CLEAN TECHNOLOGIES FOR WASTE MINIMISATION

Final report

EUROPEAN
COMMISSION

European Commission

Clean technologies for waste minimisation

Final report

Prepared for the attention of the Waste Management Unit of the European Commission DG XI

Contract number B4-3040/95/001056/MAR/E3

January 1997

Authors:
EurEco Interdisciplinary Environmental Studies (Luxembourg)
Witteveen and Bos consulting engineers (the Netherlands)

Document

A great deal of additional information on the European Union is available on the Internet.
It can be accessed through the Europa server (http://europa.eu.int).

Cataloguing data can be found at the end of this publication.

Luxembourg: Office for Official Publications of the European Communities, 1998

ISBN 92-828-2121-8

Printed in Belgium

PREFACE

The present final report on 'Clean Technologies for Waste Minimisation' provides a comparative review of the opportunities for waste minimisation in fourteen key sectors of manufacturing industry, with emphasis on small and medium-sized enterprises. The study aims on the one hand to stimulate manufacturers' thinking about their own production processes, and on the other to serve public officials responsible for promoting waste minimisation.

Waste minimisation is not new in manufacturing industry, where there is a traditional focus on product recovery and by-product re-use. However, environmental concerns have renewed attention to waste minimisation and changed its orientation. Modern waste minimisation no longer concentrates exclusively on product recovery and by-product re-use; it also takes account of the less valuable wastes and is based on a systematic evaluation of waste minimisation opportunities.

This report should be seen in the context of the ongoing developments in the field of waste minimisation and clean technology. There have been, and continue to be, many policy studies and policy initiatives in this area by national governments, international bodies and industry. They all identify the need for accessible information on practical opportunities for waste minimisation, especially in relation to SMEs. This need is confirmed by the European industrial federations that were invited to co-operate in producing the present report.

The report aims to respond in a *comparative* way to the need for information on waste minimisation. It lists and evaluates waste minimisation options by industrial sector within a *uniform analysis structure*. The report can be used to give a quick overview of waste minimisation opportunities in a specific sector, or for comparison between sectors. It can also serve as a starting point for in-depth, sector-specific work and for promotional activities on waste minimisation within specific industrial sectors, or as a basis for future programmes of information exchange, educational or funding activities.

The authors hope that the report will provide input for the further implementation of waste minimisation, and contribute to closer co-operation between industry, industrial federations and public authorities.

ACKNOWLEDGEMENTS

The present study would not have been possible without the information supplied by various sources. EurEco and Witteveen+Bos would therefore like to thank sincerely the following organisations that contributed to the study :

- Administration de l'Environnement, Division des Déchets, Luxembourg (L)
- Agence de l'Environnement et de la Maîtrise de l'Energie, Département Industrie Milieux et Technologies, Angers (F)
- Asociacion de Investigacion de las Industrias del Curtido y Anexas (AIICA), Barcelona (E)
- Association Européenne des Métaux (Eurométaux), Brussels (B)
- Bundesministerium für Umwelt, Sektion III, Wien (A)
- Centro Tecnológico das Indústrias do Couro (CTIC), Alcanena (P)
- Clean Technology Centre, Dublin (IRL)
- Confederation of European Paper Industries (Cepi), Brussels (B)
- Confederation of National Associations of Tanners and Dressers of the EC (Cotance), Brussels (B)
- Danish Technological Institute (DTI), Taastrup (DK)
- Department of Trade and Industry, Environmental Technology Best Practice Programme, Oxfordshire (UK)
- Environment Protection Agency, Washington (USA)
- European Aluminium Association (EAA), Brussels (B)
- European Chemical Industry Council (CEFIC), Brussels (B)
- European Dairy Assocation (EDA), Brussels (B)
- European Commission DG XI.E.3, Waste management policy, Brussels (B)
- European Commission DG XII.D.1, Environmental Technologies, Brussels (B)
- European Commission DG XVII, Energy, Brussels (B)
- European Confederation of Iron and Steel Industries (Eurofer), Brussels (B)
- European Newspaper Publishers Association (ENPA), Brussels (B)
- European Secretariat of Manufacturers of Light Metal Packaging (Sefel), Brussels (B)
- Federation of Finnish Metal, Engineering and Electrotechnical Industries (FIMET), Helsinki (FIN)
- Federation of the Electronics Industry (FEI), London (UK)
- IMd Micon, Barneveld (NL)
- Ingenieurgemeinschaft Technischer Umweltschutz, Berlin (D)
- International Confederation of Printing and Allied Industries (Intergraf), Brussels (B)
- International Confederation of Paper and Board Converters in Europe (Citpa), Frankfurt am Main (D)
- KNP LEYKAM, Maastricht (NL)
- Liaison Group of the European Mechanical, Electrical, Electronic and Metalworking Industries (Orgalime), Brussels (B)
- Liaison Office of the Rubber Industry of the EC (Blic), Brussels (B)
- Luxinnovation, Luxembourg (L)
- Masure Tannery, Estaimbourg (B)
- Miljoestyrelsen, Cleaner Technology Division, Copenhagen (DK)
- OECD, Environment Directorate, Paris (F)
- Rijkstinstituut voor Volksgezondheid en Milieuhygiëne (RIVM), Bilthoven (NL)
- The European Apparel and Textile Organisation (Euratex), Brussels (B)
- The European Cement Association (Cembureau), Brussels (B)
- The European Confederation of Associations of Manufacturers of insulated Wires and Cables (Europacable), Brussels (B)
- The Malt Distillers Association of Scotland, Moray (UK)

- Umweltbundesamt, Abteilung III.4 Entsorgung, Berlin (D)
- Union Nazionale Industria Conciaria, Milan (I)
- UNEP Industry and Environment, Cleaner Production Programme, Paris (F)
- Versuchsanstalt für Lederindustrie, Vienna (A)
- Waste Reduction Resource Centre, Raleigh (USA)
- Westdeutsche Gerberschule Reutlingen (WGR), Reutlingen (D)
- Wollsdorf Leder, Wollsdorf (D)
- Zentralverband Elektrotechnik- und Electronikindustrie (ZVEI), Frankfurt am Main (D)

Special thanks goes to the Waste management unit (DG XI.E.3) of the European Commission, which provided guidance to the project and offered an appropriate platform for discussion on the scope, themes and results of the study.

EurEco and Witteveen+Bos would like to point out that the conclusions drawn are the authors' own and do not necessarily correspond with the views of the European Commission or the actors involved.

STUDY 'CLEAN TECHNOLOGIES FOR WASTE MINIMISATION'

- Table of contents / final report -

PART I : GENERAL ASPECTS

1. INTRODUCTION

>> *Chapter 1 presents the background to the study, sets out its objectives and introduces the reader to the different parts of the report.*

1.1 Background to the study

Waste minimisation[1] has been part of Community waste management policy from the outset. Already in 1975, Directive 75/442/EEC[2] contained the provision that Member States should take appropriate measures to prevent waste generation[3]. It became a more explicit Community priority with the adoption in 1989 of the Community strategy for waste management[4]. This laid down a hierarchy of waste management options in which primary emphasis is placed on waste prevention, followed by the promotion of recycling and re-use, and then by the optimisation of final disposal methods for waste that is not re-used.

The 1996 review of the Community strategy on waste[5], and the Council resolution of 9 December 1996 in this regard, lay further emphasis on waste prevention through concerted measures with the actors involved. According to the 1996 review, the Commission will continue to promote clean technologies in the context of the various funding facilities available (although the initiative in having recourse to such technologies rests with the Member States and economic operators). Emphasis is also laid on the use of eco-audit schemes. The new strategy further foresees the promotion of the use of quantitative targets of an indicative nature, with a view to achieving significant reductions in the amount of waste generated and increasing the levels of re-use, recycling and recovery. Prevention will also be encouraged by a number of product-oriented measures.

1.2 Objective of the study

The purpose of the study is, on the one hand, to stimulate manufacturers' thinking about waste minimisation in their processes. On the other hand, it is intended to serve public officials responsible for promoting waste minimisation in manufacturing industry. There is an emphasis on small and medium-sized enterprises (SMEs[6]) because they have a particular need for information on waste minimisation.

---

1 In this study, the term waste minimisation is used as an equivalent for waste prevention and includes source reduction by input material change, technological change (equipment and/or process) and good-operating practice. It also covers on-site re-use and on-site reclamation of waste materials. All these methods are considered to be preventive or clean technologies.

2 Council Directive on waste, OJ 1975, n° L 194, p. 47.

3 This principle was later modified. Directive 91/156/EEC (OJ 1991. n° L 78, p. 32), amending Directive 75/442/EEC, indicates that Member States should take the appropriate measures to encourage the prevention or reduction of waste production and its harmfulness, in particular by the development of clean technologies.

4 Communication from the Commission to the Council and to Parliament, "A Community Strategy for Waste Management", SEC(89)834 final, Brussels, 18 September 1989.

5 Community strategy on waste - review 1996, COM(96)399, July 1996.

6 Defined in the EU as enterprises with fewer than 500 employees.

1.3 Structure of the report

The present report consists of two parts :

- *Part I: General aspects*

  This part introduces the study, presents the uniform analysis structure, describes the process of selecting the industrial sectors and gives details on the applied methodology (chapter 2). It also provides conclusions and an overview of the results of the individual sector reports (chapter 3).

- *Part II: Sector reports*

  This part includes the fourteen sector reports drawn up for the selected key industrial sectors. The sector reports follow the uniform analysis structure and the system of classifications and assessments as described in part 1. The reports provide a broad outline of waste prevention options; the literature sources will facilitate further research.

2. APPROACH OF THE STUDY

\>> *Chapter 2 provides details on the uniform analysis structure developed for the purpose of the study (§ 2.1), the classifications and assessments applied for waste streams and prevention options (§ 2.2), the key industrial sectors that were selected for analysis (§ 2.3) and the information gathering efforts undertaken (§ 2.4).*

2.1 Uniform analysis structure

A uniform analysis structure (figure 1) was developed in order to give the reader easy access to information on processes, waste streams and prevention aspects of the selected sectors, and to permit a horizontal comparison between the sectors.

Figure 1 : Outline of the uniform analysis structure

	SECTOR REPORT
§ 1	Sector characterisation
§ 2	Processes and wastes
§ 3	Waste prevention
§ 4	Evaluation
§ 5	Bibliographic references
Annex A	Process and waste description
Annex B	Prevention options

EurEco / Witteveen+Bos 1997

Each sector report comprises a general section (§ 1-5), which offers elements of an overall perspective on waste minimisation in the sector, and technical annexes (Annexes A and B), which provide more detailed information on processes, wastes and minimisation options.

Paragraphs 1-5 aim to assist the reader in understanding the main features of the sector concerned, and provide a general evaluation of waste prevention opportunities in that sector. They include a general industry profile (§ 1), a summary description of waste streams and processes (§ 2), an overview of waste prevention options (§ 3), an evaluation of the prospects for waste minimisation (§ 4) and an overview of the relevant information sources (§ 5).

Annex A describes in a concise way the principal processes and waste streams that are common to the production of the sector concerned. The waste descriptions offer an insight into why and how waste is generated at a specific source, the quantities (if available) of waste generated, the composition and hazardous character of the waste and the way in which it is generally disposed of.

Annex B presents concise descriptions of the options identified. Each page describes one prevention option in a uniform way, including information on costs and prevention potential wherever possible. The structure of the annex reflects the division of processes and wastes that is made in the sector report.

The options described in annex B provide a broad outline of waste minimisation methods. The outline of options is intended to provide a systematic approach, covering the principal types of waste minimisation methods. As such it forms a starting point for programmes on waste minimisation by public authorities, industrial federations and individual companies. The purpose is not to cover all possible options known in industry, nor to provide all necessary technical and economic details. The literature sources mentioned will facilitate further research.

2.2 Classifications and assessments

Classifications and assessments have been applied in order to offer a comparative approach. Table 1 gives an overview of the classifications and assessments applied, which are described below.

Table 1: Classifications and assessments used in the sector reports

	Classifications	**Assessments**
Waste streams	- Process origin - European Waste Catalogue - European Hazardous Waste List	- Tentative priority ranking
Waste prevention options	- Level of state-of-the-art (group 1-3) - Nature of the methods	- Indication of the prevention potential

EurEco / Witteveen+Bos 1997

Waste streams

Waste streams identified for each sector are primarily classified according to their *process origin*. In this way the (industrial) reader can quickly find information that is relevant to the specific processes applied.

Secondarily, the waste streams are classified according to the categories of the *European Waste Catalogue*[7] (EWC) in order to facilitate possible approaches and evaluations from this point of view. Whenever possible, it is indicated if waste streams referred to from the EWC are included in the *Hazardous Wastes List* [8].

The significance of the waste streams identified are assessed by a *tentative priority ranking*[9], based on the amount and the hazardous character of the waste. The ranking remains tentative because comparative statistics on occurences of waste are not currently available.

Prevention options

Prevention options are classified in three groups related to different *levels of state-of-the-art*, combining availability with economic information.

7 Commission Decision 94/3/EC of 20 December 1993, establishing a list of wastes pursuant to Article 1 (a) of Council Directive 75/442/EEC on waste (OJ EC, N° L 5, 7.1.1994, p. 15- 33).

8 Council Decision 94/904/EC of 22 December 1994, establishing a list of hazardous wastes pursuant to Article 1 Paragraph 4 of Council Directive 91/689/EEC on hazardous waste (OJ EC, N° L 356, 31.12.1994, p. 14).

9 The priority rank is based on a sector-wide evaluation and can therefore not be applied to an individual enterprise nor can different sectors be directly compared to each other.

The groups are defined as follows[10]:

- group 1: technically proven and established methods which are in general use at modern plants and which do not entail excessive costs

- group 2: methods in operation at a limited number of plants; economically not attractive unless there are subsidies available, market wishes to be fulfilled or inexpensive chemicals, electric power or other input available

- group 3: emerging technology in its early stages of development (usually only bench or pilot-scale operating trials).

The prevention options are further classified according to the *nature of the methods* involved, as listed below. The first three methods (IMC, TC, GOP) refer to source reduction. On-site re-use substitutes spent input materials for new input materials in the manufacturing process. On-site reclamation, on the other hand, recovers valuable material from waste streams for incorporation in some other process or product.

- input material change (IMC)
- technological change (equipment and/or process) (TC)
- good operating practice (GOP)
- re-use (RU)
- reclamation (RC).

Finally, an *indication of the prevention potential* of the prevention options is given by way of three scores (high, moderate or low potential). The scores have been allocated on the basis of the following criteria:

- the amount of waste expected to be reduced in combination with the hazardous properties;

- the degree to which the method is implemented in the sector (the potential can be 'high' if not many companies have implemented the method).

- the classification 'level of state-of-the-art': group 2 and 3 methods are not (yet) expected to be applied on a large scale and will generally be ranked as 'low', however, if a method implies a high or very high waste reduction potential, it can be classified as 'moderate' or 'high' respectively.

The scores were assigned using expert judgement, on the basis of the available information.

2.3 Selection of industrial sectors

The NACE Rev.1 classification has been taken as a reference for the selection of industrial sectors because this classification is, on the one hand, the accepted standard for economic and industrial activities in the EU and, on the other hand, the basis used for drawing up the European Waste Catalogue, which lists wastes according to their occurence in economic sectors (with some exceptions).

The NACE two-digit level was taken as the starting point and an initial selection was made of sectors with manufacturing industry. On the two-digit level of NACE codes, manufacturing

10 The same approach is applied in studies on Best Available Techniques (BAT) undertaken on behalf of the European Commission, e.g. in Pöyry 1994.

industry covers 22 sectors, described in NACE 15-36[11]. A further selection and clustering of sectors was made, with the emphasis on SME coverage and process similarities. The result of the selection process and clustering is presented in Table 2, followed by a short explanation.

Table 2 : Selected industrial sectors analysed within the study

Section	NACE code	NACE description	Sub-sectors focused on:
1	151	Production, processing and preserving of meat and meat products	
2	155	Manufacture of dairy products	
3	159	Manufacture of beverages	brewing industry
4	17	Manufacture of textiles	
	18	Manufacture of wearing apparel; dressing and dyeing of fur	
5	19	Tanning and dressing of leather; manufacture of luggage, handbags, saddlery, harness and footwear	tanning and dressing
6	20	Manufacture of wood and of products of wood and cork, except furniture; manufacture of articles of straw and plaiting materials	
	361	Manufacture of furniture	
7	21	Manufacture of pulp, paper and paper products	manufacture of paper and board
8	22	Publishing, printing and reproduction of recorded media	printing
9	24	Manufacture of chemicals and chemical products	
10	25	Manufacture of rubber and plastic products	
11	26	Manufacture of other non-metallic mineral products	manufacture of glass, glass products, ceramic goods, products in baked clay and articles of concrete, plaster and cement
12	27	Manufacture of basic metals	casting of metals (foundries)
13	28	Manufacture of fabricated metal products	
	29	Manufacture of machinery and equipment N.E.C.	
	33	Manufacture of medical, precision and optical instruments, watches and clocks	
	34	Manufacture of motor vehicles, trailers and semi-trailers	
	35	Manufacture of other transport equipment	
14	30	Manufacture of office machinery and computers	manufacture of printed circuit boards
	31	Manufacture of electrical machinery and apparatus N.E.C.	
	32	Manufacture of radio, television and communication equipment and apparatus	

EurEco / Witteveen+Bos 1997

11 NACE 37 is involved in the recycling of scrap materials (metal, plastics, etc.) and is as such an important waste management party. The sector has not been treated separately as it is not part of manufacturing industry. It has nevertheless an important place in the report as many on-site recovery and reclamation options are included. These options are similar to those operated by the recycling industry.

Sectors excluded or clustered are discussed briefly below.

- *NACE 15 (manufacture of food products and beverages):*
  Because of the diversity in production processes occurring in the food sector, a further division into three-digit levels of NACE has been chosen. Three sectors with significant waste arising and an important economic position within the food sector have been retained for analysis (meat industry, dairy industry, beverages industry/beer brewing).

- *NACE 16 (manufacture of tobacco products):*
  This sector has been excluded because its waste problems are minor in relation to those of other sectors, and because of the small economic value of the sector.

- *NACE 17 and 18 (manufacture of textile and clothing):*
  These sectors have been clustered because of the integration of the processes applied and the strong relationships between companies.

- *NACE 20 and 361 (manufacture of wood and furniture):*
  NACE 20 has been combined with the wood processing activities of NACE 361 (manufacture of furniture), the economically most important sector of NACE 36. For other processes applied in the manufacture of furniture, the reader is referred to the manufacture of clothing (sector report 4), leather (sector report 5), rubber and plastic products (sector report 10) and metal products (sector report 13).

- *NACE 23 (manufacture of coke, refined petroleum products and nuclear fuel):*
  This sector has been excluded from the study because manufacture of these products is undertaken by large enterprises, not by SMEs.

- *NACE 28, 29, 33, 34, 35 and NACE 30, 31 and 32*
  These sectors have been clustered because of the similarities of the industrial processes applied.

- *NACE 362-366*
  These sectors (manufacture not earlier referred to) have been excluded by reason of their limited economic importance and the multitude of processes involved.

2.4 Information gathering

In order to make available the data of the study, extensive literature research and information gathering actions have been carried out. In accordance with the terms of reference of the study, the following steps have been undertaken :

- full exploitation of the in-house literature sources and know-how of the two partners (such as EU reports on emissions and BAT in industrial sectors, specific studies on the waste prevention options of industrial sectors and national governments);

- consultation of specific general sources (such as Cordis database, Eureka database, UNEP ICPIC database, Panorama of EU industry);

- consultation of databases and handbooks on practices and processes applied in specific industrial sectors (such as the European Database for Corrugated Board Life Cycle Studies, Fefco);

- specific information requests to key international and national players in the field of waste minimisation and clean technologies (such as UNEP IE, OECD, European Commission DG III, XI, XII, Eureka Euroenviron working groups, national Environment Ministries). This took place notably through existing personal contacts.

The literature sources obtained include: EU-wide studies undertaken on behalf of the European Commission, Austrian / Danish / Dutch / French / German / Irish / UK reports on waste and environmental problems in industrial sectors, specific waste minimisation audit reports, industry environment information, database extracts, information on research programmes and projects at EU and national level, US EPA waste prevention guides, and UNEP IE technical documents. The references to the literature used are presented in the bibliographies of the sector reports.

Industrial federations involved in the different sectors have been consulted. In a first phase, in May / June 1996, the federations were requested to provide information for the study. In a second phase, in October / November 1996, selected federations were asked to comment on the draft sector reports. The comments transmitted have all been taken into account, within the possibilities of the scope and budget of the study. The results of the industry consultation process are described briefly in the bibliography section of each sector report.

3. CONCLUSIONS AND RESULTS OF THE STUDY

>> *Chapter 3 offers general conclusions and suggestions on the basis of the sector reports (§ 3.1). It concludes with an overview of the major results of the sector reports (§ 3.2).*

3.1 Conclusions and suggestions

The study is primarily directed towards the collection and evaluation of the available information on waste minimisation in the industrial sectors. On the basis of the sector reports, the authors draw the following conclusions and suggestions :

Conclusions

- *Sector-specific and up-to-date information is scarce.*
  Despite the extensive literature search and the information gathering actions undertaken, with approaches to international bodies, national authorities, and industrial federations, relatively little practical and detailed information has become available. Valuable sources of information are sector-specific waste prevention fact sheets and manuals (available in some countries (DK, NL) for some sectors), the sector-specific waste prevention guidelines and reports on trials provided by US EPA and the sector-specific technical reports of UNEP IE.

  The following remarks can be made as regards other information sources:
  - study reports on environmental aspects of industry rarely contain waste minimisation options.
  - waste audits and demonstration projects of individual companies are helpful but are restricted to the specific activities of a company, within given financial and technical conditions.
  - existing general information sources are often outdated (they date from the late 1980s and early 1990s)
  - detailed information on costs and benefits of waste minimisation is also scarce; the process-integrated character of most options means that their suitability is strongly related to individual enterprise and exploitation conditions.
  - some waste minimisation information has become available through other environmental programmes. Many of the minimisation options for solvent-containing waste streams are, for example, essentially methods for reducing VOC emissions to air. Other examples can be found in the field of waste water control. In some industrial sectors (e.g. textile industry, leather industry) substantial efforts have been made towards reducing hazardous constituents in the effluents. Some studies on waste water control therefore contain valuable waste prevention options, on the one hand because waste water sludges often constitute significant waste streams, on the other hand because such studies include source reduction and preventive process-integrated measures which are useful from the point of view of waste prevention as well.

- *The waste minimisation perspective is oriented towards the continuation and extention of ongoing efficiency improvement efforts in several sectors.*
  The sectors concerned are: meat industry, dairy industry, beverage / brewing industry, textile industry, leather industry, wood industry, paper industry, mineral products industry, basic metals industry / foundries, metal products industry. In these sectors, the minimisation options identified are mainly directed towards good operating practice, material re-use and material reclamation.

- *Fundamental changes in technology and input material are promising for waste minimisation in some sectors.*
  The sectors concerned are: publishing and printing industry, chemical industry, rubber and plastic processing industry, electrical equipment industry. In these sectors, technologies are advancing rapidly and expenditure on research and development is high. The changes require a high level of innovation and new technology, for which the research bases are in general available in the sector.

- *General good operational practices are applicable to all sectors and constitute a significant part of the waste prevention potential in the short term.*
  These principles include organisational and technical methods such as spill prevention and control, segregation of waste streams, optimisation of raw materials packaging and storage, minimisation of residue losses in batch processes, optimisation of material use to reduce cutting losses. Organisational aspects are also important in all sectors because waste minimisation is a company specific activity that has to be adopted as a continuous self-evident process. Organisational aspects include, for example, personnel awareness, motivation and training; maintenance procedures; production scheduling; periodic and systematic evaluation of waste generation and opportunities for prevention; registration and control of waste streams.

- *Most identified options do not necessitate excessive costs and generate significant benefits.*
  A large number of the identified options are classified in group 1, i.e. technically proven methods which do not require excessive costs. The waste prevention prospects for these options are often assessed as significant; pay-back times are in general low because of reduced costs for waste disposal and savings on the purchase and processing of raw materials.

- *Industrial federations are positive towards waste minimisation, but in general not yet proactive.*
  For reasons of competitiveness, waste minimisation is traditionally undertaken at individual company level. The federations consulted were in general very positive towards the issue of waste minimisation. However, only a few industrial federations have undertaken initiatives in this field (e.g. the leather industry with the Geric data base and of the chemical industry with the Sustech programme). Other co-ordinated initiatives have not been identified.

Suggestions for the promotion of waste minimisation through information

The issue of waste minimisation can, in many cases, be taken up on a voluntary basis because it has become clear that waste minimisation generates benefits that often outweigh costs. Moreover, waste streams generated and suitable minimisation methods are strongly dependent on company specific conditions, so that general rules and quantitative objectives are difficult to establish.

Public authorities could thus concentrate on developing stimulatory instruments - in close co-operation with industrial federations - to support the further implementation of waste minimisation. There is, however, an obvious need for qualitative and quantitative information on waste minimisation, and for the dissemination of this information. On the basis of the sector analyses and the contacts with industry and public authorities throughout the study, the authors would like to make the following suggestions:

- *Collection of information*
  The authors consider that the collection of information on different methods of clean technology and waste minimisation could best be co-ordinated at a transnational level. The European Commission, or a specific bureau on behalf of the Commission, could play the co-ordinating role and set up and maintain a specialised and up-to-date database on the

subject of clean technologies / waste minimisation. This bureau could also initiate work on the further establishment of methods for the development, implementation and assessment of waste minimisation. The information collected could be distributed regularly to national government organisations, general intermediate organisations and industrial federations. The Commission could also co-ordinate the work with other international bodies such as UNEP, OECD and with countries outside the EU (as Japan and US).

