants are properly collected and treated.

The scale of the facilities as well as the operator model ensures cost effective operation and cost recovery.

(See chapter 13.5.3)

14.6 Strategic Area “Segregation, Collection, Storage and On-site Treatment”

The following objectives have to be achieved in this area:

Waste is effectively segregated and managed at the source

Enterprises perform environmentally sound on-site recycling and -treatment of HW in a transparent manner

The requirements of temporary storage have been investigated and environmentally safe (centralized) facilities are realized

Related activities have

To be detailed in the “HWM Action Plan”, in connection with waste prevention, recycling, recovery and disposal, proposing a step-by-step approach, e.g.

1) Consider legal restrictions on waste segregation (e.g. ban of mixing hazardous with non-hazardous waste)
2) Improve compilation and dissemination of know-how
3) Conduct demonstration- and pilot projects
4) Conduct advanced training

To consider hazardous as well as non-industrial hazardous waste
To focus on methods and systems for segregation, temporary storage, collection, and transport; the arrangements have be sufficient to comply with national requirements
To give priority to source oriented segregation measures, with the aim:
To segregate hazardous waste at the earliest possible point
To gain “clean” fractions of recyclable material
To minimize waste fractions for disposal,
To consider that services for the collection and transport should be efficient and cost-effective.

Enforcement in this area should rely on on-site waste investigation campaigns that focus on temporary on-site storage of hazardous waste within waste producer’s premises, separation of hazardous waste streams, collection and particularly on-site treatment, recycling and disposal of hazardous waste (see chapter 5.2.). After evaluation of these campaigns measures must be taken to ensure that hazardous waste segregation, on-site storage, on-site treatment and recycling is in compliance with the respective regulation. Experience has shown that conduction even of a limited number of on-site waste investigations has a positive educative impact on the regulated community.

14.7 Strategic Area “Financial Instruments”

The objectives of this Strategic Area reflect the Polluter Pays Principle and the Producer Responsibility.

❖ **Financial sources for funding the implementation of the HWM infrastructure plan have been identified and are available.**

The options and projects of the HWM Plan finally selected for implementation have to be subjected to a detailed financial analysis. Subsequently, a financial plan has to be drawn up with a detailed specification of funding requirements and allocation of financial resources.

❖ **Charges/fees for waste management services reflect the true costs of the services**

It is the aim to ensure that full costs are encompassed in prices for waste management services. Within this strategic area also a price formation scheme for providing waste management services has to be developed, reflecting the true costs of the services according to the ‘Polluter Pays Principle’ (e.g. including costs for the aftercare of landfills after site closure).
Economic and financial instruments support effectively the implementation of Sustainable Waste Management

The introduced economic and financial measures shall

Reflect the ‘Long Run Marginal Costs’ (LRMC) of waste management services and facilities provided by public or private operators – collection, transport, pre-treatment, disposal

Be incentive to support waste prevention and recycling through innovative and resource efficient production technologies (e.g. providing loans with discounted interest rates for equipment procurement that meets ‘Cleaner Production’ criteria defined by the regulator)

Be incentive to support the development and implementation of innovative and environmental friendly waste recycling and treatment technologies

Introduce deposit refund systems for selected hazardous and/or recyclable spent products or waste materials (e.g. batteries, oil)

Give preference to recycled as well as recyclable products and materials in public sector procurement policies

Be incentive to support the set-up of Public Private Partnerships (PPP).

The seven strategic areas listed above may serve as orientation for conducting a gap analysis of the HWM situation in your country.
The Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH was formed on 1 January 2011. It has brought together under one roof the capacities and long-standing experience of three organisations: the Deutscher Entwicklungsdienst (DED) gGmbH (German Development Service), the Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ) GmbH (German technical cooperation) and Inwent – Capacity Building International, Germany. For further information go to www.giz.de.