- *Dissemination of information*
  The dissemination of information to companies, particularly SMEs, should take place at local level. In the authors' opinion, a distinction should be made between sector-specific dissemination (by industrial sector) and general dissemination.

  - *sector-specific dissemination (by industrial sector).* The authors suggest that funding facilities should be made available for dissemination projects by industrial sector, co-ordinated by the European and national industrial federations concerned. Such projects could include the preparation of easily understandable manuals and data sheets on waste minimisation. The sector reports in the present study could provide basic input for this work. Other projects could promote the implementation of the manuals and data sheets within the sector by offering companies low-cost participation in information meetings, workshops and training, and individual waste mini-audits.

  - *general dissemination.* Dissemination that is not related to specific industrial sectors should further encourage companies to take up the issue of waste minimisation. One could envisage the dissemination of information through bodies such as local chambers of industry, local innovation agencies and local / national clean technology agencies.

- *Presentation of the study and debate on information collection and dissemination*
  The present study offers new input to practical discussions with industry and public authorities on the subject of information collection and dissemination in the field of waste minimisation. The authors suggest organising a Round Table - involving European industrial federations and the public authorities of the Member States - at which the results of the present study could be presented. This would afford an opportunity to discuss the prospects for further activities, such as in-depth sector-specific work and dissemination projects.

3.2 Comparative overview of results of the sector reports

The main results of the sector analyses are summarised in Table 3. The table permits comparison of the waste streams and prevention potentials of the different industrial sectors.

Table 3 : Summary evaluation of waste streams and prevention potentials within selected industrial sectors

Waste stream	Prevention potential
1. Production, processing and preserving of meat and meat products	***NACE 151***
• Several by-products (blood, offal) and waste streams (waste water, manure, packaging waste) are generated in the meat sector. • All product loss, by-product loss, and wastes that have not been segregated, end up in the waste water stream.	• The meat sector has a traditional focus on product recovery and by-product processing. • There is nevertheless still room for improvement. • The identified options are mainly good housekeeping options oriented towards a reduction of the waste load sent to the sewer.
2. Manufacture of dairy products	***NACE 155***
• The major waste streams of the dairy sector are related to product losses and cleansing operations, resulting in waste water streams and sludges. • Most wastes are typically composed of organic substances and have good re-use or recycling possibilities.	• The dairy industry has extensive experience with the issue of product recovery, as part of cost reduction and production rationalisation programmes. • Available waste minimisation audits report that there are further possibilities for waste minimisation through product recovery.
3. Manufacture of beverages: brewing industry	***NACE 159***
• Major by-products of the brewing industry are spent grains and surplus yeast. • Waste water is the major liquid waste stream, containing raw materials and product losses as well as cleansing agents. • All wastes are typically composed of organic substances and can easily be treated, re-used or recycled.	• The brewing industry has a traditional focus on the issue of recovery of raw materials and product from the waste water. • Waste minimisation must be considered as a continuation of efficiency improvement efforts ongoing. • Prevention potentials have been evaluated as between low to moderate, because it is anticipated that many options will already have been implemented.

Waste stream	Prevention potential
4. Manufacture of textiles and clothing	***NACE 17 and 18***
• Major waste problems within the textile industry are associated with finishing processes, resulting in (hazardous) liquid waste, waste water streams and sludges. • Cutting losses and rejects in textile manufacturing are important sources of solid textile wastes, especially within garment and carpet manufacturing.	• In recent decades, major environmental efforts have been made in relation to finishing processes, resulting in substantially improved control of effluents. • Much literature has become available on clean technologies for finishing processes. Further continuation of implementation is related to economic opportunities. • Minimisation of textile wastes is considered to be largely a matter of good operational practices; for economic reasons, its introduction is a continuous process.
5. Tanning and dressing of leather	***NACE 19***
• Significant waste streams from tanneries are chrome-containing, liquid salty effluents and sludges, related to cleansing and wet treatment in tanning and post-tanning. • By-products generated by beamhouse operations consist of chemicals and organic matter; virtually all streams are recovered and re-used as secondary raw material in other industrial activities. • Tannery wastes can be seen in relation to upstream activities: tanneries actually reduce meat-industry wastes/by-products (skins and hides) while waste production at the tannery is influenced by the cleanness of these input materials.	• External reclamation has been (and still is) an important waste management strategy in the leather industry. Nearly all waste materials can be re-used externally. • In relation to the use of hazardous materials (e.g. chrome), much attention has traditionally been paid to clean technologies to minimise the environmental effects. • Further waste minimisation potential is related to (external) developments regarding better quality of input materials (cleaner hides and chemicals).
6. Manufacture of wood and wood products / Manufacture of furniture	***NACE 20 and 361***
• The largest waste volume in the wood sector is made up of wood losses and wood dust. Re-use for fibre production or use as fuel are obvious options. • Hazardous waste streams arise from wood preservation. • A minor, but nevertheless significant waste stream results from paint application. • Apart from wood losses, the manufacture of furniture generates textile and leather cutting losses, and wastes from the manufacture of plastic and metal products.	• Prevention options identified for wood wastes mainly involve good housekeeping. As wood is the principal raw material, a high level of implementation is anticipated. • Many studies are available on environmental aspects of preservation, including waste minimisation, but with particular attention towards soil protection and air pollution control. Implementation can be considered as an on-going activity.

Waste stream	Prevention potential
7. Manufacture of paper and paperboard	***NACE 21***
• The paper industry itself plays an important role in waste recycling. Waste paper utilisation represents the majority of overall fibrous material input in the EU. • The major waste stream in paper and board production is formed by waste water treatment sludges. Generally, these sludges possess good external re-use properties. • Important paper industry wastes are de-inking sludges from recycled fibre processing.	• For reasons of competitiveness, low waste technology - especially for the recovery of valuable fibres (consequently reducing waste water treatment sludge production) - has been widely used in the paper industry for many years. • Potentials for further waste prevention may be found in advanced treatment and recovery of specific waste (water) streams, e.g. from coating processes. Major constraints, however, are the costs of these methods.
8. Publishing, printing and reproduction of recorded media: printing and photoprocessing	***NACE 22***
• The printing industry generates a variety of waste streams, including liquid paint, ink and solvent wastes and solid wastes consisting of paper, used plates and ink residues. • Photoprocessing generates primarily aqueous wastes that can contain metals and other contaminants. Solid wastes consist of paper and films.	• Printing is a modern, high-tech industry, in which waste minimisation opportunities through technological changes are promising. • Waste minimisation in photoprocessing is mainly directed towards re-use and recovery methods that are considered to be well-known; implementation is therefore likely to a large extent.
9. Manufacture of chemicals and chemical products	***NACE 24***
• The chemical industry is a significant consumer of materials and energy, and a major generator of wastes, in terms of quantity and hazard potential. • Waste streams are complex due to the varied operations and reactions employed. They arise from a variety of sources which are associated with the chemistry and plant operations.	• Most of the waste minimisation options implemented to date are good housekeeping, product recovery and by-product re-use options. • The greatest potential for waste minimisation is, however, in the production processes, where fundamental changes to processes are often required in order to achieve cleaner operation. This will demand a high level of innovation and new technology.
10. Manufacture of rubber and plastic products	***NACE 25***
• Product loss in the form of rejected and excess material is an important source of waste in the rubber and plastic processing industry. • Solvent wastes are another important source of waste, in particular in the fibre-reinforced composite and plastic processing industry.	• The rubber and plastic processing industry has a traditional focus on product loss minimisation. The ongoing process of cutting costs has reinforced attention to the issue and demonstrated potential for further prevention. • Good possibilities for prevention have also been identified for solvent wastes. • Technologies are advancing rapidly in the sector, which means that companies should continually educate themselves.

Waste stream	Prevention potential
11. Manufacture of mineral products	***NACE 26***
• The main waste streams from the manufacture of mineral products are mineral solid residues, sludges and particles. • In general, the waste streams are not hazardous and can be used for various external purposes.	• Wastes are considered a less significant environmental issue within this sector. The existence of good possibilities for external use plays an important role. • Waste prevention methods are related to good operational practices and particularly to internal recycling.
12. Manufacture of basic metals: casting of metals (foundries)	***NACE 27***
• The major waste problem of foundries is caused by foundry sands. • In spite of a high degree of internal recycling, large volumes of sand still have to be disposed of to landfill. • External recycling opportunities and inertization continue to develop.	• The foundry industry in general has long experience with foundry sand regeneration. • Good housekeeping and the use of alternative binders and moulding techniques offer further potential for reducing waste foundry sands. • SME level foundries have a need for economically feasible regeneration methods. Various possibilities on this level are becoming available.
13. Manufacture of metal products, machinery and equipment	***NACE 28, 29, 33, 34 and 35***
• Metal scrap constitutes a major waste stream. In spite of its very good recycling properties, prevention is important for economical and environmental reasons. • Other important waste streams are related to the use of chemicals, such as metal working fluids, plating solutions, solvents and paints.	• The metal industry is one of the main European industrial sectors, and there have been many studies on waste minimisation with a view to furthering the implementation process. • Reduction of metal scrap waste is largely a matter of good operational practices. Improvements regarding separation, collection and external recycling appear to be a point of interest. • Many options are available in relation to the different chemicals used in the metal industry, and their prevention potential has frequently been evaluated as medium to high. However, specific support for the assessment of alternatives seems useful at SME level.
14. Manufacture of electrical equipment: printed circuit boards (PCBs)	***NACE 30, 31 and 32***
• Highly significant waste streams, including spent bath solutions and etchants, arise from electroplating in PCB manufacture. • Other significant wastes involve solvents and chemicals for cleaning and photoprocessing.	• The electronics industry is a high-tech industry where rapid changes take place. Therefore, there are frequent instances of waste minimisation through material input and technological change. • Good prevention opportunities are anticipated for further recovery of spent etchants and plating solutions. • Waste prevention methods for the further manufacture of electrical equipment are largely covered by metal and plastic products manufacture.

EurEco / Witteveen+Bos 1997

PART II

SECTOR REPORTS FOR SELECTED KEY INDUSTRIAL SECTORS

SECTION 1

PRODUCTION, PROCESSING AND PRESERVING OF MEAT AND MEAT PRODUCTS

SECTOR REPORT

Contents :

NACE sectors involved in the present sector report:

Retained for analysis:	15.11	Production and preserving of meat
	15.12	Production and preserving of poultry meat
	15.13	Production of meat and poultry meat products
Excluded from analysis:	--	

1.1 SECTOR CHARACTERISATION[1]

The animal slaughtering and meat processing industry includes all of the processing stages following animal rearing up to final market consumption. In particular, reference is made to the slaughtering, processing and storage of beef, pork, sheep meat, goat, and poultry. Also included is the intermediate processing of products, like the manufacturing of plasma and the melting of animal fats. The final products covered are cuts of meat; processed meat, included chilled and frozen meat; canned meat and deli meats, to which must be added pre-prepared foods.

Meat presents the biggest single item of expenditure with regard to the overall purchase of agri-foodstuffs (30% on average). In 1990, this figure was particularly high in France, Belgium and Denmark (35%), while the lowest figures are to be found in Greece, the Netherlands and the United Kingdom (25%). The biggest meat producers within the EU are, on average, France and Germany, thanks to their respective climatic conditions which are well-suited to stock farming. In terms of value added, France (24%), the United Kingdom (21%), Germany (15%), Ireland (11%) and Spain (10%) achieved the highest value added (1993).

The meat sector comprises a high number of large companies, as well as numerous small and medium-sized enterprises. The production structure is fragmented, even though Community regulations relating to new agricultural policies and the level of concentration achieved by large and modern distribution networks have given rise to a level of concentration in the meat sector that is among the highest of the entire agricultural and food sector.

Over the next few years, competitiveness between enterprises is expected to become more intense due to the substantial lack of opportunity to expand and to consolidate European exports to south-east Asian markets, which will be served to a greater degree by the USA and New Zealand as a result of the ratification of the GATT treaty. Other reasons are the increase in the level of concentration of large and modern distribution networks, the drop in beef, pork, sheep meat and goat consumption and the more stringent Community measures regarding the control of the production and distribution processes (that will particularly affect the cottage and small enterprises).

To face the changes under way, enterprises are increasing their degree of concentration on the Community market by an extensive process of acquisitions and are turning their attention to higher value-added products.

1.2 PROCESSES AND WASTES

The processes applied cannot be uniquely categorised in a totally unambiguous fashion. For the purpose of this study, the following steps have been distinguished :

- *Slaughtering (*receiving area, killing, hide/hair/feather removal, eviscerating / trimming)
- *Meat processing (*cutting / deboning, processing, packaging)
- *Utility processes* (cleansing)

Three types of plants can be distinguished, according the type of operation: (i) slaughterhouses or abattoirs that perform only the killing and dressing of animals, (ii) processing plants that process meat but perform no slaughtering, and (iii) integrated plants, that perform killing and dressing, as well as processing.
Plants can further vary between large and medium-sized industrial plants and small local slaughterhouses and butcher's shops. The processes are in general however similar.

---

1 Main source: European Commission, 1995

Annex A gives further details on the processes applied in the meat sector.

Table 1.2.1 lists the identified major waste streams, together with their process origin. The table includes a priority ranking, based on a sector-wide tentative evaluation of the amount and the hazardous character of the waste streams.

Table 1.2.1: Major waste streams of the meat sector

Process origin	Waste streams	Priority rank	Description and code according to EWC[2]	
Slaugthering	Waste water	+	sludges from washing and cleaning sludges from on-site effluent treatment	02 02 01 02 02 04
	Manure	o	materials unsuitable for consumption or processing	02 02 03
	Blood	o	wastes not otherwise specified	02 02 99
	Offal	o	animal tissue waste	02 02 02
Meat processing	Waste water	+	sludges from washing and cleaning sludges from on-site effluent treatment	02 02 01 02 02 04
	Offal	o	animal tissue waste	02 02 02
	Packaging waste	o	wastes not otherwise specified	02 02 99
Cleansing	Cleansing waste water	+	sludges from washing and cleaning sludges from on-site effluent treatment	02 02 01 02 02 04

Priority rank: + : high significance, o : medium significance, - : low significance — EurEco/Witteveen+Bos 1997

Several by-products and waste streams are generated in the meat sector. The distinction between by-product and waste is not always possible. Offal is, for example, in general valorised in inedible or edible rendering plants, but can also be disposed of as solid waste.

The major waste stream is the waste water stream, in which all product loss, by-product loss and wastes that have not been segregated, end up. The waste water contains in general scraps of fat and tissue, animal oils, animal greases, residual hair and feathers, blood, dirt as well as cleansing and disinfecting agents.

Further details on wastes are provided in annex A.

The meat industry is involved in other environmental issues than waste. The main problems are energy use, water use, CO_2 production and the discharge of fumes into the atmosphere.

2 Waste water treatment generates in general waste water treatment sludges. The streams 'waste water' and 'cleansing waste water' have therefore been coupled to the EWC codes that concern waste water sludges (codes 020201 and 020204).

1.3 WASTE PREVENTION

This section discusses waste prevention options identified in literature. The major waste streams along with prevention options are summarised in table 1.3.1, following the division into processes and waste streams as made in the preceding chapter. The selected options are described in detail in Annex B.

Table 1.3.1: Identified waste prevention options for the meat sector

Process	Waste streams	Priority rank	Waste prevention method	Group	Potential
Slaugthering	Waste water	+	1-1 Waste segregation (GOP / RU)	1	+
	Manure	o	1-2 Good housekeeping in the receiving area	1	-
	Blood	o	1-3 Efficient blood handling and recovery (GOP)	1	o
	Offal	o	1-4 Minimisation of waste water arising during eviscerating (GOP)	1	o
Meat processing	Waste water	+	1-1 Waste segregation (GOP / RU)	1	+
	Offal	o	1-5 Good housekeeping during cutting and cooking	1	o
	Packaging waste	o	1-6 Good housekeeping in packaging (GOP)	1	-
Cleansing	Cleansing waste water	+	1-7 Optimisation of cleanup methods (GOP)	1	+

+ = high, o : medium, - : low, .. = insufficient data EurEco/Witteveen+Bos 1997

The identified waste prevention options are largely oriented towards a reduction of the waste load passed on to waste water treatment. This offers the advantages of (i) a greater recovery of organic by-products which can be processed to provide an economic return and (ii) reduced required treatment capacity for on-site treatment or reduced sewer surcharges for off-site treatment.

Potentials have been evaluated as high for the options related to waste water segregation and cleanup optimisation, two major options in relation to waste minimisation in the meat sector. Other options are evaluated between moderate and low. All identified options are considered as good operating practice (GOP) and do not necessitate excessive costs.

1.4 EVALUATION

The meat sector has a traditional focus on product recovery and by-product processing. Waste audit reports (e.g. IMd 1994) and waste minimisation publications (Allard 1995, Hrudey 1984, Stimular 1994) indicate however that there is still room for improvement. The identified options are mainly good housekeeping options oriented towards a reduction of the waste load sent to the sewer.

1.5 BIBLIOGRAPHIC REFERENCES

Abwassertechnischen Vereinigung (1985), "Lehr- und Handbuch der Abwassertechnik, Band V: Organisch verschmutzte Abwässer der Lebensmittelindustrie", Ernst & Sohn Verlag, Berlin, 1985.

Allard P.-Y. (1995), "Panorama de la lutte contre la pollution dans les abattoirs", in UNEP IE (1995), "Industry and Environment", Volume 18 no, 1, Paris, March 1995, pp. 32-35.

Bundesministerium für Umwelt (1995), "Branchenkonzept Nahrungs- und Genussmittelindustrie, Abfälle und Stoffströme", in cooperation with the 'Fachverbandes der Nahrungs- und Genussmittelindustrie Österreichts', Wien, 173 p

European Commission (1995), "Panorama of EC Industry 95/96 - an extensive review of the situation and outlook of the manufacturing and service industries in the EU", Bruxelles-Luxembourg, Office for Off, Pub. of the EC, 1995

Flair-flow Europe (1991-1996), selected project summaries of Flair-flow projects of the EU AAIR and VALUE programmes (F-FE 141/94 "Cleanability of food processing equipment", F-FE 170/95 "Production systems and meat consumption in France and Spain", F-FE 187/95 "European forum on meat research"), Dublin.

Geudens P. (1994), "Afvalwaterzuivering en slibafzet door de voedings en genotmiddelenindustrie, 1992", CBS, in: Kwartaalbericht Milieu nr. 94/4, p. 17 -23..

Hrudey S. (1984), "The management of waste water from the meat and poultry products industry", in Barnes D., Forster C., Hrudey S. (ed.) (1984), "Surveys in Industrial Wastewater Treatment, Vol. I Food and allied industries", Pitman Publishing Ltd, London, p. 128-208.

IMd (1994), "Preventie van afval en emissies in de vleesindustrie", Barneveld (NL), February 1994, 23 p.

Ministry of Environment and Energy (1995), Project summary "Cleaner technology in bacon factories and cattle slaugtherhouses", in "Cleaner Technology Projects in Denmark 1987-1992 (English Summaries)", Working report nr. 59, p. 12 (project nr. 116), Copenhagen, 1995.

RIVM (1985), "Vogelvluchtverkenning voedings- en genotmiddelenindustrie", rapportnr. 841221001, Bilhoven (NL), March 1985.

Stimular (1994), "Minder afval in vleeswarenproductiebedrijven kan !", preventie-factsheet, Rotterdam (NL), September 1994, 6 p.

SECTION 1

PRODUCTION, PROCESSING AND PRESERVING OF MEAT AND MEAT PRODUCTS

ANNEX A

PROCESSES AND WASTES DESCRIPTION

Contents :

A.1 OVERVIEW OF PROCESSES

Product lines vary according to the animals involved. The production of beef and pork take a central position within the meat sector with 69% of the total usable production. They are produced in a fairly similar slaughtering process. Poultry follows with 20% and has some specific process steps. Sheep and goats take only 3% of the total usable production, other meat 5%. The last 6% is offal, i.e. the less valuable edible parts of a carcass, especially the entrails and internal organs.

The processes applied cannot be uniquely categorised in a totally unambiguous fashion. Focusing on beef and pork processes for the purpose of the study (and on some specific bird processes), the following steps have been distinguished:

Slaughtering
- Receiving area
- Killing
- Hide removal / hog dehairing / defeathering
- Eviscerating / trimming

Meat processing
- Cutting / deboning
- Processing
- Packaging

Utility processes
- Cleansing

Three types of plants can be distinguished in the meat industry, according the type of operation: (i) slaughterhouses or abattoirs that perform only the killing and dressing of animals, (ii) processing plants that process meat but perform no slaughtering, and (iii) integrated plants, that perform killing and dressing, as well as processing. Plants can further vary between large and medium-sized industrial plants and small local slaughterhouses and butcher's shops. The processes are in general however similar.

A description of the above mentioned process steps and of their wastes is included hereafter. Because of their specific character in relation to the scope of the study, by-product processing methods (e.g. the melting of animal fats, inedible and edible rendering) have been not been studied in detail here. A list of processes applied, but not studied, for reason of their minor relevance in terms of waste generation, or their being too specific, is included at the end of the present annexe (A.5).

A.2 SLAUGHTERING

* Process description

The following process steps are applied in slaughtering:

- *Receiving area*
  Animals are held in storage areas for a few hours prior to slaughter. They are generally watered, but not fed unless holding exceeds one day.

- *Killing*
  Animals are driven from the receiving area to the slaughtering area where they are first stunned, then suspended from an overhead rail by their (hind) legs, and finally stuck and bled over a collecting trough.

- *Hide removal / hog dehairing / defeathering*
  Cattle, and in some cases hogs, are skinned after bleeding. In larger plants, this is generally performed mechanically. The largest source of waste from this operation is from blood and tissue which falls on the floor.

  Hogs are in general scalded with water at 45 to 65 °C to loosen their hair. After scalding, the hogs are mechanically dehaired by abrasion. Hair is carried away by fluming and is recovered by screening the spent flume water.

  Birds are also scalded prior to defeathering. After scalding, feathers are mechanically abraded from the birds usually by rotating rubber fingers. Removed feathers drop to underlying troughs which flume the feathers to screening devices for recovery.

- *Eviscerating / trimming*
  Following hide, hair or feather removal, carcasses are beheaded and cut open and the viscera are pulled out for inspection. Approved carcasses are eviscerated and trimmed prior to subsequent washing and cooling stages. Carcass trimmings and heads become part of the waste or offal which is collected for disposal or inedible rendering. Viscera are sorted to recover organs such as heart and liver. The remaining inedible viscera are added to offal. Blood and smaller scraps of fat and other tissue will reach the floor during this operation.

* **Waste description**

Several by-products and waste streams are generated in the slaughtering process. The distinction between by-product and waste is not always possible. Feathers for instance can be recovered and disposed of as solid waste or can be cooked and used as livestock feeding for young birds.

The main *by-products* are:

- blood
- hides
- offal

Examples of streams that are in general considered as *waste* are:

- manure (includes also the contents of the paunch and intestines)
- waste water
- hair
- feathers

All product loss, by-product loss and wastes that have not been separated, end up in the waste water stream. The waste water contains for example scraps of fat and tissue, oils, grease, residual hair, feathers, blood and dirt.

Different sludge types arise due to waste water treatment. Sludges with coarse solids arise at the screens, sludges with settleable solids and fat, oils and greases at the gravity clarification or flotation units and sludges from biological waste water treatment at the biological waste water treatment plant (if installed).

A.3 MEAT PROCESSING

* **Process description**

The following process steps are applied in meat processing:

- *Cutting / deboning*
  A meat processing unit can receive beef and pork in the form of whole graded carcasses, or in retail cuts. The received carcasses and cuts will be subject to cutting and deboning operations, which generate trimmings, blood, bones and bone dust. The cutting and deboning operations need however not contribute significantly to plant raw waste load, depending on the quality of the cleaning operations.

- *Processing*
  Meat processing covers a variety of operations including curing, cooking, pickling, sausage-making and smoking. These generate raw waste load from blood, tissue and fats which reach the sewer during clean-up.

- *Packaging*
  Processed meat is in general weighed, graded and packaged. Many products are cooled or frozen for shipment to retail market. Packaging materials are metal and plastic.

* **Waste description**

Wastes generated in meat processing are :

- Waste water
- Offal
- Packaging waste

A.4 UTILITIES: CLEANSING

* **Process description**

Because of the inspection requirements associated with the production of food, cleansing is an important activity in meat industry. A wide range of cleanup practices are employed, including hand cleanup or mechanical cleanup. Hot water and steam are largely applied for cleanup and disinfecting. Caustic and/or acid are normally used as cleaning agents.

* **Waste description**

Cleansing can significantly add to the total raw waste load if processing operations are sloppy and compensatory cleanup is achieved by flushing everything to the sewer.

The cleansing water, which becomes waste water, contains many different pollutants, e.g. scraps of fat and tissue, oils, greases, residual hair, feathers, blood and dirt. There will in addition be caustic, acid, detergent and disinfectant in the cleansing water.

A.5 OTHER PROCESSES

* Process description

Processes that are not characteristic, too specific or of minor importance in terms of waste generation, have not been studied in detail. Examples of these processes are :

- heating
- cooling and freezing.
- melting of animal fats
- inedible rendering
- edible rendering
- intestine handling
- hide processing[1]
- waste water treatment

1 Hide processing is dealt with in the sector report on the leather industry (section 5).

SECTION 1

PRODUCTION, PROCESSING AND PRESERVING OF MEAT AND MEAT PRODUCTS

ANNEX B

PREVENTION OPTIONS

Contents :

Sector	Production, processing and preserving of meat and meat products (NACE 151)
Process	Slaughtering and meat processing
Waste stream	Waste water

Prevention option	**Waste segregation**
Option No	1-1
Type	GOP/RU
Group	1
Description	It is desirable to segregate major waste streams carrying different classes of pollutant in order that individual smaller waste flows can receive individual treatment. The following waste water streams of the slaughter and meat processing area are suitable for segregation[1]: • *manure sewer.* Receiving area waste water is generally contaminated with manure solids and dirt which are amenable to removal by screening and sedimentation. These materials are incompatible with grease which could otherwise be recovered for high quality tallow production; • *blood drain and tank.* Low-water-content blood is a potentially valuable by-product. However, separate collection of blood is necessary to obtain an economic return on this material. Blood is also incompatible with recoverable grease because it will discolour the product tallow; • *grease sewer.* Waste waters from areas relatively low in blood but high in fat, oils and grease, such as cutting, rendering, lard storage and meat processing, should be segregated for quality grease recovery by gravity and/or dissolved air flotation; • *low grease sewer.* Waste waters which are relatively low in fat, oils and grease (FOG), such as those from the slaughter area, hog and bird scalding, dehairing, defeathering, evisceration and hide washing, do not necessarily require extensive FOG removal. The solids removal processes for this stream will then not be hampered by grease fouling. • *sanitary wastes.* Health requirements normally preclude the mixing of human sanitary wastes with process waste waters prior to by-product recovery. Consequently, a segregated sewer system is necessary. • *clean water sewer.* Water streams such as cooling-waters and steam condensates have normally been exposed to negligible contamination and are, therefore, amenable to reuse.
Remarks	--
Economics	A detailed cost breakdown of these measures can not be given. The measures are considered as good operating practice for modern slaughterhouses and meat processing plants and do not necessitate excessive costs. The costs have to be balanced with reduced waste water charges and extra revenues for increased by-product generation.
Potential	The prevention potential is evaluated as *high* as waste water segregation is the basic measure for waste minimisation in the meat sector. Although many plants will have implemented waste segregation measures, literature[2] indicates that there are still possibilities in many plants.

1 Hrudey 1984.
2 e.g. Allard 1995.

Sector	Production, processing and preserving of meat and meat products (NACE 151)
Process	Slaughtering
Waste stream	Manure

Prevention option	**Good housekeeping in the receiving area**
Option No	1-2
Type	GOP
Group	1
Description	Manure arising at the receiving area is a significant source of waste. The following measures can be taken to minimise waste and optimise re-use [1]: • *shorten the stay time in the receiving area*: since waste load generation from the receiving area is a direct function of the length of time for which animals are held prior to slaughter, the load can be reduced by an optimal organisation of deliveries to co-ordinate with processing capacity. • *dry removal of manure*: dry removal instead of wet removal avoids an unnecessary waste water pollution load. The receiving area should be covered to prevent rain water to carry along the manure. Manure can be stocked and re-used in agriculture. • *segregated waste water treatment* : receiving area waste water is generally contaminated with manure solids and dirt which are amenable to removal by screening and sedimentation (see also option 01-1).
Remarks	--
Economics	A detailed cost breakdown of these measures can not be given. The measures are considered as good operating practice for modern slaughterhouses and do not necessitate excessive costs. The costs have to be balanced with reduced waste water charges and extra revenues for increased by-product generation.
Potential	The prevention potential is evaluated as *low* because the measures have only limited waste prevention possibilities. They rather higher the re-use potential of manure and of offal / waste water sludge.

1 Allard 1995, Hrudey 1984.

Sector	Production, processing and preserving of meat and meat products (NACE 151)
Process	Slaughtering/killing
Waste stream	Blood

Prevention option	**Efficient blood handling and recovery**
Option No	1-3
Type	TC
Group	1/2
Description	Inefficient blood handling and recovery is a large factor in determining the raw waste load for a slaughterhouse. It should be avoided that blood, as valuable resource and major pollutant (high BOD), is sent to the sewer. Several blood collection technologies can be applied[1]: • open bleeding trough (a relatively crude method for blood recovery) • using a flat sticking knife equipped with a collection vessel at the base. Blood is drained into the vessel and removed by vacuum. • forcing of a perforated tube attached to the sticking knife assembly into the incision with suction being applied to remove blood. The efficiency of the methods can be enhanced by the application of anticoagulant to the blood being collected. A segregated blood drain and collection tank should be provided for the concentrated blood. High concentrations of blood recoverable from the process line immediately following the slaughter area can so be directed to the blood collection drain prior to final wet wash down. Bird killing by stunning prior to throat-cutting will prevent unnecessary splattering of blood in the slaughter area. Splattered blood is difficult to recover.
Remarks	--
Economics	A detailed cost breakdown of these measures can not be given. The measures are considered as good operating practice for modern slaughterhouses and do not necessitate excessive costs. The costs have to be balanced with reduced waste water charges and extra revenues for increased by-product generation.
Potential	The prevention potential is evaluated as *moderate* because, on the one hand, blood recovery can significantly reduce the waste water load of a slaughterhouse, but, on the other hand, it is anticipated that many plants will already have implemented similar measures.

1 Allard 1995, Hrudey 1984.

Sector	Production, processing and preserving of meat and meat products (NACE 151)
Process	Slaughtering/eviscerating
Waste stream	Offal

Prevention option	**Minimisation of waste water arising during eviscerating**
Option No	1-4
Type	GOP
Group	1
Description	Water used in the eviscerating area will carry along blood and particles that could otherwise be sent to rendering. The following options concern the minimisation of waste water arising during eviscerating [1]: • *dry transfer of stercoraceous matter of the paunch and intestines*: the contents of the paunch and intestines can be transferred in a dry process, e.g. with compressed air, instead of by means of process water. This waste stream can so be treated separately. • *dry transfer of viscera in the poultry sector*: the viscera of the birds are traditionally transported by process water to the screen where they are recovered and sent to rendering. A central vacuum system has been installed in some enterprises in order to collect the viscera. This avoids the reduction of the amount of organic feed stock that can be sent to rendering. • *eliminate washing of viscera prior to inedible rendering.* Washing prior to inedible rendering is a non-productive step which only reduces the amount of organic feed stock to the inedible rendering process while increasing the overall plant raw waste load. Elimination of this step is therefore desirable for waste load reduction.
Remarks	--
Economics	A detailed cost breakdown of these measures can not be given. The measures are considered as good operating practice for modern slaughterhouses and do not necessitate excessive costs. The costs have to be balanced with reduced waste water charges and extra revenues for increased by-product generation.
Potential	The prevention potential is evaluated as *moderate* because, on the one hand, water use minimisation during eviscerating can significantly reduce the waste water load of a slaughterhouse, but, on the other hand, it is anticipated that many plants already apply similar measures.

1 Allard 1995, Hrudey 1984.

Sector	Production, processing and preserving of meat and meat products (NACE 151)
Process	Meat processing / cutting and cooking
Waste stream	Offal

Prevention option	**Good housekeeping during cutting and cooking** [1]
Option No	1-5
Type	GOP
Group	1
Description	Good housekeeping in the *cutting* process can reduce product loss. Examples of measures that can be implemented are: • *reduce product loss at cutting tables*: a correct table height and a raised table border can reduce losses. • *install splatter flaps on the cutter and grinder*: this will reduce product loss, waste arising and the need for cleanup. • *increase slowly the cutting speed*: this will reduce product loss through splatters. Examples of good housekeeping measures in the *cooking* process are: • *remove fat from the cooking water*: continuous renewing of the cooking water will spill energy, fat and meat juices. Better is to remove the fat by removing little quantities of the cooking water via an overflow. • *remove broken products from the kettle*: this results in a lower pollution of the cooking water and thus increases its life-cycle. • *use heat resistant packaging:* products can then be cooked without losing juice and without polluting the cooking water. • *do not over-charge the kettle*: this leads to a higher level of product contact, resulting in broken products, product loss and extra polluted cooking water.
Remarks	--
Economics	A detailed cost breakdown of these measures can not be given. The measures are considered as good operating practice for modern meat processing plants and do not necessitate excessive costs. The costs have to be balanced with reduced waste water charges and reduced product loss.
Potential	The prevention potential is evaluated as *moderate* because, on the one hand, good housekeeping during cutting and cooking can significantly reduce the waste load of a meat processing plant, but, on the other hand, it is anticipated that many plants will already have implemented similar measures.

1 Stimular 1994.

Sector	Production, processing and preserving of meat and meat products (NACE 151)
Process	Meat processing / packaging
Waste stream	Packaging waste

Prevention option	**Good housekeeping in packaging**
Option No	1-6
Type	GOP
Group	1
Description	Examples of options that can reduce packaging waste in the meat processing plant [1]: • *improved production planning* : packaging machines have to be adjusted when the product changes. This leads to extra packaging wastes (e.g. foils). Product changes can be minimised by good production planning. • *frequent check on the adjustment of the packaging machines*: this avoids packaging waste and product loss due to product rejected for packaging reasons. • *preventive maintenance*: this minimises production breakdown and related packaging waste and product loss. • *direct intervention in case of machine breakdown:* this can significantly reduce the quantity of packaging waste. Machine breakdown can be pointed out by a sound signal. • *reduce packaging*: packaging can in some cases be avoided or can be returned after use. Both the meat processing facility and its client can benefit from reduced packaging measures (e.g. by reduced material purchase costs, reduced waste charges). Reduced packaging will however not always be possible. Possibilities should be considered in close co-operation with (major) clients.
Remarks	--
Economics	A detailed cost breakdown of these measures can not be given. The measures are considered as good operating practice for modern meat processing plants and do not necessitate excessive costs. The costs have to be balanced with reduced waste charges and reduced packaging material purchase costs.
Potential	The prevention potential is evaluated as *low* because it is anticipated that many plants will already have evaluated and used the possibilities of the above mentioned measures.

1 Stimular 1994.

Sector	Production, processing and preserving of meat and meat products (NACE 151)
Process	Cleansing
Waste stream	Cleansing waste water

Prevention option	**Optimisation of cleanup methods**
Option No	1-7

Type: GOP

Group: 1

Description

Cleanup operations can play a pivotal role in determining plant raw waste load. The following good housekeeping options can be applied[1]:

- *extensive dry cleanup.* Remove scrap meat from machines first with scrapers or vacuum cleaners. Use squeegees for floors before cleanup with water. This prevents that scrap meat and meat juice is sent to the sewer.
- *direct cleansing.* Remove waste directly after its arising. This prevents drying of the waste, extra cleaning work and the use of aggressive cleansing agents.
- *less cleansing.* Consider for the different process operations the range between 'too much' and 'not enough' cleaning and lay this down in the cleaning programme and procedures. Some areas do for example not necessitate daily floor cleaning (e.g. the packaging area).
- *restrict the number of cleansing agents.* A lower number of agents leads in practice to a reduction in use. The number of agents could for example be restricted to four (office and sanitary cleanup excluded): (i) a moderate basic foam agent, (ii) a strong basic agent, (iii) an acid agent, and (iv) a disinfecting agent.
- *do not use integrated agents.* Integrated agents for cleansing and disinfecting are in general less effective. A higher quantity of agent is needed and there is an increasing risk that the bacteria develop a resistance against the agents.
- *install a dosage system.* A semi-automatic dosage system can reduce the use of cleansing agent significantly. Hand dosage leads in general to a 40% overdose.
- *use water of maximal 60 °C.* The water has then a temperature of 50 °C when it is in contact with the surface to be treated. This is the optimal temperature in terms of the solubility of proteins and greases and of effectiveness of the cleansing agent.
- *take account of the cleaning aspect in the purchase decision of a new machine.* Examples of aspects to be considered: avoidance of the use of blind angles, narrow openings and rubber flaps, use of smooth instead of rough surfaces.

Remarks: --

Economics

A detailed cost breakdown of these measures can not be given. The measures are considered as good operating practice for modern slaughterhouses and meat processing plants and do not necessitate excessive costs. The costs have to be balanced with reduced waste water charges and reduced costs for the purchase of cleansing agents.

Potential

The prevention potential is evaluated as *high* as cleansing is a basic source of waste in the meat sector and literature[2] indicates that there are many possibilities to improve cleansing.

1 Stimular 1994.
2 e.g. Stimular 1994, Hrudey 1884, Allard 1995.

SECTION 2

MANUFACTURE OF DAIRY PRODUCTS

SECTOR REPORT

Contents :

NACE sectors involved in the present sector report:

Retained for analysis:	15.51	Operation of dairies and cheese making
Excluded from analysis:	15.52	Manufacture of ice cream

2.1 SECTOR CHARACTERISATION[1]

The dairy sector includes activities of milk thermo treatment for alimentary use - e.g. pasteurised and ultra heat treated (UHT) milk - and the processing of milk into by-products. The latter are used as both intermediate processed products (casein) and end products like cream, butter, yoghurt and cheeses. The dairy industry is among the major agri-foodstuff sectors in all European economies and represents about 13% of the overall food budget on average. Although consumer patterns within the EU differ significantly, the most consumed dairy products are milk, followed by cheese, yoghurt and butter.

The production of milk by volume has dropped following a Community policy aimed at the overall restriction of production surpluses in Europe. EU consumption of milk and cream is stable, that of butter continues to drop and that of yoghurt and cheese is rising. EU countries are fully self-sufficient at the exception of Greece, Italy, Spain and the UK. Enterprises are strengthening their respective positions on domestic markets through a process of take-overs, particularly on the German market, in order to gain access to East European countries. Such a process is continuing despite the high degree of concentration existing in most sectors already. Employment shrunk from 281 000 in 1984 to 246 000 in 1993. Production and consumption had a steady growth at current prices in the 1984-1993 period. Exports and the trade balance show a more uncertain pattern, with a 20% drop in exports and an almost 26% drop in the trade balance in 1986. The EU remained the world's largest producer and exporter of dairy products between 1984-1993.

This report focuses on dairies and cheese making factories. The manufacture of ice cream made from milk (NACE 15.52) is excluded from this report, because it is only of limited economic importance in relation to dairy industry.

2.2 PROCESSES AND WASTES

The dairy sector is distinguished by the presence of companies of different size, starting with the small cottage industries producing cheese only, to the large multinationals with high production outputs and fully-automated production cycles.

Production levels vary significantly depending on the type of company. Production steps are nevertheless in many cases similar and depend on the type of product. The following processes have a relevant waste arising :

- production of fluid milk and milk products
- cleansing
- cheese making
- production of milk powder
- packaging

Annex A gives further details on these processes.

Table 2.2.1 lists the identified waste streams, together with their process origin. The table includes a priority ranking, based on a sector-wide tentative evaluation of the amount and the hazardous character of the waste streams.

1 Main source: European Commission, 1995

Table 2.2.1: Waste streams of the dairy sector				
Process origin	**Waste streams**	**Priority rank**	**Description and code according to EWC**	
Production of fluid milk and milk products	Product spills and losses	+	Materials unsuitable for consumption or processing	02 05 01
Cleansing operations	Milk / water and product / water mixtures	+	Materials unsuitable for consumption or processing	02 05 01
	Waste water sludges	+	Sludges from on-site effluent treatment	02 05 02
Cheese making	Whey	o	Materials unsuitable for consumption or processing	02 05 01
	Salt brine	o	Materials unsuitable for consumption or processing	02 05 01
Milk powder production	Powder losses	-	Materials unsuitable for consumption or processing	02 05 01
Packaging	Packaging wastes	-	Wastes not otherwise specified	02 05 99

Priority rank: + : high significance, o : medium significance, - : low significance   EurEco/Witteveen+Bos 1997

The major wastes streams of the dairy sector are related to product losses and cleansing operations, resulting in waste water streams and sludges. Specific waste streams occur in cheese making (whey, salt brine) and milk powder production (milk powder loss). Wastes streams of low significance, not included in the table, are laboratory wastes, oily wastes and office wastes. Further details on wastes are provided in annex A.

The dairy sector is involved in other environmental issues than waste. Major issues are water pollution (by discharge of treated or untreated waste waters containing organic matter and cleansing agents); use of water resources; energy use; air emissions (SO_2, NO_x, CO_2, particles); CFC emissions (from cooling installations); noise production; risk of industrial installations (cooling with NH_3).

2.3 WASTE PREVENTION

This section discusses waste prevention options identified in literature[2]. The major waste streams along with prevention options are summarised in table 2.3.1, following the division into processes and waste streams as made in the preceding chapter. The options are described in Annex B.

2 Major sources for the listed prevention options were published results of waste minimisation audits (e.g. Hunter 1988, Berkel 1991, IMd 1994). Other sources were general reports on environmental aspects and waste arising of dairy industry, realised by national environment ministries in co-operation with industry (Lijzen 1993, Bundesministerium 1995).

Table 2.3.1: Waste prevention options for dairy products					
Waste streams	**Priority rank**	**Waste prevention method**		**Group**	**Potential**
Product spills and losses (in general)	+	2-1	Central milk solids recovery system (RU / RC)	1	o
		2-2	UHT recovery systems (RU / RC)	1	o
		2-3	Fluid products filler recovery (RU / RC)	1	o
		2-4	Recovery of remnants of production tanks (GOP)	1	o
Milk / water and product / water mixtures (from cleansing)	+	2-5	Pasteurised rinse recovery (RU / RC)	1	o
		2-6	Raw rinse recovery (RU / RC)	1	o
		2-7	No rinsing between certain batches (GOP)	1	o
		2-8	Optimisation of cleansing (GOP)	1	o
Whey	o	2-9	Reclamation of valuable whey resources (RC)	1 / 3	-
Salt brine	o	2-10	Re-use of the salt brine surplus (RU)	3	-
Powder losses	-	2-11	Recovery of powder lost during drying (TC / RU)	2 / 3	-
Packaging wastes	-	2-12	Reduction of materials used for packaging (TC)	1 / 2	-

+ = high, o : medium, - : low

EurEco/Witteveen+Bos 1997

Product recovery is an issue of dairy industry since the early seventies. It has mainly been addressed at individual company level for competitiveness reasons. The prevention options identified for product recovery (options 2-1 to 2-8) address losses during production and cleansing, and are typical process-integrated prevention options. These options have all been classified in group 1, i.e. technically proven and established methods which are in general use at modern plants and which do not require excessive costs. The waste prevention potential for the product recovery options is assessed as moderate because, on the one hand, it is anticipated that many companies have already implemented basic recovery options, but, on the other hand, that there are still possibilities for further waste prevention related to recovery of products (as indicated in the available waste minimisation audits).

Options 2-9 to 2-12 are related to specific waste streams. These waste streams are significant but less important than losses through production and cleansing. For this reason and because of technical / economic / organisational difficulties occuring, these options are considered to have low prevention potentials.

2.4 EVALUATION

The dairy industry has extensive experience with the issue of product recovery, within cost reduction and production rationalisation programmes. Pollution of dairy industry has traditionally been addressed within water quality control. The theme of waste minimisation is largely considered as a matter of competitiveness of individual dairy companies, not as a matter of public authorities.

Despite the company programmes that were run, waste minimisation audits report that there are further possibilities for waste minimisation through product recovery.

2.5 BIBLIOGRAPHIC REFERENCES

Berkel van C.W.M., et al. (ed.) (1991), "Business Examples with Waste Prevention: Ten Case Studies from the Dutch PRISMA-project", Amsterdam, Ministry of Economic Affairs, 1991

Bruinsma F. (1993), "Landelijk onderzoek milieusituatie zuivelindustrie", Inspectie Milieuhygiène, report no. 1993/82, Zoetermeer, 72p.

Bundesministerium für Umwelt (1995), "Branchenkonzept Nahrungs- und Genussmittelindustrie, Abfälle und Stoffströme", Wien, report produced in cooperation with the Austrian Food Industry Association ('Fachverbandes der Nahrungs- und Genußmittelindustrie Österreichs), ENTEC/AFC, 173p

Coolen S. (1995), "Milieuvriendelijk reinigen en desinfecteren in de zuivelindustrie", report produced by the Chemiewinkel / University of Amsterdam for Stichting Natuur en Milieu, Amsterdam, 25p.

European Commission (1995), "Panorama of EC Industry 95/96 - an extensive review of the situation and outlook of the manufacturing and service industries in the EU", Bruxelles-Luxembourg, Office for Off, Pub. of the EC, 1995

European Commission (1996), Cordis data base, Luxembourg, June 1996.

Hunter Jersey Farms (1988), "Reduction in waste load from a fluid milk plant", published within the Pollution prevention program of the North Carolina Department of Natural Resources & Community Development, Raleigh NC, USA, June 1988, 62p.

IMd Industriële Milieudiensten bv (1994), "Preventie van afval en emissies in zuivel-, ijs- en salade-industrie", report produced for the Province of Overijssel, Barneveld, July 1994, 40p.

Jong A.D. de, et al. (1989), "Melk en milieuzorg: de rol van milieuzorgsytemen in het verminderen van de milieubelasting door de zuivelsector", studierapport UBM 1989/3, Amsterdam, June 1993

Kessler H.G. (1981), "Food engineering and Diary technology", Munich, Institute for Diary Science and Food Process Engineering, 1981

Lijzen J. (1993), "Verkenning van technologische oplossingen voor milieuproblemen in de zuivelindustrie", RIVM, report no. 736101018, Bilthoven, March 1993, 55p.

Marshall K.R., Harper W.J. (1984), "The treatment of wastes from the dairy industry", in Barnes D., Forster C.F., Hrudey S.E. (ed.) (1984), "Surveys in Industrial Wastewater Treatment - volume 1 Food and Allied Industries", Pitman Publishing ltd, London, p. 296-370.

Middlebrooks J. (1979), "Industrial pollution control volume I : Agro-industries", New York, Chicester, Brisbane, Toronto, John Wiley & Sons, 1979.

Ministry of Environment and Energy (1995), Project summary "Cleaner technology in dairying", in "Cleaner technology projects in Denmark 1987-1992 (English summaries)", Working report nr. 59, p. 32 (projectnr. 167), Copenhagen, 1995.

RIVM (1985), "Vogelvluchtverkenning voedings- en genotmiddelenindustrie", RIVM, report no. 841221001, Bilthoven, March 1985, 89p.

Ros J.P.M., Loos B. (1993), "Procesbeschrijvingen industrie: Zuivelindustrie", Bilthoven, RIVM, 17 p.

The European Dairy Association has been informed of the study and has been invited to comment the draft sector report. We did not receive specific comments within the period made available for comments (November - December 1996).

SECTION 2

MANUFACTURE OF DAIRY PRODUCTS

ANNEX A

PROCESSES AND WASTES DESCRIPTION

Contents :

A.1 OVERVIEW

Within the wide variety of products of the dairy sector, basically five different groups of processes can be distinguished, i.e. :

- production of fluid milk and milk products
- cheese making
- production of milk powder
- butter making
- production of concentrated milk

Standardisation of raw milk, heat treatment (pasteurisation, sterilisation, condensation, spray-drying), cooling, cleansing and packaging are utility processes applied all through the dairy industry.

Process descriptions are presented hereafter for those processes that have a relevant waste arising. The following processes are concerned :

- production of fluid milk and milk products (§A.2)
- cleansing (§A.3)
- cheese making (§A.4)
- production of milk powder (§A.5)
- packaging (§A.6)

A.2 PRODUCTION OF FLUID MILK AND MILK PRODUCTS

* **Process description**

The delivery of the raw cow's milk is the starting point for milk production processes, followed by standardisation of the cow's milk, what means that some of the fat of the milk is removed in order to obtain the correct fat content in the end product. Two intermediate products result from this step, standardised milk and (raw) cream.

The process steps that follow depend on the end products :

- for *drinking milk* production, the standardised milk is made suitable for consumption by pasteurisation, sterilisation or UHT and homogenisation;

- *fresh milk products* as yoghurt and custard are manufactured after further treatment. For yoghurt a bacterial culture is added to the milk, while for custard production ingredients such as thickening agents and natural flavouring and colouring are added.

Important general processes are :

- *heating processes* (pasteurisation, sterilisation, drying, condensation etc.). Large dairy plants have generally their own heat production units because of the high energy demand of the plants.

- *cooling of raw materials and products*. Applied cooling media are CFCs, ammonia and water. Air cooling is also applied.

* **Waste description**

Product spills and losses occur in all production processes of dairy industry. For the Netherlands has been reported that 0,6% of the milk is lost as raw material[1]. Examples of causes are :

- Cleaning out product remaining in tank trucks, cans, piping, tanks, and other equipment (performed routinely after every processing cycle)

- Spillage product by leaks, overflow, freezing-on, boiling-over, equipment malfunction, or careless handling

- Processing losses, including:
  a) Sludge discharge from Cleaning-In-Place (CIP) clarifies
  b) Product wasted during UHT pasteurise start up, shutdown, and product changeover
  c) Evaporator entrainment
  d) Discharges from bottle and case washers
  e) Splashing and container breakage in automatic packaging equipment
  f) Product changeover in filling machines.

- Wastage of spoiled products, returned products, or by-products such as whey

Some product loss waste streams can be re-used in dairy production or in cattle feed production. In general they are however sent to the sewer. Waste waters contain consequently high loads of organic material, nitrogen and phosphorous. They are treated in municipal waste water treatment plants but on-site treatment also occurs.

Waste water sludge occurs if on-site effluent treatment is employed. In the Netherlands the sludge stream generated by the dairy industry is estimated at 5 000 tonnes dry material per annum (1985)[2]. Depending on their content of heavy metals, that is generally low in dairy industry, these sludges are used as fertiliser in agriculture or treated in specific sludge treatment installations.

A.3 CLEANSING

* **Process description**

Milk products cling to the piping and machinery, and may lead to loss of product quality. The frequency of cleansing and disinfecting depends on the sort of product and the activity. Cleansing operations are particularly important in dairy industry because of the tendency of milk products to cling to surfaces, of the viscosity of the products and of the application of batch productions. Cleansing and disinfecting agents are based on substances such as sodium hydroxide, hydrochloric acid, hydrogen peroxide, chloride hydroxide and peracetic acid[3].

* **Waste description**

Cleansing operations generate waste waters, which contain significant amounts of organic matter as well as cleansing agents and disinfectants.

1 Jong, 1989
2 Ros, 1993
3 Bruinsma, 1993

A.4 CHEESE MAKING

* **Process description**

For cheese making the (standardised) milk is first coagulated into curd. Whey is extracted and the cheese is pressed into its form. Salting and ripening complete the cheese manufacturing process.

* **Waste description**

- *Whey*

  The liquid waste stream of whey contains valuable resources that are however difficult to recover and to process into commercial products as lactose. The whey can be concentrated and turned into reusable products as baby food, lactose and cattle food. Whey contains lactose but also salt, casein and fat.

- *Salt brine*

  Salt brine is used to remove water from the curd and to salt the cheese. Salt brine is recycled but surplus salt brine arises due to the water removed from the curd (a waste stream of 5 000 t/a dry solids in the Netherlands). This waste stream contains, apart from sodium chloride, also proteins and fat. Salt discharges pose problems to the water authorities.

A.5 PRODUCTION OF MILK POWDERS

* **Process description**

The fluid milk is first concentrated by evaporation, in one or several steps. Reversed osmosis is a promising, low energy-consuming alternative for evaporation. Spray-drying is a proven technique applied to produce milk powders from the concentrated milk. Fluid bed drying is another technique reported in literature.

These techniques are applied for the manufacture of skimmed and whole milk powders, as well as for the manufacture of whey powder for baby-food production.

* **Waste description**

During (spray-)dry processes, the heated air carries along some of the product. Cyclones and wash units reduce the losses. Other waste streams mainly occur due to cleansing.

A.6 PACKAGING

* **Process description**

Packaging is the last step of the production processes. Consumer packing materials are pure packs (cardboard packaging), plastic or glass packaging for fresh milk products, drinking milk and cream. Cheeses and butter are wrapped up in paper and plastic foils. Hard cheeses are covered by a plastic layer.

* **Waste description**

Losses occur during packaging. The resulting waste streams are relatively pure and have good properties to be recycled. These streams consist e.g. of paper, cardboard, pure packs, plastic containers and bottles, rejected and broken glass bottles.

SECTION 2

MANUFACTURE OF DAIRY PRODUCTS

ANNEX B

PREVENTION OPTIONS

Contents :

Sector	Manufacture of dairy products (NACE 15.5)
Process	Production of fluid milk and milk products
Waste stream	Product spills and losses

Prevention option	**Central milk solids recovery system**
Option No	2-1
Type	RU / RC
Group	1

Description

Recovery systems are installed in order to collect and recover milk solids from milk / water and product / water sludges. These systems are a central part of all waste reduction measures and lay emphasis upon collection of product losses and returning them into the production process, where possible. Only if this is not possible, re-use as cattle-food or discharge into the sewer is envisaged.

Recovery systems are integrated in the plant design and are basically a refrigerated tank with several inlets and one outlet. A pump and air valve on the outlet direct the material to either the milk tanker or farm tank for disposal or animal feeding.

Technological changes are part of the recovery system, but management action accompanied by recording of results and instruction of operators, is vital for an optimal recovery of milk solids.[1]

Remarks

The chief concerns with the reuse of reclaimed dairy solids are sanitation of the reclaimed products, the microbiological condition of the products, the wholesomeness or freedom from adulteration of the materials and compliance with applicable regulations. Other factors of concern may be colour (added chocolate or added flavour/colour compounds), the presence of fruit, nuts and candy, or fermentation flavours as in the case of buttermilk. Products as buttermilk can be reworked only into similar products, and should be bagged and kept separate. This complicates the system considerably and creates a potential for mishandling the product.

Typically, in dairy plants producing ice cream, chocolate ice cream is chosen to rework flavoured and coloured reclaimed solids. A major hindrance is the presence of overpowering flavour compounds such as mint or the presence of particulate. Fluid milk plants that only produce drinking milk and milk products as yoghurt and custard have restricted reuse potentials. Dairy solids which can be reused, must be sold to milk drying, condensing or butter plants or to dairy plants making ice cream.

Economics

Material costs for a basic recovery system with a 15 m^3 refrigerated tank system were estimated to be 23000 ECU. Installation of the tank, sanitary piping and electrical hook-up for the pump was estimated to be 11000 ECU. Total estimated initial cost was 34000 ECU. Net cost per year was estimated at 13000 ECU/a. Reduced costs and/or increased revenues have not been estimated because the recovery system only supports other waste reduction measures.

continued on the next page >

1 Hunter Jersey Farms, 1988.

Prevention option	**Central milk solids recovery system**
Option No	2-1
Potential	Exact information on the application of recovery systems in EU dairy industry is not available. Research in the US in the mid seventies[1] indicated that a fluid milk plant can have a product loss of 0,45% if recovery systems be applied and excellent recovery management be ensured. Literature indicates a product loss of 0,6% for the Netherlands[2]. The waste prevention potential for this option is assessed as *moderate* because, on the one hand, it is anticipated that many companies have already implemented such recovery options, but, on the other hand, the available waste minimisation audits indicate that there are still possibilities for further waste prevention related to recovery of products.

1 EPA 1974 (in Hunter Jersey Farms, 1988).

2 Jong, 1989

Sector	Manufacture of dairy products (NACE 15.5)
Process	Production of fluid milk and milk products
Waste stream	Product spills and losses

Prevention option	**UHT recovery systems**
Option No	2-2
Type	RU / RC
Group	I
Description	UHT treatment is responsible for a large part of product losses in fluid milk processing. Methods for the recovery of UHT start up, changeover and shutdown mixtures of product and water have consequently been proposed. Systems utilising automatic timing or meter-controlled volume measurement can be applied. • The *meter system* requires a meter for each system to measure the flow through the UHT and direct the selection of product-water mixes to the pasteurised recovery tank or sewer. Level controls are necessary and should be added to the balance tank. A water solenoid should be added to control the potable water supply with the meter. • The *automatic timing system* requires a balance tank level control, three relays, one sector switch and one switch for each system. Substantial labour hours would be necessary to reprogram the controller and install the parts. [1]
Remarks	--
Economics	Initial costs were estimated at 12000 ECU for both a metered and an automatic timing system in the case of a US fluid milk plant. Increased annual costs were estimated at 5000 ECU for the metered system, 3000 ECU/a for a timing system. Revenues were estimated at 53000 ECU/a in the case of re-use of milk solids in dairy production (at 2000 ECU/a if only use in cattle-food production were possible, e.g. because the plant does not produce ice cream). Reduced costs were estimated at 21000 ECU/a (for reduction of waste water treatment costs and the value of product loss prevention).
Potential	The waste prevention potential for this option is assessed as *moderate* because, on the one hand, it is anticipated that many companies have already implemented such recovery options, but, on the other hand, the available waste minimisation audits indicate that there are still possibilities for further waste prevention related to recovery of products.

1 Hunter Jersey Farms, 1988.

Sector	Manufacture of dairy products (NACE 15.5)
Process	Production of fluid milk and milk products
Waste stream	Product spills and losses

Prevention option	**Fluid products filler recovery**
Option No	2-3
Type	RU / RC
Group	1
Description	Filling is responsible for a significant part of product losses in fluid milk processing. Filler recovery systems have consequently been installed for foam, filler bowl dump and damaged or under-filled cartons. A system proposed for filler recovery is a vacuum collection system with two recovery tanks per filler. The foam tank recovers foam from the filler's foam recovery system and also collects product left in the bowl at the end of a product run. The other tank is used by the machine operator to dump damaged or improperly filled cartons. The recovered material is sent through the vacuum header assembly to the high solids recovery tank. The recovered material, having been collected in a sanitary fashion, is considered suitable for use as an ice cream ingredient. An alternative recovery means would be necessary for any product not suitable for recovery.[1]
Remarks	A negative aspect of the system is an additional 5 hr/day of labour needed to keep the system operating and especially to clean the collection units and the line. Another negative aspect is that the tanks need cleaning during the day, rendering them inoperative while the cleaning is in process.
Economics	Each filler needs the two tanks and the header necessary to connect the vacuum manifold. Material costs for each filler were estimated at 7000 ECU, including pumps, tubing, fitting and valves. Installation was estimated at 4000 ECU. The total initial costs for each filler were 11000 ECU. Annual increased costs were estimated at 6000 ECU/a. Revenues per filler were estimated at 12000 ECU/a in the case of use in ice cream production (at 500 ECU/a if only use in cattle-food production were possible, e.g. because the plant does not produce ice cream). Reduced costs were estimated at 7000 ECU/a (for reduction of waste water treatment costs and for the value of product loss prevention).
Potential	The waste prevention potential for this option is assessed as *moderate* because, on the one hand, it is anticipated that many companies have already implemented such recovery options, but, on the other hand, the available waste minimisation audits indicate that there are still possibilities for further waste prevention related to recovery of products.

1 Hunter Jersey Farms, 1988

Sector	Manufacture of dairy products (NACE 15.5)
Process	Production of fluid milk and milk products
Waste stream	Product spills and losses

Prevention option	**Recovery of remnants of production tanks**
Option No	2-4
Type	GOP
Group	1
Description	The filling of products takes place in batches. Remnant remains in the production tank at the end of a batch. This remnant is often removed by the CIP system and sent into the cattle food production or the sewer. Instead of this procedure, the product can also be caught up in cans, positioned below the drainage point, and re-used in the production process.[1]
Remarks	--
Economics	A case study in milk industry showed that a reduction of 1,6% of total product loss of a company could so be achieved. The savings did not bring about extra costs.
Potential	The waste prevention potential for this option is assessed as *moderate* because, on the one hand, it is anticipated that many companies have already implemented such recovery options, but, on the other hand, the available waste minimisation audits indicate that there are still possibilities for further waste prevention related to recovery of products.

1 Berkel, 1991

Sector	Manufacture of dairy products (NACE 15.5)
Process	Cleansing operations
Waste stream	Milk / water and product / water mixtures from cleansing

Prevention option	**Pasteurised rinse recovery**
Option No	2-5
Type	RU / RC
Group	1
Description	Rinse recovery from tanks and lines can greatly reduce product loss in fluid milk industry. Systems were developed for the recovery of product rinses. Initial rinsing is recommended to recover product left in tanks and lines. This can be achieved by the discharge of high pressure water through the CIP lines and nozzles. This would also wash away easily removable residual product from the tank and line walls. A water-in manifold assembly could be added to the CIP system with water entry controlled by the water solenoid valve. The water is discharged through the systems in several bursts. The recovered material is delivered into the milk solids recovery system. [1]
Remarks	--
Economics	Material costs of the pasteurised initial rinse recovery system were estimated at 8000 ECU for a US milk processing plant. Installation was estimated to take 90 hr costing 3000 ECU. Total initial costs were estimated to be 11000 ECU. Increased annual costs were estimated at 6000 ECU/a. Revenues were estimated at 66000 ECU/a in the case of re-use in ice cream production (at 3000 ECU/a if only use in cattle-food production were possible). Reduced costs were estimated at 33000 ECU/a (for reduction of waste water treatment and the value of product loss prevention).
Potential	The waste prevention potential for this option is assessed as *moderate* because, on the one hand, it is anticipated that many companies have already implemented such recovery options, but, on the other hand, the available waste minimisation audits indicate that there are still possibilities for further waste prevention related to recovery of products.

1 Hunter Jersey Farms, 1988.

Sector	Manufacture of dairy products (NACE 15.5)
Process	Cleansing operations
Waste stream	Milk / water and product / water mixtures from cleansing

Prevention option	**Raw rinse recovery**
Option No	2-6
Type	RU / RC
Group	1
Description	Reasons for rinse recovery for the raw side are the same as those for pasteurised rinse recovery. Recovery on the raw side is from the tankers, raw milk lines and the raw tanks. The water burst-rinse technique as used for the pasteurised side is recommended. A refrigerated tank is required to recover the rinse materials during the day. At process day's end, the collected material in the raw tank are used to flush through the system including the UHT's. It is pasteurised and delivered to the milk solids collection tank. [1]
Remarks	--
Economics	Material costs for the initial rinse system addition on the raw side CIP are estimated at 21000 ECU for a US milk processing plant. Installation labour was estimated to cost 11000 ECU. Total initial cost was estimated at 32000 ECU. Increased annual costs were estimated at 12000 ECU/a. Increased revenues were estimated at 61000 ECU/a in the case the milk solids could be re-used in dairy production (at 2000 ECU/a if only use in cattle-food production were possible). Reduced costs were estimated at 23000 ECU/a (for reduction of waste water treatment and the value of product loss prevention).
Potential	The waste prevention potential for this option is assessed as *moderate* because, on the one hand, it is anticipated that many companies have already implemented such recovery options, but, on the other hand, the available waste minimisation audits indicate that there are still possibilities for further waste prevention related to recovery of products.

1 Hunter Jersey Farms, 1988.

Sector	Manufacture of dairy products (NACE 15.5)
Process	Cleansing operations
Waste stream	Milk / water and product / water mixtures from cleansing

Prevention option	**No rinsing between certain batches**
Option No	2-7
Type	GOP / RU / RC
Group	1
Description	Rinsing between batches is used to prevent the mixing of different products, e.g. different kind of yoghurts. Rinsing between batches brings about significant product losses, that are added to cattle- food or discharged into the sewer. Instead of rinsing, the product can also be removed from the filling machine by letting it drain out. The last remnants of the product can be removed by the next product. The mixed zone can be collected and added to cattle food.[1]
Remarks	--
Economics	Tests in a specific dairy plant's yoghurt production show that a reduction of 55% is achieved in the product loss by rinsing between batches, a reduction of 2,5% of the total product loss arising during filling. A decrease of water consumption can be mentioned as well as a gain of time: emptying the filling machine and separating the mixed zone is reported to take one hour less than rinsing. No cost investments are reported so that the measure yields benefits without pay back period.
Potential	The waste prevention potential for this option is assessed as *moderate* because, on the one hand, it is anticipated that many companies have already implemented such recovery options, but, on the other hand, the available waste minimisation audits indicate that there are still possibilities for further waste prevention related to recovery of products.

1 Berkel 1991

Sector	Manufacture of dairy products (NACE 15.5)
Process	Cleansing operations
Waste stream	Milk / water and product / water mixtures from cleansing

Prevention option	**Optimisation of cleansing**
Option No	2-8
Type	GOP
Group	1
Description	If the cleansing process is not proceeding optimally, significant loss of product and cleansing agents can occur. Continuous measuring (of e.g. temperature and conductivity) can help to optimise cleansing. Case studies in dairy industry report on measures as the installation of a level controller, the lowering of the temperature of heat exchangers and the shortening of cleansing programmes, resulting in a reduction in consumption in cleansing agents and disinfectants of 23%.[1]
Remarks	--
Economics	The above mentioned case study reports of a pay back time of one month (the only incurred costs were the installation of the measuring equipment).
Potential	The waste prevention potential for this option is assessed as *moderate* because, on the one hand, it is anticipated that many companies have already implemented such recovery options, but, on the other hand, the available waste minimisation audits indicate that there are still possibilities for further waste prevention related to recovery of products.

1 Berkel 1991

Sector	Manufacture of dairy products (NACE 15.5)
Process	Cheese making
Waste stream	Whey

Prevention option	**Reclamation of valuable resources of the whey**
Option No	2-9
Type	RC
Group	1/3
Description	Collection of the whey and re-use in cattle-food production is part of good operating practices in dairy industry. Reclamation of valuable resources as lactose and proteins, as an alternative for re-use in cattle-food production, is progressively applied. In Austria for example, recovery of lactose and casein is reported to be applied for 25% of the whey; the rest is directed towards cattle-food production[1]. To make reclamation possible, the whey is first desalted and then concentrated by evaporation. *Proven technologies for reclamation* are[2]: • to spray-dry the concentrated whey so that desalted whey powder is produced for baby-food production; • to crystallise and centrifuge the concentrated whey, so that a mother liquid and lactose are produced. The lactose can be refined and washed, and used in baby-food production or in pharmaceutical products. The mother liquid can be re-used in cattle-food production. A *promising technology* is : • ultra- and micro filtration for the recovery of proteins[3].
Remarks	Literature reports that the market for whey products is becoming largely satisfied in the Netherlands[4].
Economics	Re-use of whey components in baby-food or in pharmaceutical products gives much higher revenues than re-use in cattle-food production. The literature available provides no further details on costs and revenues of the recovery of valuable resources of the whey.
Potential	Although the whey stream is a significant waste stream of the cheese making process, the waste prevention potential for the whole of the dairy sector has been assessed as *low*: the amount of waste expected to be reduced is low because whey is to a large extent already re-used in cattle-food production. This does not mean that reclamation of whey components in baby-food production and pharmaceutical products, and research hereto, are not interesting; re-use as high-added-value materials is beneficial for both environmental aspects (scarce use of resources) and economic aspects.

1 Bundesministerium für Umwelt, 1995.
2 Ros, 1993
3 Lijzen, 1993.
4 Lijzen, 1993.

Sector	Manufacture of dairy products (NACE 15.5)
Process	Cheese making
Waste stream	Salt brine

Prevention option	**Re-use of salt brine surplus**
Option No	2-10
Type	RU
Group	3
Description	Literature reports that the discharge of salt brine could be reduced with about 80% by the application of a combination of evaporation and micro filtration of the salt brine surplus[1]. The high energy costs of evaporation form however a barrier for application. Research is being carried out on various related themes, e.g. the re-use of the salt brine surplus, the recovery of casein out of the surplus and the lowering of the salt content of the surplus[2].
Remarks	--
Economics	Until now, the increased costs for recovery of the resources of the salt brine surplus by evaporation and micro filtration, are not balanced by increased revenues or reduced waste water treatment charges or product loss costs.
Potential	The waste prevention potential is considered as *low*. There is perspective that the waste stream of salt brine surplus will be reduced, but technological and economic barriers should still be passed.

1 NIZO 1991 (quoted in Ros, 1993).
2 Jong 1989, Lijzen 1993

Sector	Manufacture of dairy products (NACE 15.5)
Process	Milk powder production
Waste stream	Powder losses

Prevention option	**Recovery of powder lost during drying**
Option No	2-11
Type	TC / RU
Group	2/3
Description	Cyclones are used in (spray-)drying installations of milk powder production to separate the product from the heated air. These cyclones can separate up to 99,4% of the product; 0,6% is carried along with the air. *Proven technologies* developed to prevent air pollution are fabric filters and wet scrubbers. The powder collected in fabric filters can - with some exceptions - be re-used. The sludges of the scrubbers can only be re-used in cattle-food production. A major dairy industry in the Netherlands said to prefer fabric filters instead of scrubbers for all its powder plants[1]. Literature reports on possible quality problems with fabric filters. Other problems occurring are losses during the start-up or shut-down of filters, due to condense. The application of *new drying technologies* is considered interesting for both lower energy use and lower product losses. Research is going on[2].
Remarks	--
Economics	Revenues of powder recovery in fabric filters are considered to be equal to the operational costs of the filters[3]. Since the powder production is falling over a number of years, the sector's margins are under pressure and new investments are avoided. Possibilities for the installation of filters and switches to other drying techniques only occur when old installations are replaced.
Potential	In 1983 in the Netherlands, 65% of the spray-dry installations were equipped with fabric filters and another 15% with scrubbers. Significant changes are not reported since then. No information was available for other countries. The waste prevention potential is considered as *low* because the option has only a small impact in terms of waste minimisation (reduced air pollution is the principal interest).

1 Lijzen 1993 (interviews with industry).
2 Lijzen 1993.
3 Jong 1989 and Lijzen 1993.

Sector	Manufacture of dairy products (NACE 15.5)
Process	Packaging
Waste stream	Packaging wastes

Prevention option	**Reduction of materials used for packaging**
Option No	2-12
Type	TC
Group	1/2
Description	Literature reports on cost-effective reductions of the material use in packaging of dairy products[1]. Examples are given of 30% less glass used in bottles for drinking milk, 14% less aluminium in beverage packages, 10% less plastic in tins for coffee cream and 7% less material in gable top packaging for drinking milk.
Remarks	--
Economics	No information.
Potential	Changing packaging systems requires changes in the filling lines, in cleaning lines (in case of re-usable packaging), in distribution and often also in the shops. Extensive co-ordination is consequently required for such changes. The waste prevention potential for *on-site* waste reduction is *low*. However, within a cradle-to-grave approach going beyond on-site waste minimisation that is the subject of this study, material reduction of packaging has a high prevention potential since significant less waste is produced in the end stage of packaging.

1 NIZO 1991 (in RIVM 1993).

SECTION 3

MANUFACTURE OF BEVERAGES : BREWING INDUSTRY

SECTOR REPORT

Contents :

NACE sectors involved in the present sector report:

Retained for analysis:	15.96	Manufacture of beer
Excluded from analysis:	15.91	Manufacture of distilled potable alcoholic beverages
	15.92	Manufacture of ethyl alcohol from fermented materials
	15.93	Manufacture of wine
	15.94	Manufacture of cider and other fruit wines
	15.95	Manufacture of other non-distilled fermented beverages
	15.97	Manufacture of malt
	15.98	Manufacture of soft drinks and mineral water

3.1 SECTOR CHARACTERISATION[1]

The beverage industry is composed of four main product groups : alcohol and spirits (NACE 15.91 and 15.92), wine and vermouth (NACE 15.93 - 15.95), beer and malt (NACE 15.96 and 15.97), soft drinks and mineral water (NACE 15.98). This report concentrates on beer making because the processes in this sector are also typical for other sectors of the beverage sector[2] and because of the strong economic position of the brewery sector within the beverage industry (brewing accounts for about 45% of the value added of the beverage sector[3]).

The beer brewing sector includes the processing of hops, maize and barley to make biological beer, exotic beer, light beer, non-alcoholic beer, normal beer, special beer and double-malt beer. These product types are further categorised by colour (pale, red and dark), while in terms of packaging, they are divided in draught beer, bottled beer (returnable and non-returnable bottles) and canned beer.

The beer-making process is fairly complex and requires big capital assets. The value added in the brewing industry is very high compared to related industries. Germany is the country that contributes the most to the level of EU value added (41%), followed by the United Kingdom (21%), Spain (12%), the Netherlands (9%) and France (8%).

In 1993, 1.611 breweries were operating throughout the Community, of which 1.281 in Germany. The breweries employed 139.000 workers and produced 289.000 hectolitres (hl) of beer. The beer brewing sector compromises companies of various size, starting with small firms which meet local demand right up to the large multinationals with their direct productions and licensed productions, the latter granted to other companies in other countries. The productivity levels vary considerably depending on the type and size of the manufacturers.

Prospects for the sector, in the medium term, are for a general growth and concentration of beer manufacturing enterprises. There is a general tendency to keep costs down by concentrating production facilities.

3.2 PROCESSES AND WASTES

Beer is obtained through fermentation of malt, barley or other cereals, mixed with aromatic substances (e.g. hops), carbon dioxide and water. For the purpose of this report, the brewery processes have been divided into four sub-processes, i.e.:

1 Main source: European Commission, 1995

2 There are important process similarities between the processes applied in the four product groups. Fermentation is the basic process for three of the four groups (alcohol production, wine production and beer and malt production). All sectors generate waste waters with a significant organic pollution and, if on-site waste water treatment is applied, waste water sludges. Product loss and cleansing activities are the main sources of this waste water. The waste situation of the sectors not studied in detail is as follows:

- *Alcohol and spirits manufacturing (NACE 15.91 and 15.92)*: the production of alcohol from cereals, potatoes or molasses by fermentation and distillation generates one major waste stream: vinasse. This waste is in general sent to cattle feed production.
- *Wine manufacturing (NACE 15.93 and 15.94)*: the major waste of wine production is draff (the kernels, pulp and skins of the grapes), that arises when the mashed grapes (mash) are pressed and the draff is separated from the juice.
- *Soft drinks and mineral waters (NACE 15.98)*: the only waste stream arising in mineral water production is the sediment of removed (ferrous) ions. No specific waste streams are identified for the soft drinks production, where the central process is that of mixing the different ingredients.

3 This figure includes the closely related malting sector, whose value added is very low in relation to the brewing sector. The other cited sectors account for 27% (soft drinks and mineral waters), 14% (wine sector) and another 14% (alcohol and spirits sector) of the value added of the beverage sector.

- brewhouse processing
- fermentation / beer processing
- packaging
- cleansing

Annex A gives further details on these processes.

Table 3.2.1 lists the identified waste streams, together with their process origin. The table includes a priority ranking, based on a sector-wide tentative evaluation of the amount and the hazardous character of the waste streams.

Table 3.2.1: Major waste streams of the brewery industry

Process origin	Waste streams	Priority rank	Description and code according to EWC[4]	
Brewhouse processing	Spent grains	o	Wastes from the washing, cleaning and mechanical reduction of the raw material	02 07 01
	Weak wort	-	Wastes not otherwise specified	02 07 99
	Trub	-	Materials unsuitable for consumption or processing	02 07 04
Fermentation / beer processing	Spent yeast	o	Materials unsuitable for consumption or processing	02 07 04
	Residual beer	o	Wastes not otherwise specified	02 07 99
	Kiezelguhr	o	Wastes not otherwise specified	02 07 99
Packaging	Residual beer	o	Wastes not otherwise specified	02 07 99
Cleansing	Cleansing waste water	o	Wastes not otherwise specified	02 07 99

Priority rank: + : high significance, o : medium significance, - : low significance — EurEco/Witteveen+Bos 1997

Beer making wastes are typically composed of organic substances and cause high BOD loads if discharged in the waste waters.

Major waste streams arise due to loss of raw materials and product. *Spent grains* (the insoluble parts of the malt and other raw materials) are generated in large quantities and are normally sent to cattle feed production. *Weak wort* is raw material remaining in the lauter tun, that can in principle be reprocessed. *Trub* are insoluble parts of the beer extract and can be disposed of together with the spent grains.

The fermentation process generates *surplus yeast*, that is sent to the sewer or used in cattle feed production or prepared for human consumption. Used *kieselguhr* (diatomaceous earth) is generated in beer filtration operations. Significant quantities of *cleansing waste water* arise; cleansing and disinfection are of vital importance to prevent beer from being infected.
Further details on wastes are provided in annex A.

The brewing industry is involved in other environmental issues than waste. The main problems are linked to the disposal of packaging (which is now progressively reused during production), energy use, water use, CO_2 production and the discharge of fumes into the atmosphere.

4 All organic matter that is not treated separately, ends up in the waste water of the brewery. Large breweries usually have their own waste water treatment plant, in which waste water sludge (EWC 020705) arises.

3.3 WASTE PREVENTION

This section discusses waste prevention options identified in literature. The major waste streams along with prevention options are summarised in table 3.3.1, following the division into processes and waste streams as made in the preceding chapter. Within the scope of the study, only general discussions on options can be given, with the intent to stimulate the thinking of manufacturers about their processes. The selected options[5,6] are described in Annex B.

Table 3.3.1: Waste prevention options for the brewing industry

Process	Waste streams	Priority rank	Waste prevention method	Group	Potential
Brewhouse processing	Spent grains	o	3-1 Improvement of brewhouse yield (IMC/TC)	1/2	-
	Weak wort	-	3-2 Collection, treatment and re-use (RU)	1	-
	Trub	-	3-3 Collection, treatment and re-use (RU)	1	-
Fermentation / beer processing	Spent yeast	o	3-4 Collection, treatment and re-use (RU)	1	o
	Residual beer	o	3-5 Self-draining tanks and pipes (TC) 3-6 Good housekeeping in filtration (GOP)	1/2 1	- -
	Kiezelguhr	o	3-7 Beer centrifugation before filtration (TC)	1/2	o
Packaging	Residual beer	o	3-8 Good housekeeping in cask / bottle filling (GOP)	1	-
Cleansing	Cleansing waste water	o	3-9 Optimisation of CIP installation (GOP) 3-10 Caustic sediment tanks (TC) 3-11 Good housekeeping in cask / bottle washing (GOP)	1 1 1	- - -

+ = high, o : medium, - : low, .. = insufficient data EurEco/Witteveen+Bos 1997

With its high resource consumption (malt, energy, water), the brewing industry is well placed to benefit from waste minimisation. A range of technologies and techniques are available to improve the efficiency of a brewery and to reduce inputs and undesired outputs. Options range from high-investment technologies, such as the installation of a process centrifuge, to good housekeeping measures.

Breweries with a relative high unit resource consumption (ranges of resource consumption are included in annex A.1) can achieve a substantial reduction by addressing management issues and small changes in ancillary operations and process systems. These breweries can start with the identified options of group 1 (that do not require excessive costs), consisting of re-use (RU) options (3-2, 3-3, 3-4), that aim to set up simple recovery systems, and good operating practice (GOP) options (3-6, 3-8, 3-9, 3-11).

5 The options mentioned here concentrate on waste. Reduction of the use of energy and water are other fields with major pollution prevention options. Actions in one area should be co-ordinated with those in others in order to benefit from the synergy and to avoid pollution transfer from one compartment to another.

6 An extensive review of pollution prevention options is given in UNEP IE 1996. Abwassertechnischen Vereinigung 1985 and Rüffer 1984 provide a thorough review of options that reduce the waste water load.

It is important that actions in other pollution prevention areas (water use, energy use) should be co-ordinated with waste actions in order to benefit from the synergy and to avoid pollution transfer from one compartment to another.

Breweries with relatively low consumption could envisage to focus on a co-ordinated programme of management options, engineering options and plant equipment options. Implementation of the technology change (TC) options (3-1, 3-5, 3-7, 3-10) could here be considered, in the medium or longer term. The same applies to new breweries or existing breweries where a major refurbishment will be carried out, as this offers possibilities for reducing consumption of resources in a cost-effective manner.

In general, however, the prevention potentials have been evaluated as low or moderate. Given the traditional focus on raw material and product recovery, it is anticipated that the options are already largely applied. Another aspect is that the involved waste streams are not high priority ranked as they can easily be treated and recycled.

3.4 EVALUATION

The brewing industry has a traditional focus on the issue of recovery of raw materials and product from the waste water. There is considerable literature on waste prevention available. Wastes and waste waters generated by the brewing industry contain high organic loads but can easily be treated or re-used / recycled.

Literature indicates that there are further opportunities for waste minimisation. These opportunities should be considered as a continuation of the ongoing efficiency improvement efforts of brewing industry, not as a new issue that would need significant new development and efforts.

3.5 BIBLIOGRAPHIC REFERENCES

Abwassertechnischen Vereinigung (1985), "Lehr- und Handbuch der Abwassertechnik, Band V: Organisch verschmutzte Abwässer der Lebensmittelindustrie", Ernst & Sohn Verlag, Berlin, 1985.

Bundesministerium für Umwelt (1995), "Branchenkonzept Nahrungs- und Genussmittelindustrie, Abfälle und Stoffströme", in cooperation with the 'Fachverbandes der Nahrungs- und Genussmittelindustrie Österreichts', Wien, 173 p

DTI/DOE (1996), "Saving money through waste minimisation", Environmental Technology Best Practice Programme, examples related to breweries (GC 21, GG 26/3 and 26/9, GG 27/3), London, March 1996.

European Commission (1995), "Panorama of EC Industry 95/96 - an extensive review of the situation and outlook of the manufacturing and service industries in the EU", Bruxelles-Luxembourg, Office for Off, Pub. of the EC, 1995

Flair-flow Europe (1996), selected project summaries of the Flair-flow project of the EU AAIR and VALUE programmes (F-FE 213/96 "Good practice manuals for the European brewing industry"), Dublin, June 1996

Fürstenberg (1995), "Fürstenberg Umwelterklärung", Fürstlich Fürstenbergische Brauerei KG, Donaueschingen (D), November 1995, 18 p.

Geudens P. (1994), "Afvalwaterzuivering en slibafzet door de voedings- en genotmiddelen-industrie, 1992", CBS, in: Kwartaalbericht Milieu nr. 94/4, p. 17 -23..

Hommel Th. (1996), "La bière en Allemagne - enjeux économiques, sociaux et environnementaux à l'échelle locale et régionale", in Courrier de l'Environnement de l'INRA, no. 28, Paris, August 1996, p. 70-76.

Huizinga K, Hoogenkamp A. (1994), "Alcoholfabrieken en distilleerderijen", Samenwerkingsproject procesbeschrijvingen Industrie Nederland, RIVM, rapportnr. 773006168, Bilhoven (NL), March 1994.

Huizinga K, Matthijsen A. (1993), "Productie van frisdranken", Samenwerkingsproject procesbeschrijvingen Industrie Nederland, RIVM, rapportnr. 736301140, Bilhoven (NL), January 1993.

Malt Distillers' Association of Scotland (1994), "The distilling equation", Malt Distillers' Bulletin, Spring 1994, 1 p.

RIVM (1985), "Vogelvluchtverkenning voedings- en genotmiddelenindustrie", rapportnr. 841221001, Bilhoven (NL), March 1985.

Rüffer H. and Rosenwinkel K.-H. (1984), "The treatment of waste water from the beverage industry", in Barnes D., Forster C., Hrudey S. (ed.) (1984), "Surveys in Industrial Wastewater Treatment, Vol. I Food and allied industries", Pitman Publishing Ltd, London, p. 69-127.

UNEP IE (1996), "Environmental management in the brewing industry", Technical Report no. 33, Paris, 1996, 106 p.

Zötler (1995), "Umwelt-Erklärung der Privat-Brauerei Zötler", Rettenberg (D), November 1995, 18 p.

SECTION 3

MANUFACTURE OF BEVERAGES : BREWING INDUSTRY

ANNEX A

PROCESSES AND WASTES DESCRIPTION

Contents :

A.1 OVERVIEW

Beer production methods differ from brewery to brewery, as well as according to brewery equipment and beer types. The main process is however similar. The processes described hereafter are those of the production of a typical lager beer[1].

For the purpose of this report, the brewery processes have been divided into four sub-processes, i.e.:

- brewhouse processing
- fermentation / beer processing
- packaging
- cleansing

Ancillary processes, other than cleansing, are listed in section A.6 of this annex.

The consumption figures of a typical lager beer brewery are summarised below.

• Malt/adjunct 15-18 kg • Energy 150-350 MJ • Electricity 8-20 kWh • Water 5-20 hl	->	• Brewhouse processing • Fermentation / beer processing • Packaging • Cleansing • Ancillary operations	->	• 1 hl Beer • Waste water 3,5-18,5 hl (0.8-1,2 kg BOD) • Spent grains 14-17 kg • Excess yeast 3 kg • Kieselguhr 0,1-0,3 kg

All organic substances not contained in the beer, in the by-products (e.g. spent grains, excess yeast) or in the kieselguhr, will end up in the waste water.

A.2 BREWHOUSE PROCESSING

* Process description

The first stadium in the brewing process is the preparation of the wort for fermentation. The malt is crushed to a grist of suitable fineness and then mashed in the mashing tun with warm water. During the mashing process, the insoluble components (starches) and the high-molecular protein compounds are converted or decomposed by enzymes into soluble compounds (sugar, dextrin). The solution formed is called the 'wort'.

The spent raw materials ('spent grains') are subsequently separated from the wort by straining (in a lauter tun, a mashing filter or a strainmaster). The wort is then boiled with hops or hop extracts. A precipitate consisting mainly of proteins is obtained (the 'trub'). After separation of the trub, the hot wort is cooled to the temperature of fermentation.

1 The main sources for the description of processes and wastes are: Abwassertechnischen Vereinigung 1985, Rüffer et al. 1984 and UNEP IE 1996. Other sources are: Bundesumweltministerium 1995, Fürstenberg 1995, RIVM 1985, Zölter 1995.

*   **Waste description**

Loss of raw materials (wort) can occur at several stages of brewhouse processing. Extracts remain in particular in the following waste streams :

- *Spent grains*
  The spent grains contain residual extract and water. The amount of spent grains is normally 14-17 kg per hl beer (dry matter content of 20%). Extract is lost through the spent grains if the difference between the actual yield of extract and the laboratory yield is higher than 1%.

  The spent grain left over can be sold as fodder, provided that neither carbon nor asbestos is used as filter medium. To avoid putrefaction, the wet spent grains must be sold the same day they are strained. If this is not possible, the spent grains can be dried for storage. Ideally the heat for drying can be recovered from another process.

- *Weak wort*
  The wort remaining in the lauter tun is called weak wort. The weak wort volume is 2-6% of the wort volume. The weak wort still contains extract (1-1,5% of the weak wort). If the weak wort is sent to the waste water, extract is lost and the BOD load of the waste water is increased.

- *Trub*
  The trub is a slurry consisting of entrained wort, hop particles and unstable colloidal proteins coagulated during wort boiling. The trub slurry is separated from the wort prior to wort cooling, for instance in a whirlpool. The amount of trub from an effective whirlpool is 0,2-0,4 of the wort volume, with a dry matter content of 15-20%.

  The trub contains wort. Extract loss related to the trub will depend on how efficiently the wort and trub are separated. The trub suspension can be treated in different ways, added to the spent grains or sent directly to the waste water. BOD of trub is around 110.000 mg/kg wet trub.

A.3 FERMENTATION / BEER PROCESSING

*   **Process description**

After the cooled wort and the yeast have been combined, the fermentation process begins in the fermenting tanks. For lager beers, primary fermentation is carried out at 5 - 10 °C. The duration of this fermentation is between 7 and 10 days. The secondary fermentation takes place in substantially smaller tanks at temperatures around 0 °C. During fermentation an average of 20-30 litres of liquid yeast with about 10% dry solids per m3 of beer output is produced.

The healthy seed yeast is salvaged and some is used again in a new brew. The yeast that is not reused can be utilised as animal or human food supplement. Waste beer recovery from the yeast sediment, using centrifugation or filter pressing, results in higher beer production and a reduction in the pollution load. The remainder of beer from the deposits or sediments of the secondary fermentation can also be reclaimed.

Before the beer is pumped to the packaging area, the beer must be filtered to improve its storage properties and to give it a bright, clear appearance. Pulp filters, kieselguhr filters, layer filters and centrifugal filters are commonly used. After the filtering process the beer is placed in a carbon dioxide pressure tank before packaging.

* **Waste description**

The following waste streams arise during fermentation / beer processing :

- *Excess yeast*
  Excess yeast is produced during the fermentation process. Only part of it can be reused. The amount of the surplus is 2-4 kg (10-15% dry matter content) per hectolitre produced beer. The yeast suspension, which contains yeast and beer, has a very high BOD value (120.000-140.000 mg/litre). Very often the yeast, or part of it, is sent directly to waste water.

- *Residual beer*
  Beer loss occurs during various steps of fermentation / beer processing, mainly during the emptying of process tanks and pipes and during filtering. Together with the losses in packaging (see A.4), the beer loss will equal around 1-5% of total production. Most of it can be collected and reused in the brewery processes. Any residual beer not collected is discharged as effluent. The BOD of residual beer is 80.000 mg/l.

- *Kieselguhr*
  Depending on initial clarity, yeast cell count and beer type, 0,1-0,3 kg kieselguhr (diatomaceous earth) is typically used per hectolitre beer. Kieselguhr removed from the filters is not allowed to be discharged into sewers, because it would add considerably to the pollution load, and would settle out in the sewerage system.

  Various recycling methods are under development, but at present they are not capable of totally replacing new kieselguhr with recycled. The spent kieselguhr can be disposed of on landfills or as a soil conditioner / fertiliser. It may also be used in the production of cement and as a component in brick making. It can also be added (up to 5%) to the spent grains, provided that neither carbon nor asbestos is used as filter medium.

A.4 PACKAGING

* **Process description**

From the storage tanks, the beer is pumped to the packaging area, where it is bottled, canned or kegged.

Bottling starts with bottle washing that likely consists of soaking, rinsing, sterilisation and re-rinsing. Bottling continues with filling, crowning, pasteurising, labelling and transport packaging. Sterile filtration is an alternative to pasteurisation.

In packaging lines using non-returnable bottles and cans, the bottles / cans are only flushed with water before filling. Kegs are cleaned and sterilised with steam before filling.

* **Waste description**

Residual beer is a major waste stream arising in the packaging area. Together with the losses in fermentation / beer processing (see A.3), the beer loss will equal around 1-5% of total production. Most of it can be collected and reused in the brewery processes.

Significant sources of residual beer are :

- Exploding bottles: this may occur because of poor quality bottles, poor bottle inspection or lack of temperature control in the tunnel pasteuriser.

- Rejected beer: the beer can be rejected due to, for example, quality defects, wrong filling height, or incorrect placement of labels. The number of rejected bottles will depend on the brewery's quality requirements in combination with the level of process control.

- Returned beer: beer may be returned to the brewery if, for example, it has not been sold or the quality has been deemed unacceptable.

Other waste streams arising in the packaging area are :

- *Broken glass:* at breweries using returnable bottles, broken glass will be a large category of the solid wastes. It is possible to recycle this glass in the production of new glass.

- *Paper pulp from the bottle washer process:* label pulp from washing of returnable bottles can be disposed by composting or recycling. It may contain caustic liquor and heavy metals from the ink.

- *Packaging waste*: breweries using one-way packaging materials such as cans and one-way bottles usually generate particularly large amounts of plastic and cardboard waste. These wastes can be source-separated and recycled.

A.5 CLEANSING

* Process description

All process equipment of a brewery is kept clean and disinfected. Cleaning is done by means of cleaning-in-place (CIP) plants, where cleaning agents are circulated through the equipment or sprinkled over the surface of the tanks. Acid is normally used to clean process tanks in which CO_2 has been generated or used at top pressure. Caustic is used for pipework and occasional tank cleaning to remove proteinaceous material. Several CIP units are usually required in order to cover all the process areas in the brewery.

Disinfection takes place through a combination of high temperature, cleaning agents and disinfectants.

The cleaning and disinfection of the brewery equipment can involve the use of substantial amounts of energy, water, cleaning agents and disinfectants.

* Waste description

Cleansing waste water will contain caustic, acid and detergent as well as product and raw material, i.e. extract loss. Waste water from the bottle washer will in addition contain organic substances from labels and glue.

A.6 OTHER PROCESSES

* Process description

Processes that are not characteristic and/or of minor importance in terms of waste generation, have not been studied in detail. Examples of these processes are :

- malting (convert barley to a form of malt suitable for brewing; some breweries have their own malting plant).
- product storage (in warehouses)
- laboratory (equipped for quality control and process control)
- heating and cooling (heat is usually supplied by steam or hot water, produced on-site; process cooling is in general supplied by a central on-site plant)
- water treatment (in case of water intake from surface water or wells, the water should be treated in conventional water treatment plants; water should typically be soft and chlorine-free.)
- waste water treatment (large breweries have in general on-site waste water treatment)
- CO_2 recovery (the CO_2 generated during the fermentation process can be collected and reused or sold).

* Waste description

Waste streams that are not characteristic and/or of minor importance are :

- Packaging materials from received auxiliary material
- Boiler ash (if the boiler is coal-fired)
- Waste oil and grease
- Waste paints and thinners

SECTION 3

MANUFACTURE OF BEVERAGES : BREWING INDUSTRY

ANNEX B

PREVENTION OPTIONS

Contents :

Sector	Manufacture of beverages (NACE 15.9)
Process	Brewhouse processing
Waste stream	Spent grains

Prevention option	**Improvement of the brewhouse yield**
Option No	3-1
Type	IMC/TC
Group	1/2
Description	If the difference between the actual brewhouse yield from malt and the laboratory yield is higher than 1%, extract will be lost with the spent grains, indicating that the raw material is badly utilised. The washable extract remaining in the spent grain should be less than 0,5%, the remaining extract that can be broken down and dissolved less than 0,8%[1]. Reasons for a poor brewhouse yield are: • poor malt quality • unsatisfactory crushing of malt in the mill • unsatisfactory mashing process • poor design of lauter tun • incorrect operation of lauter tun Ways to improve the brewhouse yield may range from changing the process to adjusting the mill, and/or renewing the lauter tun or installing alternative plants such as a mash filter [2].
Remarks	--
Economics	Some of the measures mentioned above can be implemented at little or no cost to the facility, others will claim significant research and development or investments. These costs should be brought in relation with the effects of increased efficiency and reduced waste.
Potential	It is anticipated that these measures are already largely applied, given the costs of the raw materials loss. A *low* prevention potential has therefore been estimated.

1 Abwassertechnischen Vereinigung 1985
2 UNEP IE 1996

Sector	Manufacture of beverages (NACE 15.9)
Process	Brewhouse processing
Waste stream	Weak wort

Prevention option	**Collection, treatment and re-use of weak wort**
Option No	3-2
Type	RU
Group	1
Description [1]	Weak wort can be collected in a tank equipped with heating jackets and a slow-speed agitator and used for mashing in the next brew. This saves raw material and water and reduces the organic load in the waste water. Before being used for mashing, weak wort can be pre-treated (e.g. by sedimentation, centrifugation or activated carbon) to recover the extract that it still contains.
Remarks	--
Economics	The installation of a weak wort tank will need some investment, that should however be brought in relation with the effects of increased efficiency and reduced waste.
Potential	It is anticipated that this measure is already largely applied, given the costs of the raw materials and product loss. A *low* prevention potential has therefore been estimated.

1 UNEP IE 1996, Rüffer et al. 1984

Sector	Manufacture of beverages (NACE 15.9)
Process	Brewhouse processing
Waste stream	Trub

Prevention option	**Collection, treatment and re-use of trub**
Option No	3-3
Type	RU
Group	1
Description [1]	The extract content of the hot trub will depend on how well the whirlpool is functioning. A well-functioning whirlpool will leave a trub with quite high dry matter content, in which case the extract loss will be small. In whirlpools with a trub cone, the loss will be high. By installing a centrifuge or decanter to separate the remaining wort from the hot trub, a large part of the extract can be recovered. The recovered wort can be returned to the hot wort, and the solids can be returned to the spent grains. Trub can also be returned to the mash kettle or lauter tun.
Remarks	--
Economics	Whirlpool optimisation and the installation of centrifuges or decanters will require significant research and development and investments. These costs should however be brought in relation with the effects of increased efficiency and reduced waste.
Potential	It is anticipated that these measures are already largely applied, given the costs of the raw materials and product loss. A *low* prevention potential has therefore been estimated.

1 UNEP IE 1996

Sector	Manufacture of beverages (NACE 15.9)
Process	Fermentation / beer processing
Waste stream	Spent yeast

Prevention option	**Collection, treatment and re-use of yeast**
Option No	3-4
Type	IMC/TC
Group	1/2
Description [1]	As much as possible yeast must be collected, because it can be valorised and to avoid high BOD levels in the sewer system. Yeast can be collected from fermentation and storage tanks, the yeast storage plant and the filter line. The yeast collection system may include a centrifuge, storage tanks, pipes and pumps. The yeast suspension contains a great deal of beer: a brewery losses about 1-2% of its production with the yeast. This beer can be recovered and recycled. Beer recovery can take place by a centrifuge, a cross flow filter or a press filter. Recovered beer is added to the hot wort in the brewhouse or pasteurised and blended in the fermentation tanks. The remaining surplus yeast can be : • sold as animal feed, e.g. to pig farms. • dried for storage and sold as fodder or for human consumption. Ideally the heat for drying can be recovered from another process.
Remarks	--
Economics	The installation of a yeast collection, treatment and re-use system will require some investments. These investments should however be brought in relation with the effects of increased efficiency, increased revenues (if the yeast is sold) and reduced waste water charges.
Potential	Literature reports that yeast, or part of it, is often directly sent to the waste water. The prevention potential has been estimated as *moderate.*

1 UNEP IE 1996, Abwassertechnischen Vereinigung 1985

Sector	Manufacture of beverages (NACE 15.9)
Process	Fermentation / beer processing
Waste stream	Residual beer

Prevention option	**Self-draining tanks and pipes**
Option No	3-5
Type	TC
Group	1/2
Description [1]	Residual beer should as much as possible be avoided, in order to minimise losses of this valuable commodity and to avoid high BOD levels in the waste water. Beer loss related to the emptying of process tanks and pipes is significant. The amount of beer remaining after emptying depends on the design of the tanks and pipes and the efficiency with which they are emptied. When beer is pushed out with water, a mixture of water and beer is produced, which is difficult to valorise. A major option is the installation of self-draining tanks and pipes. This option should be accompanied by other options as an efficient monitoring system that ensures that cleaning is done only when the tanks are as empty as possible.
Remarks	--
Economics	The installation of self-draining tanks and pipes will require significant investments. These costs should however be brought in relation with the effects of increased efficiency and reduced waste water charges.
Potential	It is anticipated that this measure is largely applied, given the costs of the raw materials and product loss. A *low* prevention potential has therefore been estimated.

1 UNEP IE 1996, Rüffer et al. 1984

Sector	Manufacture of beverages (NACE 15.9)
Process	Fermentation / beer processing
Waste stream	Residual beer

Prevention option	**Good housekeeping in filtration**
Option No	3-6
Type	GOP
Group	1
Description [1]	There are loss minimisation possibilities when filtering the beer before bottling. At the beginning of the filter run the filter is full of water, which is pushed out with beer. At the end of a filter run, the beer is pushed out with water. These 'pre-runs' and 'after-runs' result in a mixture of beer and water of low value. The arising of these mixtures can be minimised when CO_2 is used to push out the water and the beer.
Remarks	Problems with foam and a poor distribution of kieselguhr have been reported to occur in some breweries.
Economics	Good housekeeping measures can often be implemented at little or no cost to the facility. When one considers the effects of reduced waste water, increased efficiency, and little or no implementation cost, they usually provide a very high return on investment.
Potential	It is anticipated that these measures are already largely applied, given the costs of the raw materials and product loss. A *low* prevention potential has therefore been estimated.

1 Abwassertechnischen Vereinigung 1985

Sector	Manufacture of beverages (NACE 15.9)
Process	Fermentation / beer processing
Waste stream	Kieselguhr

Prevention option	**Beer centrifugation before filtration**
Option No	3-7
Type	TC
Group	1/2
Description [1]	Kieselguhr consumption and arising can be reduced by centrifuging the beer before filtration, so that less yeast has to be separated by filtration with kieselguhr. With a highly efficient centrifuge, up to 98-99% of the yeast remaining in the beer is removed. Implementation of a centrifuge will have the following effects: • Reduction in the amount of kieselguhr which needs to be dosed during filtration • Prolongation of filter runs • Improved utilisation of kieselguhr filter • Reduction in water consumption for backwashing of the filter • Minimisation of problems with handling wet and dry kieselguhr • Possibility to collect more surplus / spent yeast Prior to investing in a centrifuge, there are other factors to consider to improve yeast settling and therefore reduce kieselguhr consumption, i.e. : • Selection of malt • Optimum brewhouse procedures • Use of flocculent yeast strains • Well designed storage and transfer equipment • Long storage periods Another possibility is filtering without kieselguhr. There have been some promising trials of beer filtration using cross-flow membranes.
Remarks	--
Economics	The installation of a centrifuge will involve significant investments. These costs should be brought in relation with the effects of increased efficiency, reduced waste water charges and reduced waste.
Potential	It is anticipated that this measure has not yet been applied largely, given the required investment. A *moderate* prevention potential has therefore been estimated.

1 UNEP IE 1996

Sector	Manufacture of beverages (NACE 15.9)
Process	Packaging
Waste stream	Residual beer

Prevention option	**Good housekeeping in cask and bottle filling**
Option No	3-8
Type	GOP
Group	1
Description [1]	Several measures can be taken to minimise losses during filling, e.g. : • *cask filling :* - precise adjustment of cask fillers to avoid beer loss - excess beer collection and re-use • *bottle filling :* - precise adjustment of bottle fillers to avoid beer loss - installation of a metal sheet under the fillers to collect split beer; this collected beer can be saved, or added to the yeast in the yeast collection tank and sold. Rejected beer (rejected because of in-plant quality procedures) and returned beer (returned by the client) should also be re-used in the process. How the beer is re-used will depend on the quality of the residual beer. High-quality residual beer can be collected and dosed directly into the beer flow in the filter line. Low-quality residual beer (which might have been oxidised or contaminated) has to be returned to the whirlpool of the fermenters after pasteurisation. Low-quality residual beer will normally come from the packaging area.
Remarks	--
Economics	Good housekeeping measures can often be implemented at little or no cost to the facility. When one considers the effects of reduced waste water charges, increased efficiency, and little or no implementation cost, they usually provide a very high return on investment.
Potential	It is anticipated that these measures are already largely applied, given the costs of the loss of product. A *low* prevention potential has therefore been estimated.

1 Rüffer et al. 1984

Sector	Manufacture of beverages (NACE 15.9)
Process	Cleansing
Waste stream	Cleansing waste water

Prevention option	**Optimisation of CIP installation**
Option No	3-9
Type	GOP
Group	1
Description [1]	The design of CIP plants can vary greatly: from simple systems in which a batch of cleaning solution is prepared and pumped through the system before draining, to fully automatic plants with tanks for water and cleaning solutions, which make it possible to reuse certain amounts. If a new CIP plant is to be installed, a CIP system with tanks that make it possible to recover cleaning solutions should be preferred. In the case of an existing CIP plant, it is important to optimise the plant and the procedures for its use in order to avoid unnecessary losses of cleaning solutions and water. Use of more effective cleaning agents can result in shorter cleaning times at lower temperatures, and thus in a reduction of chemical, water and energy consumption. Biodegradable cleaning agents reduce the environmental effects of cleaning and are gradually introduced at breweries.
Remarks	--
Economics	Good housekeeping / optimisation measures can often be implemented at little or no cost to the facility. When one considers the effects of reduced waste, increased efficiency, and little or no implementation cost, they usually provide a very high return on investment.
Potential	It is anticipated that these measures are already largely applied, given the costs of the raw materials, product, cleansing agents, water and heat required for cleansing. A *low* prevention potential has therefore been estimated.

1 UNEP IE 1996

Sector	Manufacture of beverages (NACE 15.9)
Process	Cleansing
Waste stream	Cleansing waste water

Prevention option	**Installation of caustic sediment tanks**
Option No	3-10
Type	GOP
Group	1
Description [1]	A caustic sediment tank can be installed in connection with the bottle washer. When the brewery is not operating (e.g. in weekends), the contents of the bottle washer are pumped to the sediment tank, where impurities and sediment are removed. After sedimentation, the caustic is returned to the bottle washer. The lifetime of the caustic can thereby be increased from one to three weeks up to three to six months. Furthermore, if the caustic sediment is insulated, only reheating of the caustic is necessary during start-up. The recovered caustic sediment needs to be handled carefully and neutralised before disposal.
Remarks	--
Economics	The installation of a caustic sediment tank will involve some investments. These costs should however be brought in relation with the effects of the reduced waste water charges and reduced costs for the purchase of caustic.
Potential	It is anticipated that this measure is already largely applied, given the waste water charges and the costs of caustic. A *low* prevention potential has therefore been estimated.

1 UNEP IE 1996

Sector	Manufacture of beverages (NACE 15.9)
Process	Cleansing
Waste stream	Cleansing waste water

Prevention option	**Good housekeeping in cask and bottle washing**
Option No	3-11
Type	GOP
Group	I
Description [1]	Several measures can be taken to minimise losses during washing, e.g. : • *cask washing :* - use of second washing water for pre-washing - steaming of casks - precise rinse dosages; eventually intermittent rinsing. • *bottle washing :* - optimum utilisation of the cleaning liquor in bottle-washing and eventual separation through settling, flocculation, filtering. - use of the water from bottle-washing to wash the casks, or in malting - rapid shifting out of labels, broken glass and foils. - use of liquor-proof labels and reduction of the amount of the glue.
Remarks	--
Economics	Good housekeeping measures can often be implemented at little or no cost to the facility. When one considers the effects of reduced waste water charges, reduced water and energy use, and little or no implementation cost, they usually provide a very high return on investment.
Potential	It is anticipated that these measures are already largely applied, given the costs of the cleansing agents, water and heat required for cleansing. A *low* prevention potential has therefore been estimated.

1 Rüffer et al. 1984

SECTION 4

MANUFACTURE OF TEXTILE AND CLOTHING

SECTOR REPORT

Contents :

NACE sectors involved in the present sector report:

Retained for analysis:	17	Manufacture of textiles
	18	Manufacture of wearing apparel; dressing and dyeing of fur
Excluded from analysis:	18.1	Manufacture of leather clothes

4.1 SECTOR CHARACTERISATION

The sectors of NACE 17 and 18 comprise the upstream industries of textile and the downstream industries of clothing[1].

The European textile manufacture sector (NACE 17) covers the preparation, spinning, weaving and knitting of a number of natural and man-made fibres. It also covers the process of textile finishing and the manufacture of carpets.
The sector is mainly made up by a large number of small and medium-sized companies. The total number of companies in the EU in 1993 was about 47 000, of which 72% employed less than 20 people. These smaller firms employed 18% of the total workforce. The sector employs approximately 1.3 million people.
Between 1984 and 1993 nearly 500 000 jobs (28%) were lost. This downfall in jobs was mainly caused by high import-pressure on the European market. The textile sector accounts for 3.1% of the European industrial production output. The industry is concentrated in Italy, Germany, France and the United Kingdom (nearly 80% of the production), Italy being the biggest producer (32%).

The clothing sector (NACE 18) covers the manufacture of garments and clothing accessories[2]. Even more than the textile sector, this sector is characterised by small sized companies (85% of the companies employs less than 20 people). The total number of companies in the EU in 1993 was 67 400, employing 1.1 million people.
Between 1990 and 1994 employment dropped with 16%. The clothing sector accounts for 1.8% of the European industrial production output. The industry is concentrated in Italy (22%), Germany (21%), France (18%) and the United Kingdom (17%).

4.2 PROCESSES AND WASTES

Within NACE 17 and 18, basically four different groups of processes can be distinguished. Each group itself is comprised of a number of different sub-processes. An enterprise can employ a certain mix of (sub)processes or can be dedicated to one process only. The four main processes are:

- production of yarns and texture (NACE 17)
- finishing (NACE 17)
- manufacture of carpets (NACE 17)
- manufacture of garment (NACE 18).

Minor waste generating activities are unpacking, packing, cleaning and maintenance.

In table 4.2.1 the different wastes are listed, together with their process origin; the table includes a tentative priority ranking, based on the amount and the hazardous character of the waste.

Further details on processes and wastes are provided in Annex A.

1 Main source: European Commission, 1995.
2 Excluded is subsector 18.1: Manufacture of leather clothes, which is treated in section 5: Tanning and dressing of leather.

Table 4.2.1: Textile products wastes				
Process origin	**Waste streams**	**Priority rank**	**Description and code according to EWC** [3]	
Production of yarns and texture	Yarn losses	o	Wastes from processed textile fibres	04 02 05 to 04 02 08
Finishing	Base chemicals Dyes and pigments Additives (Waste water) sludges	+	Halogenated wastes from dressing and finishing Non-halogenated wastes from dressing and finishing Dye stuffs and pigments	04 02 11 04 02 12 04 02 13
Manufacture of carpets	Carpet waste	+/o	Wastes from composite materials (impregnated textile, elastomer, plastomer)	04 02 09
Manufacture of garment	Textile waste	o	Wastes from composite materials (impregnated textile, elastomer, plastomer)	04 02 09

Priority rank: + : high significance, o : medium significance, - : low significance EurEco/Witteveen+Bos 1997

Waste streams of minor significance, not included in the table, are:

- grease, wax etc. from natural products (mainly wool)
- fibre losses
- small amounts of textile losses during finishing
- packing, cleaning and maintenance waste.

Yarn losses, consisting mainly of yarns that remain behind on reels, are usually recycled in paper or fibre production.

Base chemicals, dyes and pigments and additives are taken together as one group with waste water treatment sludge. These chemicals are generally employed in wet finishing processes; the wastes are directly disposed of as (mostly hazardous) waste or are discharged into the plant waste water system. As this waste water is treated, these wastes end up as waste water treatment sludge. This category of waste is generally hazardous due to the chemicals and/or metals that they contain.

Textile waste can be recycled almost entirely. However, still significant quantities are lost to disposal instead of being re-used. The amounts being recycled can be increased by improving attention in enterprises or improve infrastructure. Preventing textile waste at its origin results in economic benefits and prevents environmental problems in earlier stages of the process as reprocessing textile[4] costs energy again and repeats environmental damage.

The textile sector poses greater problems for the environment than the clothing sector. The main problems are heavy use of energy in man-made fibres, cleaning processes of natural fibres and water pollution caused by many textile processes, especially finishing operations. Textile waste from the clothing sector, caused by cutting texture, gives rise to few environmental problems because of good reclamation possibilities. Carpet waste reclamation is difficult because of the backing chemicals applied.

3 EWC 04 02 11 and 04 02 13 are hazardous wastes according to the European Hazardous Waste List.
4 Some future options for reprocessing textile are to be found in Umweltbundesamt, 1988-1994.

4.3 WASTE PREVENTION

This section discusses waste prevention methods identified in literature. The major waste streams along with prevention options are summarized in the next table, following the division into four processes as made in the preceding chapter. The options are described in detail in Annex B.

Table 4.3.1: Overview waste prevention options for the textile sector

Waste streams	Priority rank	Waste prevention method		Group	Potential
Production of yarns and texture					
Yarn losses	o	4-1-1	Preventive measures and maintenance program (GOP)	1	o
		4-1-2	Automatic detection systems (TC)	1/2	o
Finishing					
Base chemicals	+	4-2-1	General preventive measures (GOP)	1/2	o
Dyes and pigments		4-2-2	Painting waste preventive measures (GOP/TC)	1/2/3	-/o
Additives		4-2-3a	Alternative paints/chemicals (IMC)	1/2/3	o
(Waste water) sludges		4-2-3b	Checklist on alternative paints/chemicals (IMC)	1/2	o
		4-2-4	Alternative paint application methods (TC)	2/3	-/o
		4-2-5a	Process modifications (TC)	1/2/3	o/+
		4-2-5b	Checklist on process modifications (TC)	2	o/+
		4-2-6	Adaptation of waste water treatment (GOP/TC)	1/2/3	o/+
		4-2-7	Recycling of dyes and pigments (RU)	1/2	o
		4-2-8	Recycling of latex (RU)	1	-
		4-2-9	Recycling of base-chemicals and additives (RU/RC)	1/2	-/o
Manufacture of carpets					
Carpet waste	+/o	4-3-1	Preventive measures (GOP/TC)	1/3	-/o
Manufacture of garment					
Textile waste	o	4-4-1	Preventive measures (GOP)	1	-
		4-4-2	Control-system dryer (TC)	2	..

+ = high, o : medium, - : low, .. = insufficient data — EurEco/Witteveen+Bos 1997

The major waste problem within the textile sector is associated with finishing processes. As explained earlier, finishing process wastes generally occur as a waste water stream, resulting in waste water treatment sludges. In general, the reduction of raw effluent pollution loads will result in less sludge (waste) production as well. To reduce the pollution load, several options involve holding back of pollutants. As a consequence, these pollutants appear as a (new, mostly hazardous) waste stream, which has to be disposed of.

In the last decades, much attention is given towards reduction of effluent loads and hazardous character of the effluents. Therefore, a large number of studies and literature is available related to waste (water) prevention and treatment[5]. The prevention potential of the many options varies from *low to high*, depending heavily on processes applied in a company, age of the equipment, attention that already has been given to waste (water), etc.

5 Studies and reports that provide much information on prevention options in finishing are Tebodin, 1992 (only available in dutch) and Töpfer Planung, 1995 (only available in german).

Textile wastes, a second major waste stream, can be prevented by mostly good operational practices. The prevention potential has been estimated as *low to moderate* as the degree of implementation of most options is expected to be already high for economic reasons.

4.4 EVALUATION

The textile sector can be divided basically into four groups of processes that have specific waste and prevention characteristics: production of yarns and texture, finishing, manufacture of carpets and manufacture of garment.

Major attention on environmental issues has been addressed towards the (hazardous) effluents from wet finishing processes. Much international literature is available on this subject. Efforts on this subject have impact on waste production as well. A broad spectrum of chemicals is applied in finishing. Specific chemical know-how is often absent in textile companies, especially on the SME level. Professional associations and suppliers of chemicals can in this context play an important role within programmes for waste (water) minimisation.

Waste minimisation of textile is an issue that is directly related to the competitiveness of companies in manufacture of especially garment, as textile is the main raw material input. External recycling of textile can be applied to a large extent; maximising this opportunity appears to be a point of interest, as well for individual textile companies as for public and private infrastructure for collection and recycling.

Given that comparative statistics on the application of techniques were in most cases not available, the prevention potentials are based on expert judgement. Considering the great many opportunities available on the one hand, and, on the other hand, the economical pressure on the sector, the potential has been assessed generally as moderate.

Summarizing, it can be concluded that the outlook for clean technologies in the textile industry lies mainly in the field of reducing water pollution from finishing processes. This will have effects on waste production as well. Many studies are performed and information is available; however, especially on the small and medium sized enterprise level, special need may be expected on economical and company-specific technical support.

4.5 BIBLIOGRAPHIC REFERENCES

Beco (1996), "Inventarisatie afvalpreventiemaatregelen Textielveredelings- en tapijtindustrie, Concept-eindrapport", Beco Milieumanagement & Advies B.V., Rotterdam.

Centrum TNO Textiel (1994), "Milieukeur Kleding, eindrapport van het nader onderzoek en van het vervolgonderzoek", Stichting Milieukeur, Den Haag.

CUWVO (1993), "Afvalwater van de textielveredelingsindustrie, werkgroep VI", CUWVO, Den Haag.

DHV (1995), "PATIO, Preventie afvalstoffen en emissies in de textielindustrie in Overijssel", DHV Milieu en infrastructuur BV, Amersfoort.

Elzenga H.E., et al. (1994), "Preventie van industrieel afval; een verkenning van het potentieel aan kwantitatieve preventie van industrieel afval", RIVM, Bilthoven, 181 p.

Enquete Commission of the german Bundestag on the "Protection of Humanity and the Environment" (1994), "Responsibility for the future: Options for sustainable management of substance chains and material flows; interim report, Part 4.3.4. Textiles/Clothing as a Potential Field of Application, p. 224-272", Economica Verl., Bonn, Germany (also available in German).

Etman E.J. et al. (1994), "Verkenning van technologische oplossingen voor milieuproblemen in de textiel- en tapijtveredeling", RIVM, Bilthoven, 35 p.

European Commission (1995), "Panorama of EC Industry 95/96", Bruxelles-Luxembourg.

Heuvelman E.H., Matthijsen A.J.C.M. (1993), "Textielveredeling, Samenwerkingsproject Procesbeschrijvingen Industrie", RIVM, Bilthoven, 15 p.

Milliken A, "Reducing seaming losses during carpet manufacture", GG25 Guide, results of a case study at Milliken Industrials, Environmental Technology Best Practice Program, managed by AEA Technology, through ETSU and the National Environmental Technology Centre, UK.

Milliken B, "Reduction in dye volumes at a carpet tile manufacturer", GG26 Guide, results of a case study at Milliken Industrials, Environmental Technology Best Practice Program, managed by AEA Technology, through ETSU and the National Environmental Technology Centre, UK.

Nussbaumer G, Zippel E. (1995), "Branchenkonzept für den Textilbereich, Band A: Teilkonzept Abfall", Österreichischen Textil-Forschungsinstitut, Bundesministerium für Umwelt, Wien.

Tebodin (1988), "Antimoon in afvalwater van textielveredelingsbedrijven", Provincie Utrecht/Rijkswaterstaat, Lelystad.

Tebodin (1991), "Technical and economic aspects of measures to reduce water pollution from the textile finishing industry", European Commission, Bruxelles.

Tebodin (1992), "Omvang en aard van afvalwaterlozingen in de bedrijfstakken textielveredeling en tapijtindustrie, stand der techniek en te verwachten financiële consequenties (eindrapport)", Rijkswaterstaat, Lelystad.

Tebodin (1993), "Het beheersen van lozingen van milieubezwaarlijke stoffen uit de textielveredeling, Eindrapport haalbaarheidsstudie Probleem/Technologie Combinaties", Novem, Utrecht.

Tebodin (1994), "Verven in superkritisch CO_2, inventarisatie en mogelijkheden voor het verven van textiel", Rijkswaterstaat, Lelystad.

Töpfer Planung (1995), "Branchenkonzept für den Textilbereich, Band B: Teilkonzept Abwasser", Töpfer Planung + Beratung Gesellschaft m.b.H., Bundesministerium für Umwelt, Wien.

Umweltbundesamt, Projektträgerschaft Abfallwirtschaft und Altlastensanierung, Vorhaben 1988-1994, Bundesministerium für Bildung, Wissenschaft, Forschung und Technologie; Projektträger: Umweltbundesamt:
- Forschungsinstitut für Textiltechnologie Chemnitz GmbH (1992); Förderkennzeichen: 1450845.
- HFB Engineering GmbH (1992); Förderkennzeichen: 1470822.
- HFB Engineering GmbH (1993-1995); Förderkennzeichen: 1470822A.
- Institut für Technische Textilien GmbH (1992); Förderkennzeichen: 1440844.

UNEP IE Database:
- Recycling innovations in a Textile Industry, Pandelidis Textiles S.A., Greece.
- EP3, a Textile Dyeing Facility, (1995).
- Reduction of COD in the textile industry (by reclamation of sizing agents), Institut fur Textil- und Verfahrenstechnik, Denkendorf.
- TME; Instead of the traditionally used pumice stones, enzymes can be used to give the garment the same look but a better quality, The Netherlands.

UNEP IE (1993), "The Textile Industry and the Environment, Technical Report N°16", United Nations Publications, Paris, France.

The European Apparal and Textile Organisation (Euratex) has provided general information for the study and has been asked to comment the draft sector report. We did not receive any comments.

SECTION 4

MANUFACTURE OF TEXTILE AND CLOTHING

ANNEX A

PROCESSES AND WASTES DESCRIPTION

Contents :

A.1 OVERVIEW

As defined by codes 17 and 18 of NACE, this sector comprises companies of the following categories:

NACE 17:
- preparation and spinning of textile fibres
- textile weaving
- finishing of textiles
- manufacture of made-up textile articles and other textiles
- manufacture of knitted and crocheted fabrics and articles.

NACE 18:
- manufacture of leather clothes (see section 5; tanning and dressing of leather)
- manufacture of other wearing apparel and accessories
- dressing and dyeing of fur; manufacture of articles of fur.

Within the variety of products and sectors of NACE 17 and 18, basically four different groups of processes can be distinguished. Each group itself is comprised of a number of different sub-processes. The four main processes are:
- production of yarns and texture
- finishing
- manufacture of carpets
- manufacture of garment.

Typical raw materials are:
- fibres:
  - natural
  - synthetic
- pigments and dyes
- a variety of chemicals, such as acids, bleaching agents, softeners, soaps etc. etc.

A.2 PRODUCTION OF YARNS AND TEXTURE

* Process description

Yarns are produced out of a wide variety of fibres. The two basic groups of fibres are natural fibres (mainly cotton, wool and silk) and synthetic fibres (mainly polyester, polyamide and cellulosics).

Characteristic sub-processes in producing yarns are:
- opening
- carding
- spinning
- washing.

Opening is applied to cotton fibres, giving the fibres the required structure to be woven. In carding the fibres are separated and aligned in a thin web, then condensed into a continuous, untwisted strand called a sliver. Spinning implies drawing a small strand of fibres out of a large strand and converting it into yarns. Finally, woollen fibres have to be washed to remove manure, rests of plants, grease and wax.

Texture is made out of yarns by weaving or knitting. The yarns are sized to minimise abberations during weaving by applying agents such as starch or synthetic agents (PVA, CMC).

* **Waste description**

The major wastes from the production of yarns and textile are rests of fibres, rests of yarns and sludge originating in washing woollen fibres.

- *Fibre losses*
  In carding and spinning processes, some parts of the fibres arise as a waste-stream. This waste stream consists mainly of dust and rejects. Usually, this waste can be reclamated in the textile or paper industry.

- *Yarn losses*
  The main source of yarn losses consists of yarns that remain behind on reels. In general, at the weaving production-stage (especially for weaving of carpets), all reels are replaced when the first one is almost out of yarn. However, not all reels will be out of yarn in the same amount as the first one. An average of 0.5 - 1.5 kilogramme remains on the bobbins[1]. Furthermore, waste is caused by rejects. Usually, this waste can be reclamated in the textile or paper industry.

- *Grease, wax etc.*
  In washing of woollen fibres, waste water is produced, containing manure, rests of plants, grease and wax. Reclamation of grease and wax as lanoline is a proven state of the art method[2].

A.3 FINISHING

* **Process description**

Most environmental harm in the textile sector is caused by finishing processes. Textile finishing is probably the most complex stage in the textile production chain. It covers all the processes employed to improve the visual properties of a textile product or to improve the processing and handling properties of the fabric. Different finishing operations are used at various stages of the textile production process, i.e. while the textile fibre is still unspun, while it is still yarn, and once it has become woven or knitted fabric. An enormous variety of different finishing operations is in use. These processes can be divided into three main sub-groups:

- pre-treatment
- dying and printing and
- after-treatment.

Most processes are wet processes, such as impregnating, dipping, flushing etc. In the three subgroups mentioned, various processes can be distinguished, such as:

Pre-treatment:
- singeing (burning off loose surface fibres)
- desizing (removal of size material)
- scouring (removal of foreign components, usually with alkalis)
- Kier-boiling (removal of impurities in cotton by boiling with dilute caustic soda)
- mercerizing (impregnating cotton with cold concentrated caustic soda solution to increase lustre, improve strength and dye ability)

---

1 Beco. 1996

2 In Töpfer Planung, 1995, a future option is mentioned for directly winning grease by supercritic CO_2, so the organic pollution load of the waste water can be reduced.

- bleaching/optical brightening (destroying the natural colouring matter and leave the material white; hydrogen peroxide is widely used, chlorine has stronger bleaching capabilities, but harmful environmental effects).

Dying and printing:
- discontinuous dying (various types of dyes)
- continuous dying (various types of dyes and techniques)
- printing (several methods such as rollers, block, screen etc. and several colour techniques, such as direct, discharge and resist)
- fixation (of the dyestuffs or pigments).

After-treatment/dressing:
- mechanical
- thermal
- chemical.

Dressing enhances the handling properties or tactile qualities of the fabric, or impart special surface effects which enhance its appearance. Examples of operations are softening, waterproofing, lustring, dirt- and fire resistance finishes etc.

* **Waste description**

- *Base chemicals, dyes and pigments, additives and (waste water) sludges*
  Most processes in finishing are wet processes, in which various chemicals, like base chemicals, dyes, pigments and additives are applied, diluted in water. These chemicals generally end up all mixed up in the waste water flow.

  The main sources of contamination are residual baths, non fixated dyestuffs and rinsing water. When the waste water is treated in a waste water treatment plant on site, sludge will arise on the facility.

  In some companies, it is still practice to flush away residual baths and other waste in the sewer. This waste will reappear as sludge. Otherwise, it has to be disposed of as (mostly hazardous) waste.

  Textile effluents generally have a high BOD, high total dissolved solids and a high temperature. Factors that determine effluent quality and quantity include the unit operations used and the degree to which water and chemicals are preserved in a particular manufacturing plant.

  In treating textile waste water, mainly the following techniques are used:
  - biological (aerobic and anaerobic)
  - chemical, such as ozone treatment, coagulation
  - physical, such as membrane filtration.

  The most important waste streams are:

  - sludge, produced out of waste water (circa 60-70 grams sludge is produced for each kilogramme of finished product[1]):
    - organic impurities (such as wax, caused by downboiling);
    - non-fixated dyestuffs (such as sour, basic direct, dispersed, metalcomplex, reactive, sulphur, pigment);
    - base chemicals (such as NaOH from mercerising);

1 Enquete Commission, 1994

- additives (such as biological sizing agents, causing BOD, carriers, antimony, washing agents, antimicrobiotics etc.);

- other hazardous waste:
  - residual baths (dyes, latex, all kinds of chemicals).

- *Textile waste*
  Textile waste from finishing consists of shearing dust, defective product and residues from testing. Circa 30-40 grams textile waste is produced for each kilogramme of finished product[1]. Usually, textile waste can be reclamated in textile or paper production.

The only wastes from textile industry that have been retained from the European Waste Catalogue in the list of Hazardous Waste are EWC 04 02 11: "halogenated wastes from dressing and finishing" and EWC 04 02 13: "dye stuffs and pigments".

A.4 MANUFACTURE OF CARPETS

* Process description

In carpet manufacture, yarn is looped through a woven mat backing, dyed or printed, and then backed with latex. Further, a woven fabric backing is put over the latex. For transporting the carpets through the machines, margins are necessary.

* Waste description

- *Carpet waste*
  Carpet waste consists primarily of cutting-losses caused by slicing off the margins (circa 95% of the carpet-waste) and rejects (change-over losses, control rests). Usually, textile waste can be reclamated in the textile or paper production. However, carpet waste reclamation is difficult because of the backing-chemicals applied. The waste has to be disposed of to landfill.

A.5 MANUFACTURE OF GARMENT

* Process description

In manufacture of garment in general three processes can be distinguished:

- design;
- cutting;
- sewing/confectionate.

* Waste description

- *Textile waste*
  The main waste stream consists of textile. Though textile waste arises in almost all processes in the textile industry, most of it is caused by cutting losses (circa 50%) and rejects (circa 25%[2]). Estimates on the amount of waste lie in between 13 and 17% of the textile handled. Usually, textile waste can be reclamated in the textile or paper production.

---

1 Enquete Commission, 1994

2 Witteveen+Bos, 1996

SECTION 4

MANUFACTURE OF TEXTILE AND CLOTHING

ANNEX B

PREVENTION OPTIONS

Contents :

Sector	Manufacture of textile and clothing (NACE 17 and 18)
Process	Production of yarns and texture
Waste stream	Yarn losses

Prevention option	**Preventive measures and maintenance program**
Option No	4-1-1
Type	GOP
Group	1
Description	The main source of yarn losses consists of yarns that remain behind on the reels. Furthermore, yarn waste consists of rejects. Reduction can be achieved by general good housekeeping measures, including[1]: • optimising batch-sizes (the suitability is strongly dependent on the character of the orders from clients); • reducing bobbin-errors (such as bobbin to tight, yarns flowing off reels); especially in case of internal bobbin; • decreasing the amount of breaks of yarns, by using paper cones for winding threads instead of plastic cones[2]; • regularly control of length of yarns; • applying larger reels (this may require the adaptation of machines; the weight of reels limits the possibilities for this option); • replacement of reels which are almost empty, by temporal reels; • installing seaming units for linking yarns[3].
Remarks	Most of the options mentioned require discussion with suppliers.
Economics	Most of the options mentioned involve low capital costs (education, organizing, extra labour etc.). Data on costs for larger reels have not been found in literature available. The costs of temporal reels lie in between ECU 500 and 5 000. The investments can be paid back in less than 5 years[4]. Seaming units cost circa ECU 5 000 per seamer and give annual benefits of circa ECU 20 000[5].
Potential	Most of the good-operation practices mentioned will be applied to some extent already. However, because the effect on the size of the waste streams is significant, the prevention option has been estimated as *moderate*.

1 Beco, 1996
DHV, 1993
Witteveen+Bos, 1996
2 UNEP IE Database, Recycling innovations in a Textile Industry, Pandelidis Textiles S.A., Greece
3 Milliken A
4 Beco, 1996
5 Milliken

Sector	Manufacture of textile and clothing (NACE 17 and 18)
Process	Production of yarns and texture
Waste stream	Yarn losses

Prevention option	**Automatic detection systems**
Option No	4-1-2
Type	TC
Group	1/2
Description	The following systems are possible [1]: • automatic detection system for reels running out of yarns; • automatic detection of break of yarns.
Remarks	Automatic detection systems for reels running out of yarns are only useful if the exact length of the yarn on the reel is known. The system has to be guided by computers. Automatic detection of break of yarns has no technical limitations. Substantial adaptations in the organisation, however, are required. Apart from reducing waste, a higher quality of tissue and less rejects in a later production-stage will result from this option.
Economics	Investments for an automatic system for detecting reels running out of yarns lie in between ECU 5 000 and 50 000/machine. Automatic detection of break of yarns costs in between ECU 500 and 5 000/machine. Both measures will be paid back in between 2 and 5 years[2].
Potential	It is estimated that these options are not applied extensively. The first option mentioned can reduce the loss of yarns substantially (35-65%), the second only marginally (< 5%)[3]. Considering the initial costs involved, the prevention potential is estimated as *moderate*.

1 Beco, 1996
DHV, 1993
2 Beco, 1996
3 Beco, 1996

Sector	Manufacture of textile and clothing (NACE 17 and 18)
Process	Finishing
Waste stream	Base chemicals, dyes and pigments, additives, (waste water) sludges

Prevention option	**General preventive measures**
Option No	4-2-1
Type	GOP
Group	1/2
Description	Reduction can be achieved by good housekeeping measures, such as[1]: • reducing spills, for example by: - effective logistics; - good machinery (weighing-, stirring-, etc.) in clear and easy to handle atmosphere; - delivery of information (contents, size of production etc.) complete and in time; • improved administration of run-rests; especially with repeated orders; registrating residues of dyes and pigments after a run, feed-back to manufacture and production, resulting in a more accurate manufacture for the next run[2]; • central material-registration; optimum stock-management, resulting in reduction of rejects caused by over-time or non current colours; • increasing tenability of latex-baths by covering stored baths with a foil; the tenability will be increased up to 4 days (not possible for pasta's or dispersions); • preventing over-measures when scaling up (from laboratory-data to production-data); especially for over-measures at existing or new made colour-substrate combinations; • installing a softener system (a digital hardness monitor); in some cases, water hardness is calculated, using a colorimetric method; with a digital system the rinsing and service hardness end points can be determined, resulting in a reduction in the use of softeners[3]; • optimising process-conditions (for example by visual control), such as temperature, textile-transport, acidity, energy and water consumption. Optimising process-conditions results in rise of fixation, less overpainting and less rejects[4]; • optimising run-length; especially in case of discontinuous painting, lead-in and stop losses can be reduced. This option concerns mostly organisational measures such as lengthening the period of planning, link up of orders, adaptation of delivery-times etc. This option becomes more important when the size of orders decreases (which is the current trend). The possibility of this option depends on (among others) the stock-level of the products and the kind of orders; • insertion of displacement-bodies in foulards[5], reducing the volume (applicable with continuous painting and aftertreatment). This option only makes sense in case the displacement-body can easily be inserted. A reduction of the volume of the rest-bath up to 50% is possible.
Remarks	The reduction options mentioned have a positive effect on the quality of the waste-water and may produce less sludge.

To be continued on next page.

1 Beco, 1996
DHV, 1993
2 Töpfer Planung, 1995
3 UNEP IE Database, EP3, a Textile Dyeing Facility, 1995
4 Töpfer Planung, 1995
5 Beco, 1996
CUWVO, 1993

Prevention option	**General preventive measures**
Option No	4-2-1
Economics	• The first 2 options mentioned (reducing spills and administration of run-residuals) do not require large investments[1]. • The next 3 options mentioned (central material registration, covering latex-baths and prevention while scaling up) do require investments up to ECU 50 000, but will in general be paid back within 2 years; the option of prevention when scaling up can require more time, when large organisational adaptations are necessary. • For installing a softener system, a pay back time of 2 years is given in literature. • Optimising process-conditions implies an investment up to ECU 50 000. This investment will be paid back in less than 5 years. In one case study[2] an investment of ECU 40 000 for process control (per discontinuous machine) was mentioned and a nett benefit of ECU 2 000 (per machine). • For optimising run-lengths, no economic data are available. However, little costs and pay-back time are to be expected. • If in the design of the foulards insertion of displacement-bodies has been taken in account, the cost will be approximately ECU 3 000 to 5 000/machine. If this is not the case, costs can be 10 times higher. The annual benefits lie in between ECU 5 000 and 15 000[3].
Potential	The reduction that can be achieved by these options lies in between 5 and 35% for most options. The prevention potential has been estimated as *moderate*.

1 In case an information system has to be installed the costs will be higher (CUWVO, 1993).

2 CUWVO, 1993

3 CUWVO, 1993

Sector	Manufacture of textile and clothing (NACE 17 and 18)
Process	Finishing
Waste stream	Base chemicals, dyes and pigments, additives, (waste water) sludges

Prevention option	**Painting waste preventive measures**
Option No	4-2-2
Type	GOP/TC
Group	1/2/3
Description	Reduction can be achieved by the following options: • applying continuous painting instead of dis-continuous painting (whenever possible); lead-in and stop losses can thus be reduced[1]; • preparation of a minimum amount of paint; this means that a precise prediction of the required amount of paint is necessary. The use of paint is, among others, influenced by colour-absorption of the substrate and the painted area per position. It is proposed to develop a system to measure the consumption of paint (while painting); this option is also applicable for reducing the consumption of other chemicals in case of large lengths of runs (for example in the aftertreatment-stage)[2]; • optimising receptures; for example by using standardised paint-compositions, causing a constant paint-quality. This option is most effective when an automatic paint-manufacture (colour-computer, blend-computer) is installed. It is only possible for companies, which manufacture their paint themselves. Considerable knowledge is required[3]; • reduction of sieving: print-pastes are usually sieved, while this is not always necessary; reduction of sieving saves sieving-residues[4].
Remarks	The reduction options mentioned have a positive effect on the quality of the waste-water and may produce less sludge wastes.
Economics	The first 2 options mentioned require large investments. In one case study on measuring the consumption of paint, the costs were approximately ECU 400 000, resulting in annual costs of circa ECU 75 000. The annual benefits accounted for circa ECU 45 000. Concluded was that in most cases the cost could be considerably lower[5]. An automatised paint-manufacture costs more than ECU 50 000. The benefits account for a pay-back time which will lie in between 2 and 5 years. In reduction of sieving no costs are involved.
Potential	In general, these options will not be applied already. The reduction that can be achieved by these options lies in between 5 and 35%. Measuring the consumption of paint has led to a waste-reduction of 28% in one company[6]. The prevention potential has been estimated as *low to moderate*.

1 More information is to be found in Töpfer Planung, 1995.

2 CUWVO, 1993
Tebodin, 1993
Töpfer Planung, 1995

3 More information is to be found in Töpfer Planung, 1995.

4 Töpfer Planung, 1995

5 CUWVO, 1993

6 CUWVO, 1993

Sector	Manufacture of textile and clothing (NACE 17 and 18)
Process	Finishing
Waste stream	Base chemicals, dyes and pigments, additives, (waste water) sludges

Prevention option	**Alternative paints/chemicals**
Option No	4-2-3a
Type	IMC
Group	1/2/3
Description	The environmental harmfulness or the amount of this waste can be reduced by a well-considered choice of raw materials. Possibilities are[1]: • paints free of heavy metals or causing less EOX-load[2]; • sizing agents with a high bio-degradability[3]; • dispersions for vulcanisation (applying backing to carpets) containing less zinc[4]; • reactive dyes with a higher degree of fixation; a degree of fixation of 60-70% is usual; for some discontinuous painting colours[5], reactives are available with a fixation-degree of 90%[6]; • alternative thickeners for printing, resulting in a raised fixation of pigments. Only applicable for reactive dyes; • replacing kaliumdichromate ($K_2Cr_2O_7$) by, for example, hydrogenperoxyde for the chemical fixation of sulphur- and bathpigments; • thermosolfixation for continuous painting of polyestersubstrates or mixtures. This results in an open structure of the polyester-fibres, so carriers are no longer needed. A negative result can be the release of antimony from the polyester (antimony is used as a catalyst by the production of polyester)[7]; • antimicrobiotics with a very high degree of fixation (up to 100%); the applicability is not yet well known. Future options are: • "trichrome"; manufacture of applied colours out of three basic colours. This option is in the development-stage. The applicability will depend on the required spectrum of colours in a company and on the required qualities of the product; • replacement of reactive pigments by direct pigments for discontinuous painting, resulting in a higher degree of fixation, but also a lower washability and lightfastness. This option is in the development-stage.
Remarks	The reduction options mentioned have a positive effect on the quality of the waste-water and may produce less sludge wastes.

To be continued on next page.

1 Beco, 1996
CUWVO, 1993
2 Töpfer Planung, 1995
3 Elaborate information on bio-degradable sizing agents is to be found in Töpfer Planung, 1995.
4 Possibilities are not yet well known.
5 For circa 5% of the consumption of dyestuffs.
6 Detailed information is to be found in Töpfer Planung, 1995.
7 Elaborate information on antimony in waste water from textile-finshing can be found in Tebodin, 1988 (only available in Dutch).

Prevention option	**Alternative paints/chemicals**
Option No	4-2-3a
Economics	• Metal free paint is state of the art. • No economic data have been found on vulcanisation-dispersions containing less zinc and bio-degradable sizing agents. • Reactive dyes with a higher degree of fixation are approximately ECU 20 per kilogramme more expensive; change-over of receptures costs about ECU 1 200 per recepture; the pay-back time is estimated as more than 5 years. • Alternative thickeners can have annual benefits up to ECU 40 000[1]. • Replacement of kaliumdichromate and use of thermosolfixation is state of the art. • Use of trichrome will cost more than ECU 50 000, the pay-back time is not yet known; the same accounts for the replacement of reactive pigments by direct pigments.
Potential	• The use of metal free paints and vulcanisation-dispersions does not give a quantitative reduction of waste, but gives a qualitative improvement. • Pigments with higher degrees of fixation are applied extensively; reduction up to 35% is feasible. • Alternative thickeners are less extensively applied (up to 35%). Reduction up to 35% is feasible. • Replacement of kaliumdichromate and use of thermosolfixation is state of the art. • Trichrome is not yet applied in companies; the potential reduction is not known yet. • Replacement of reactive pigments by direct pigments is incidently applied; waste reduction up to 5% is achievable. The prevention potential of this group of options is estimated as *moderate.*

1 CUWVO, 1993

Sector	Manufacture of textile and clothing (NACE 17 and 18)
Process	Finishing
Waste stream	Base chemicals, dyes and pigments, additives, (waste water) sludges

Prevention option	**Checklist alternative paints/chemicals**
Option No	4-2-3b
Type	IMC
Group	1/2

Description

The next checklist of possible chemical substitutions is included in the report UNEP IE (1993), "The Textile Industry and the Environment, Technical Report N°16", United Nations Publications, Paris, France.

- Use synthetic warp sizes (based on PVA and acrylates) in place of the conventional starch-based size preparations;
- use mineral acids for acid-desizing in place of enzymatic desizing;
- use synthetic detergents in place of soaps;
- use sodium acetate in place of soda ash for neutralising scoured goods so as to convert mineral acidity into volatile organic acidity;
- use ammonium sulphate in place of acetic acid for pH adjustment in disperse dyeing and pigment printing; although the salt concentration of the effluent would increase in this substitution, ammonium would serve as a nutrient in the biological treatment process;
- substitute emulsion-thickening, fully or partially, for gum thickening in textile printing;
- use sodium bicarbonate (in place of acetic acid) in conjunction with peroxide or perborate for the oxidation of vat dyes;
- use permanent adhesive on tables and screen-printing machines (Flat Bed and Rotary types) in place of conventional gumming;
- use durable resin finishes in place of temporary finishes based on starch materials;
- use single-class dyestuffs like Indigosol, pigments, etc. for dyeing blended varieties in pale shades in place of two stage dyeing using two different classes of dyes (e.g. polyester using disperse and cellulosics using vats, reactives, etc.);
- use all-aqueous phthalogen blue dyeing in place of solvent-based phthalogen blue dyeing which requires speciality auxiliary products;
- use monochlorobenzene in the place of other carriers for dyeing Dacron;
- substitute formic acid for acetic acid in dye baths (acetic acid 0.64 kg BOD/kg; formic acid 0.12 kg BOD/kg);
- replace carding oils and anti-stat lubricants with non-ionic emulsifiers.

Remarks

The possibilities for the options given are usually very site-specific.

The reduction options mentioned have a positive effect on the quality of the waste-water and may produce less sludge wastes.

Economics

No economic data are given.

Potential

The prevention potential of this group of options is estimated as *moderate*.

Sector	Manufacture of textile and clothing (NACE 17 and 18)
Process	Finishing
Waste stream	Base chemicals, dyes and pigments, additives, (waste water) sludges

Prevention option	**Alternative paint application methods**
Option No	4-2-4
Type	TC
Group	2/3
Description	Reduction can be achieved by alternative application methods[1]: • replacement of batch-process by pad-batch process, resulting in a higher fixation-degree of pigments. After painting, a substrate has to be stored under controlled conditions for 2-12 hours before it can be rinsed. Large series are required for this option. Yet, it is only applicable for yarns; the applicability for textures is being researched[2]; • use of High-Temperature (HT-) paints for discontinuous painting of polyester or polyester-mixtures: the high temperature gives the fibres a more open structure, so the pigments can penetrate the fibres without use of carriers. This option is only feasible in case machinery has to be replaced for other reasons. It is unknown whether antimony will be released while using HT-paints on polyester (antimony is used as a catalyst by the production of polyester)[3]; • use of a paint application aggregate with continuous painting in carpet-production. The advantage over a foulard is the limited content of the system and the good control over the supply of paint, which causes a reduction of the paint consumption and a higher quality (less rejects); • alternative application-techniques with aftertreatment (so-called minimum-application- techniques), such as foaming, spraying, licking (for painting); only possible for low concentrations of additives; this option requires radical changes; • ink-jet printing (still being developed) for small series and low running-speeds; in the case of carpets, it is possible only for relatively thin carpets; • transfer printing; only suitable for some synthetic fibres, mainly polyester[4]; • 2-phase printing instead of 1-phase printing[5]. Future options are: • super-critic CO_2-painting for discontinuous painting; instead of water, liquid CO_2 functions as carrier for pigments; only for polyester yarns and textile, still being researched[6]; • "Kekko"-application (application of the paint by brushes); only for wash-out articles[7]. No detailed information on applicability available yet.
Remarks	The reduction options mentioned have a positive effect on the quality of the waste-water and may produce less sludge wastes.

To be continued on next page.

1 Beco, 1996
Töpfer Planung, 1995
2 Further information on pad-batch dyeing is given in UNEP IE, 1993.
3 Elaborate information on antimony in waste water from textile-finshing can be found in Tebodin, 1988 (only available in Dutch).
4 UNEP IE, 1993
5 Töpfer Planung, 1995
6 Tebodin 1994, is dedicated to painting in super-critic CO_2 (only available in Dutch, including an elaborate summary in English), information can be found also in Töpfer Planung, 1995.
7 Töpfer Planung, 1995

Prevention option	**Alternative paint application methods**
Option No	4-2-4
Economics	All options mentioned require investments of more than ECU 50 000, except the option of a paint application aggregate, which costs approximately ECU 25 000/machine. Most options have a pay-back time of in between 2 and 5 years. The pay back time of a paint application aggregate, ink-jet and CO_2-painting is unknown. The costs for an modified machine for HT-paints were circa ECU 100 000 (1993), which is about 1,5 to 3 times as expensive as usual[1]. No economic data on transfer printing, "Kekko"-application and 2-phase printing have been found in literature.
Potential	Pad-batch and the paint application aggregate are not yet applied extensively. Ink-jet printing and CO_2-painting are applied only incidently. The other options mentioned are applied extensively. The feasible waste-reduction of the options mentioned is in general up to 5%, with the exception of alternative application techniques and ink-jet printing, where up to 35% reduction is achievable. The prevention potential of this option is estimated as *low to moderate.*

1 CUWVO, 1993

Sector	Manufacture of textile and clothing (NACE 17 and 18)
Process	Finishing
Waste stream	Base chemicals, dyes and pigments, additives, (waste water) sludges

Prevention option	**Process Modifications**
Option No	4-2-5a
Type	TC
Group	1/2/3
Description	Reduction can be achieved by adaptation of processes[1]: • use of a dosage-unit with discontinuous painting (only with jet-machinery), resulting in a more efficient use of reactive pigments, because less paint hydrolyses in the water; • modified rotary printing-presses (reducing the contents with 3 kilogramme per position). A negative result can be an increase of energy-consumption (air pressure pumps are less efficient than mechanical pumps and smaller pipes have a higher resistance). A prototype has been developed, but needs still to be introduced commercially[2]; • linking-up of processes; for example desizing, bleaching and downboiling[3], reactive painting and aftertreatment of cotton; • use of air-pressure pumps for pumping back the contents of pipes[4]; • producing samples with ink-jet; with the production of samples, approximately 95% of the manufactured paint ends up as waste; reduction can be achieved by manufacturing the samples with an ink-jet machine[5]; • improved design of machinery, such as pumps and pipes, reducing the contents of system[6]; • mechanical scrapes in stock-barrels, to recover the remaining paint for re-use in the process[7]; • stone-washing by enzymes, instead of the traditionally used pumice stones[8].
Remarks	The options mentioned have a positive effect on the quality of the waste-water and may thus result in less sludge.
Economics	• The dosage-unit (investment up to ECU 50 000) and the modified rotary print-press (in development) will be paid back in less than 2 years; the annual costs of a modified rotary press are estimated as ECU 8 000 and the benefits as ECU 12000/a. • For linking up processes, air pressure pumps and producing samples with ink-jet the pay-back time lies in between 2 and 5 years. The required investments are respectively less than 50 000, approximately 50 000 and more than ECU 50 000. • Improved design of machinery and mechanical scrapers do not seem to pay back, in spite of a mentioned annual benefit in one company of ECU 50 000. • Use of enzymes for stone washing requires no investment costs. Further economic data have not been found in literature. To be continued on next page.

1 Beco, 1996
CUWVO, 1993
Tebodin, 1991
2 Tebodin, 1993, other examples of reducing the content of the system are given in Töpfer Planung, 1995.
3 Töpfer Planung, 1995
4 Only applicable for rotary printing-presses. For more information see Töpfer Planung, 1995.
5 Töpfer Planung, 1995
Milliken B
6 Milliken B
7 Tebodin, 1993
8 UNEP IE Database, TME, The Netherlands.

Prevention option	**Process Modifications**
Option No	4-2-5a
Potential	Only the dosage-unit is generally applied. The other options are not or only incidentally applied. The reduction potential of most options lies between 5 and 35%; linking up processes and mechanical scrapers account for a reduction up to 10%. The overall prevention potential of this group of options is estimated as *moderate to high*.

Sector	Manufacture of textile and clothing (NACE 17 and 18)
Process	Finishing
Waste stream	Base chemicals, dyes and pigments, additives, (waste water) sludges

Prevention option	**Checklist process modifications**
Option No	4-2-5b

Type: TC

Group: 2

Description: The next checklist of possible cleaner production process modifications is included in the report UNEP IE (1993), "The Textile Industry and the Environment, Technical Report N°16", United Nations Publications, Paris, France.

- Single-stage desizing-scouring-bleaching processes for the processing of cellulosics and their blends with synthetics;
- solvent-aided scouring and bleaching processes;
- activated peroxide bleaching taking chemically treated goods straight into a peroxide bath through the washing machine;
- dyeing-sizing of warp yarns for denim style products;
- hot mercerisation in place of conventional cold mercerisation, often enabling the elimination of separate scouring treatment;
- combined Disperse and Reactive/Direct colour-dying of blended fabrics containing low percentages of cellulosics;
- use of padding method in place of exhaust methods for dyeing, wherever possible;
- use of bicarbonate in a peroxide bath for vat oxidation to convert the caustic alkalinity into carbonate alkalinity for its easier removal; caustic alkalinity requires a plentiful supply of water;
- electrolytic process for the dyeing of vat colours and reduction-clearing of disperse colour printed synthetic fabrics;
- dry-heat fixation techniques for the development of Rapidogen prints in place of the conventional acid-steaming method;
- direct finishing of pigment printed goods and direct carbonizing of disperse printed goods without intermediate washing.

Remarks: The possibilities for the options given are usually very site-specific.

The options mentioned have a positive effect on the quality of the waste-water and may result in less sludge.

Economics: No economic data are given.

Potential: The prevention potential of this group of options is estimated as *moderate to high.*

Sector	Manufacture of textile and clothing (NACE 17 and 18)
Process	Finishing
Waste stream	Waste water treatment sludges

Prevention option	**Adaptation of waste water treatment**
Option No	4-2-6
Type	GOP/TC
Group	1/2/3
Description	In case the waste water is treated under own management, the amount of sludge can be reduced by[1]: • optimisation of process conditions of the waste water treatment plant; a (mobile) pilot plant can be used to optimise process conditions like oxygen-supply, chemical-supply etc.; less use of chemicals results often in less sludge arising; • application of alternative techniques that produce as little sludge as possible, such as ozonisation or ultra filtration techniques; in general, this involves systems with minimal use of chemicals; • treatment of separated waste water streams by methods that produce less sludge than in the case that all streams are treated mixed up in one central waste water treatment plant.
Remarks	The possibilities have to be evaluated by site-specific studies on the water situation and options to prevent water consumption or treatment of separated streams.
Economics	• The benefits of optimising process conditions by a mobile pilot plant usually outweigh the costs; the benefits may be less energy-consumption, less consumption of chemicals and less production of sludge. • Alternative techniques usually require large investments. Whether these investments will be payed back, will depend on the specific situation. • To what extent treatment of separated waste-streams is profitable, depends heavily on the specific situation. Sometimes, complications occur and large investments are required for changing the plant infrastructure in order to separate and transport different waste water streams. For new plants, however, separate systems can be implemented more easily within the design. Generally, (short) studies on the water situation and prevention-options do profit.
Potential	The potential of this option (especially optimising process conditions of the waste water treatment plant) is estimated as *moderate to high*,

1 In Töpfer Planung, 1995, most waste water treatment techniques are set out extensively (approximately 225 p.). Also, Tebodin, 1991 gives elaborate information on effluent treatment technology, including economic data.

Sector	Manufacture of textile and clothing (NACE 17 and 18)
Process	Finishing
Waste stream	Base chemicals, dyes and pigments, additives, (waste water) sludges

Prevention option	**Recycling of dyes and pigments**
Option No	4-2-7
Type	RU
Group	1/2
Description	The amount of paint waste discharged with waste water can be reduced by internal recycling of rests of paint[1]. The applicability depends on the type of pigment. It is necessary to collect rests of paint accurately to prevent mixing of colours. Recycled paint may be applied in processes where a lower quality is accepted. Also, less current colours can be mixed to darker or black colours. Software, supporting these recycling applications, is available. Reclamation of *thickeners of print-pastes* is considered a promising future option[2].
Remarks	The reduction option mentioned has a positive effect on the quality of the waste-water and will reduce waste water sludge production. If paint rests are normally flushed away in the sewer, a separate transport system is required. This may require extensive adaptations[3].
Economics	The costs and benefits depend strongly on the type of company and the degree in which paint already is recycled. In one case study, the costs were estimated to lie in between ECU 10 000 and 70 000 and the benefits in between ECU 15 000 and 110 000[4].
Potential	By internal recycling, a reduction of paint waste can be achieved of up to 45%[5]. However, this option is considered to be applied already extensively. The prevention potential of this option is estimated as *moderate*.

1 Beco, 1996
CUWVO, 1993
Tebodin, 1993
Töpfer Planung, 1995
2 Töpfer Planung, 1995
3 CUWVO, 1993
4 CUWVO, 1993
5 Tebodin, 1991

Sector	Manufacture of textile and clothing (NACE 17 and 18)
Process	Finishing
Waste stream	Base chemicals, dyes and pigments, additives, (waste water) sludges

Prevention option	**Recycling of latex**
Option No	4-2-8
Type	RU
Group	1
Description	The amount of latex waste can be reduced by internal recycling. For this option it is necessary for a company to manufacture the precoat themselves. The applicability further depends on the used backing-techniques en the required specifications of the latex used[1].
Remarks	The reduction option mentioned has a positive effect on the quality of the waste-water and may reduce the amount of waste water treatment sludge.
Economics	The annual benefits of this option can add up to about ECU 40 000 (for an average company) while investments of only about ECU 2 500/machine may be required[2].
Potential	This option is applied extensively as a high reduction can be achieved for low costs. The prevention potential is therefore estimated as *low*.

1 Beco, 1996
2 CUWVO, 1993

Sector	Manufacture of textile and clothing (NACE 17 and 18)
Process	Finishing
Waste stream	Base chemicals, dyes and pigments, additives, (waste water) sludges

Prevention option	**Recycling of base chemicals and additives**
Option No	4-2-9
Type	RU/RC
Group	1/2
Description	Reduction of waste consisting of base chemicals and additives can be achieved by internal recycling or reclamation; options are[1]: • recycling of NaOH at mercerizing; spent NaOH baths can be purified with for example H_2O_2 and treated, for example by evaporation. Partial supply of fresh NaOH will remain necessary[2]; • reuse of rinsing water (for example at discontinuous bleaching)[3]; • reclamation of rinsing water caused by mercerizing for cleaning of desized textures; in specific cases the rinsing-water has to be treated. The temperature and concentration of NaOH are fit for this application; • reclamation of NaOH from mercerizing for application at ungumming processes (only applicable in specific situations); • re-use of tenable baths with aftertreatment; for example baths containing flame retardants and antimicrobiotics; • reclamation of backing-sludge as latex is possible in some specific cases; difficulties are associated with the usual required specifications of the latex; • re-use of sizing-agents (such as CMC and PVA) after purifying the waste water stream of de-sizing by membrane-filtration (ultra-filtration); this is only applicable in case of sizing and de-sizing in the same facility. In case of sizing with starch, re-use is not possible because of chemical or enzymatic disintegration of starch in de-sizing[4].
Remarks	The reduction option mentioned has a positive effect on the quality of the waste-water.
Economics	The economic feasibility depends strongly on the specific situation in a company; in case transport systems have to be constructed, or if expensive reclamation/purifying equipment is necessary, large investments are required.
Potential	These options are in general expected to be widely applied, as far as possible in each specific situation. The achievable waste-reduction per option, however, is large. Therefore, the prevention potential is estimated as *low to moderate.*

1 Beco, 1996
CUWVO, 1993
UNEP IE, 1993
2 Detailed information on reuse of NaOH can be found in Töpfer Planung, 1995
3 Töpfer Planung, 1995
4 Unep IE Database, Reduction of COD in the textile industry (by reclamation of sizing agents), Institut fur Textil- und Verfahrenstechnik, Denkendorf. Further information on optimising of sizing-desizing systems is given in UNEP IE, 1993, more elaborate (technical) information is to be found in Töpfer Planung, 1995.

Sector	Manufacture of textile and clothing (NACE 17 and 18)
Process	Manufacture of carpets
Waste stream	Carpet waste

Prevention option	**Preventive measures**
Option No	4-3-1
Type	GOP/TC
Group	1/3
Description	Textile wastes in carpet production consists primarily of cutting-losses (circa 95% of the carpet-waste) and of rejects (change-over losses, control rests). Reduction can be achieved by[1]: • reducing the margin-width that is cut off; • reducing the part of the margin to which raw materials are applied. Margins are necessary for transporting the carpets through the machines. For reducing the sizes of the margins, usually drastic modifications to the machines will be necessary. Not applying raw materials to a part of the margins requires less adaptations. Possibilities for re-use of the cutting-losses will be increased as well. Reducing the length of the change-over losses at the tufting process (for example when changing colours) can be achieved by changing the reels in 6 steps instead of 3 or 4. However, more labour is required.
Remarks	Carpet waste reclamation is difficult because of the backing-chemicals applied. The waste has to be disposed of to landfill.
Economics	In general, modifications on machines in order to reduce the size of the margins are too expensive to make this option profitable. Reducing the application of raw materials to the margins will in general be paid back within reasonable time.
Potential	Reducing the size of the margins is not yet widely applied. A substantial reduction could be achieved. However, capital investments are high. Reducing the application of raw materials to the margins and reducing change-over losses are applied extensively. Up to 35% reduction can be achieved for both options. The prevention potential of this option has been estimated as *low to moderate.*

1 Beco, 1996
CUWVO, 1993

Sector	Manufacture of textile and clothing (NACE 17 and 18)
Process	Manufacture of garment
Waste stream	Textile waste

Prevention option	**Preventive measures**
Option No	4-4-1
Type	GOP
Group	1
Description	The sources of textile waste are rejects and cutting losses. Reduction can be achieved by good housekeeping measures, such as[1]: • cutting straight along the yarns of the textile (by instructing personnel or by introducing special machinery); • protection of textile in stock; • optimising fitting in of patterns (if possible with CAD/CAM); • sewing round cloth in an early stage; • optimising batch-sizes; • introducing extra seams.
Remarks	Textile waste usually is externally recycled in paper production or textile fibre production.
Economics	No data on costs and benefits of these options have been found in literature. In general minor costs will be involved concerning education, process-control machinery, extra labour and small process modifications. The option of introducing extra seams is rejected by Dutch federations for reasons of quality and costs[2].
Potential	By a combination of the options mentioned, an average waste-reduction of 15% can be achieved. Optimising batch-sizes can give a reduction of up to 10% (wool and cotton). Most options are expected to be applied already. The prevention potential has therefore been estimated as *low*.

1 DHV, 1993
Elzenga, 1994
Witteveen+Bos, 1996

2 Witteveen+Bos, 1995

Sector	Manufacture of textile and clothing (NACE 17 and 18)
Process	Manufacture of garment
Waste stream	Textile waste

Prevention option	**Control-system dryer**
Option No	4-4-2
Type	TC
Group	2
Description	At processing tricot (such as die-cutting) a constant humidity is required. This can be achieved by using an automatic, humidity-driven dryer[1]. This will cause less interruptions in die-cutting and thus result in less rejects.
Remarks	A reduction of energy-consumption may be achieved as well, because conventional dryers usually dry the cloth further than necessary.
Economics	In general, an investment of ECU 15 000/machine is required. This will be paid back in 3 years, if one mis-run per day can be avoided.
Potential	This option is not yet extensively applied. Data on reduction potentials are not yet available. A prevention potential can therefore not be given.

1 DHV, 1993
Witteveen+Bos, 1996

SECTION 5

TANNING AND DRESSING OF LEATHER

SECTOR REPORT

Contents :

NACE sectors involved in the present sector report:

Retained for analysis:	19.1	Tanning and dressing of leather
Excluded from analysis:	19.2	Manufacture of luggage, handbags and the like, saddlery and harness
	19.3	Manufacture of footwear

5.1 SECTOR CHARACTERISATION[1]

This section describes the manufacture of leather and leather products as defined by code 19 of NACE, Rev.1 (1991). Environmental issues, including waste production, within this sector are mainly associated with tanning and dressing of leather (NACE 19.1). Therefore, the focus of this report will be on tanning and dressing. The other sub-sectors of NACE 19 are the manufacture of luggage, handbags and the like, saddlery and harness (NACE 19.2) and the manufacture of footwear (NACE 19.3)[2].

Tanning is the process by which animal hides and skins are converted into leather. The tanning industry recovers a by-product of the meat industry which would otherwise be waste and would have to be disposed of. The leather produced is basically an intermediate for sectors as footwear, clothing, furniture etc. Tanning is a relatively small and capital intensive sector. The sector has lost over 1 000 production units and about 30 000 employees since 1983. Total EU leather production today is about 250 million m^2, which is 15% less than a decade ago. This trend is likely to continue as European tanneries suffer rising prices in hides and skins, while consumption of leather is dropping in the EU.

The total number of tanneries in the EU in 1993 was about 3 000, employing a total of approximately 52 000 workers. These numbers have dropped to less than 3 000 in 1995, employing some 50 000 workers[3]. Small and medium-sized enterprises predominate in the tanning sector. In the databank of the EU tanning industry[4], recording the 1 000 most important companies of the sector, in 1993 only 38 tanneries appear to employ more than 100 people, while over 700 tanneries have less than 20 workers.

Southern EU Member States predominate in the geographical distribution of production with Italy being by far the most important leather producer accounting for about 60% of the total production. Other important producers are France, Germany, Spain and the United Kingdom.

5.2 PROCESSES AND WASTES

Within the traditional production process of tanning leather, the following groups of sub-processes can be distinguished:

- beamhouse operations: soaking, liming and unhairing, fleshing, deliming and degreasing
- tanning operations: including the actual tanning as well as the preceding pickling process
- post-tanning operations: (chrome) splitting, shaving, retanning, dyeing, fat liquoring, drying, batting, trimming and finishing.

Individual enterprises generally employ all sub-processes within the groups of operations mentioned above. A further description of these processes is given shortly in Annex A.

In table 5.2.1 the different wastes are listed, together with their process origin; the table includes a tentative priority ranking, based on the amount and the hazardous character of the waste. The wastes are described in more detail in Annex A.

1 Main source: European Commission, 1995

2 Although no specific information on wastes of the manufacture of leather ware and footwear has become available in this study, the losses from cutting leather can be expected to be the largest waste streams. Reducing the amount of cutting losses is mainly a matter of optimisation and good-operation practices. Minimisation is likely to occur often for economical reasons (reducing costs of main raw materials); reducing cutting losses is, however, also important for environmental reasons as it affects the (waste) production at tanneries as well.

3 Cotance, 1996

4 European Commission, 1995

Table 5.2.1: Leather tanning and dressing wastes				
Process origin	**Waste streams**	**Priority rank**	**Description and code according to EWC**	
Beamhouse	Waste water sludge	o	Sludges free of chromium	04 01 07
	Liming waste (hair, lime, organic matter, sludge)	-	Liming waste	04 01 02
	Fleshings and limed splittings	-	Fleshings and lime split waste	04 01 01
	Greasy residues	o[5]	Degreasing wastes containing solvents without a liquid phase	04 01 03
Tanning	Spent tanning liquor	-	Tanning liquor containing chromium	04 01 04
	Waste water sludge	+	Sludges containing chromium	04 01 06
Post-tanning	Splits and shavings (chrome containing organic matter)	+	Waste tanned leather containing chromium	04 01 08
	Waste water sludge	o/+	Sludges containing chromium	04 01 06
	Spent dyes/solvents	-	Wastes from dressing and finishing	04 01 09

Priority rank: + : high significance, o : medium significance, - : low significance   EurEco / Witteveen+Bos 1997

Waste streams of low significance, not included in the table, are:
- splits and shavings from chromium free tanned leather
- spent tanning liquor, free of chromium (EWC 04 01 05)
- tanning waste and post-tanning water sludges, free of chromium
- buffing dust
- post-tanning lubricants.

The arising of wastes in tanneries is related to the operation of tannery processes, of course, but also to the quality of the input materials (hides and chemicals).

The waste streams identified for the beamhouse operations are ranked as low to medium significance. Beamhouse operations produce major *waste water* streams (especially at unhairing and liming); the treatment of this waste water produces waste sludges. These sludges have been ranked as (only) medium significance, because of the non-hazardous character and the potentials for valorisation. Virtually all of the other waste streams are recovered and actually reused as secondary raw material in other industrial activities[6], and are therefore considered to be of low significance.

The tanning and post-tanning operations include waste streams that are ranked medium to high significance. The major waste streams are sludges from the (separate) treatment of chromium (Cr(III)) containing waste water, and solid residues: fleshings, splittings and shavings of the hides[7]. The possible presence of chromium in these wastes may interfere with waste recycling opportunities and it requires attention when wastes are disposed of (see as well: footnote 5). The majority of the leathers today are chrome tanned; alternative tanning materials are not often used.

5 The only waste from leather industry that has been retained from the European Waste Catalogue in the list of Hazardous Waste is EWC 04 01 03: "degreasing waste containing solvents without a liquid phase". European leather industry has put much effort in controlling chromium pollution; as a consequence, chromium containing wastes (sludges and spent tanning liquors, EWC 04 01 04 and 04 01 06), have been retained only as possible hazardous waste streams, depending on case to case evaluation.

6 The by-products can be re-used by recovering and producing gelatin, protein, grease, meat meal, leather board and fertilizers, depending on the type and concentration of contaminants.

7 Spent tanning liquor (EWC 04 01 04) is considered of low significance, as this stream generally is discharged with waste water and consequently ends up as waste water sludge (therefore already included in EWC 04 01 06).

Other environmental issues than waste or waste water, are related to the use and emission of volatile organic compounds (VOC) at hide degreasing and at dyeing and finishing of tanned leather[8].

5.3 WASTE PREVENTION

This section discusses waste prevention methods identified in literature. The major waste streams along with their prevention options are summarized in the next table, following the division into three groups of processes as made in the preceding chapter. Short descriptions of these options are given in Annex B.

Table 5.3.1: Overview waste prevention options for tanning and dressing of leather

Waste streams	Priority rank	Waste prevention method	Group	Potential
Beamhouse operations				
Waste water sludge free of chromium	o	5-1 Water conservation (GOP/TC/RU) 5-2 General methods for reduction of waste water pollution load (GOP/IMC/TC) 5-3 Alternative process methods (IMC/TC)	1/2 1 1/2/3	o o o
Liming waste	-	5-4 Alternative liming/deliming methods (TC/IMC)	1/2/3	o/+
Fleshings/splittings	-	5-5 Green fleshing (GOP/TC/RC)	1	o
Degreasing waste	o	5-6 Alternative degreasers (IMC)	3	+
Tanning				
Spent tanning liquor and sludges, containing chromium	+	5-7 High chrome exhaustion (GOP/IMC/TC) 5-8 Alternative tanning agents (IMC) 5-9 Chrome-recycling (TC/RU/RC)	1 1/3 1	o/+ -/o +
Post-tanning operations				
Waste tanned leather containing chromium	+	5-10 Limed splitting (TC)	1	o
Waste water sludges, containing chromium	o/+	see: 5-7 and 5-8	1/3	-/o
Spent dyes/solvents	-	5-11 Alternative dyeing methods (TC) 5-12 Alternative finishing or dyeing agents (IMC)	1 1	o o

+ = high, o : medium, - : low, .. = insufficient data EurEco/Witteveen+Bos 1997

The prevention methods identified provide a broad outline and should not be seen as limitative. Tanning industry is characterized by a large diversity of processes and chemicals applied. General prevention options, as reported shortly, are not universally applicable. Further studies on waste minimisation should therefore be performed on an individual company level. To facilitate this research, GERIC[9] has developed a Databank of clean technologies applied Europe wide for the leather sector. This Database can be consulted through the GERIC Institutes or via Cotance; information from the Database can be used to support individual studies on waste minimisation.

8 WGR, 1995: In Germany nowadays, 85% of finishing processes is carried out exclusively with water-based finishes, 10% with organic solvent finishes and 5% with a combination of the two.

9 Grouping of European Leather Research Institutes

Substantial efforts are given to reduce the amount of waste water produced. Reducing waste water sludges requires reduction of the pollution load within the waste water as well. This can be achieved by preventing and removing of organic (solids) from waste water prior to (biological) treatment. The prevention potentials of various methods are assessed as medium.

For many years already, much attention has been paid to reducing chrome containing wastes, resulting in much lower consumption of chrome per product. Therefore, the waste prevention potential of the options identified for *chromium containing spent tanning liquor and sludges*, has been assessed as low to moderate.
Lower chrome consumption rates and improved chrome recovery and treatment of waste water, have resulted in lower chrome levels in waste streams. However, major alternatives for the usage of chrome, have not been developed yet.

In an increasing number of plants, much effort is put in recovering residues for converting them as input to other industries[10,11]. In addition, to improve the recovery potential, waste prevention strategies focus on reducing the amount of organic material *(liming waste, fleshings, splittings, degreasing waste and waste tanned leather)* that is contaminated with chemicals. For example, wastes produced after tanning of the hides, are in general contaminated with chromium. Therefore, attention focuses on employing as much sub-processes prior to the tanning stage as is technically and economically feasible. The prevention potential of these options has been assessed mostly as moderate.

5.4 EVALUATION

Low waste technology has become more and more integrated within EU tanneries, for reasons of competitiveness as well as legislation in regard to waste water discharges. External reclamation of by-products has been (and still is) an important waste management strategy in the leather industry. Nearly all waste materials can be externally re-used.

The quality and quantity of a part of the waste streams are dependant on the quality of raw materials used (hides and chemicals). Waste minimisation opportunities could be found in a coordinated approach of tanneries and its up-stream activities, with the objective to reduce contamination of the raw materials.

The active approach of the EU leather sector towards clean technologies is demonstrated by its development of a Databank of clean technologies. The database can be consulted through the national GERIC[9] institutes. In this way, Europe-wide experience is made available, while managed by experts of leather industry.

10 European Commission 1995 and, for example, IUE Recommendations for Tannery Solid By-Product Management, 1995.

11 External re-use options are generally available for nearly all wastes. However, for some specific wastes, still problems can arise (for technical and/or economical reasons) e.g. grease from aqeuous and solvent degreased sheepskins, buffing dust, finished leatherwaste, finishing resins, recovered salts and chromium containing waste. Chromium containing wastes are investigated for use as an energy source, for example, by gasification or incineration.

5.5 BIBLIOGRAPHIC REFERENCES

Adzet Adzet, Dr. José Mª (1993), "Reciclado de deperdicios de teneria", Escuela superior de teneria de igulada

Andres H. et al, Elsinger (1988), "Entsorgung von Machinenleimleder bei gleichzeitiger Gewinnung von Talg und Protein", Das Leder, 39. Jahrgang, Juni 1988, 7 p.

ARGELE (Arbeitsgemeinschaft Lederwirtschaft) (1992), "Branchenkonzept für die Ledererzeugenden Betriebe Österreichs", Bundesministerium für Umwelt, Arbeitsgemeinschaft Lederwirtschaft, Wirtschaftskammer Österreich Umweltbundesambt, Wien (republished 1995).

Bles G.A.B.M. et al, (1995), "Procesbeschrijvingen industrie: Lederfabricage", RIVM rapportnr. 736301127, Bilthoven, 1995, 22 p.

CTIC (1996), personal communication, Portugese Technical Centre for the Leather Industry.

COTANCE (1996), comments on the draft sector report, Brussels December 1996

DTI (Danish Technological Institute) and the European Union (1995), "European workshop on environmental technologies in the leather industry; Minutes of the workshop 10 th May 1995".

EP3 (1995), "Pollution Prevention Assessment for a Goatskin Tannery", case study 235, UNEP IE

European Commission (1995), "Panorama of EC Industry 95/96", Bruxelles-Luxembourg, Office for Off. Pub. of the EC, 1995

La Conceria (1991), "Tanning industry and environment: innovative technologies and legislative bonds in Europe, South America, South East Asia"; Minutes of the meeting, 10th May 1991", La Conceria

Masure (1996), personal communication, Estaimbourg, Belgium.

TME (1994), "The use of the enzyme Greasex, a lipase for the degreasing of skins and hides", TME, Institute for Applied Environmental Economics of the Netherlands.

UNEP (1994), "Tanneries and the environment, A technical guide", Technical report series N° 4, United Nations Environment Programme

UNEP (1991), "Audit and reduction manual for industrial emissions and wastes, Case study 2: leather manufacture", United Nations Environment Programme

Umweltbundesamt, Projektträgerschaft Abfallwirtschaft und Altlastensanierung, Vorhaben 1988-1994, Bundesministerium für Bildung, Wissenschaft, Forschung und Technologie; Projektträger: Umweltbundesamt: F.I.L.K. GmbH (1992 - 1993); Förderkennzeichen: 1480841.

WGR (Westdeutsche Gerberschule Reutlingen) (1995), "Results on Clean Technologies in the German Leather Industry", summary of results of a survey made by WGR in 1995.

The confederation of national associations of tanners and dressers of the European Community (Cotance) has provided general information for the report as well as valuable comments on the draft version of the present sector report, for which we are very grateful. Within the scope and budget of the study, we have tried to take full account of their remarks.

SECTION 5

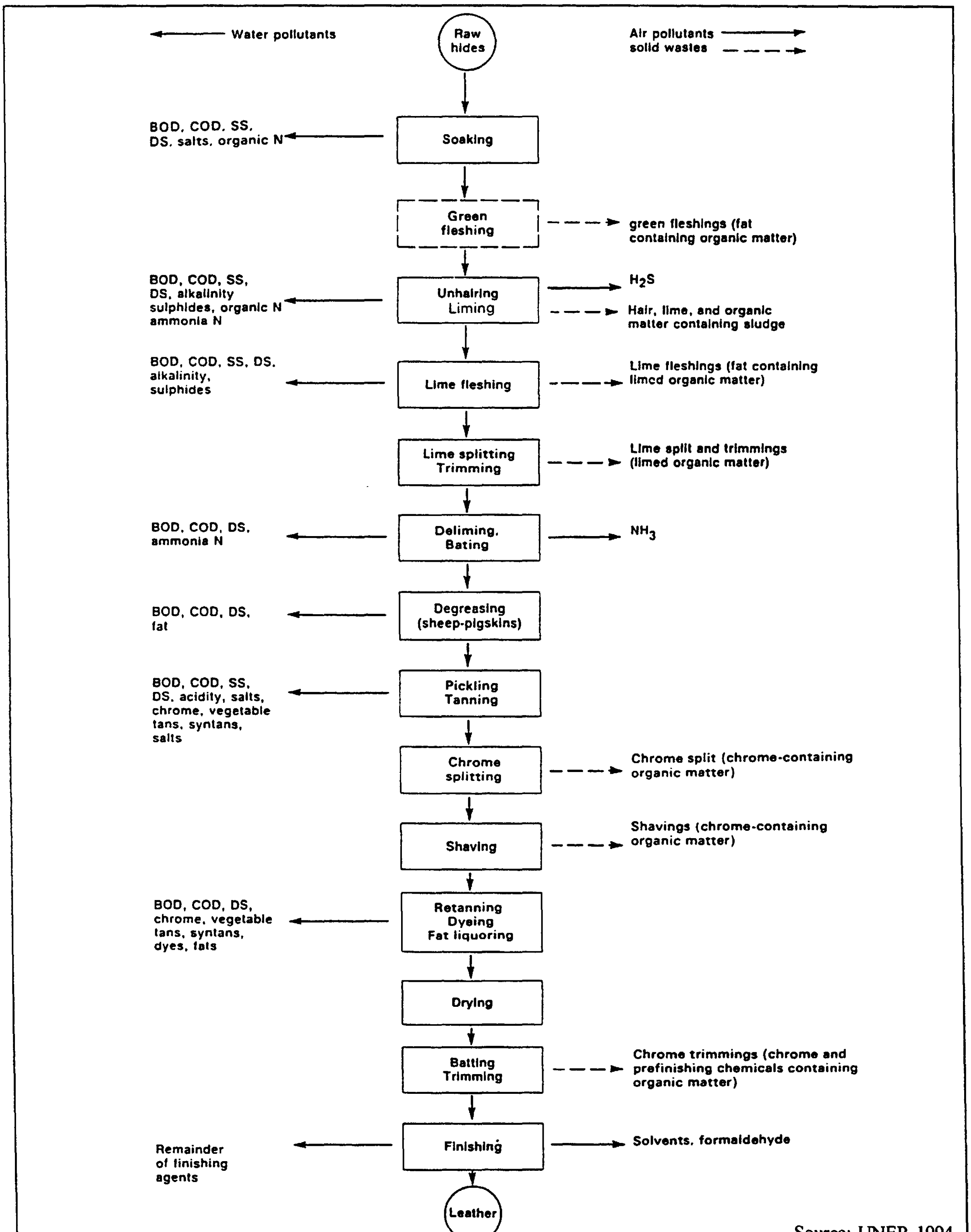
TANNING AND DRESSING OF LEATHER

ANNEX A

PROCESSES AND WASTES DESCRIPTION

A.1 OVERVIEW

An overview of the sub processes carried out at tanning leather, including the waste streams produced, is presented in figure A.1.1.



Source: UNEP 1994

Figure A.1.1: Schematic overview of the tanning process.

The sub-processes can be divided into three groups of operations:

- Beamhouse operations;
- Tanning operations;
- Post-tanning operations.

Beamhouse operations include the following sub-processes: soaking, liming and unhairing, fleshing, deliming and degreasing.

Tanning operations include the actual tanning process as well as the preceding pickling process.

Post-tanning operations include the following sub-processes: (chrome) splitting, shaving, retanning, dyeing, fat liquoring, drying, batting, trimming and finishing.

In general, the individual enterprises employ all sub-processes mentioned. The sequence of the sub-processes can however differ. For example, fleshing can be performed prior to liming and splitting can also be performed prior to the tanning on hides in a limed condition.

Raw materials consist of hides and chemicals. Hides may be fresh raw material (iced or chilled), cured and dry salted material, wet blue and crust or pickled and lime split material[12].

The average amount of solid-wastes and by-products, generated by processing one tonne wet-salted hide, is roughly 0.6 to 0.8 tonne[13].
The solid residues from tanning processes contain high quantities of nitrogen, fats and proteins.

Before discharge of effluent, generally pre-treatment is carried out by methods as filtering, neutralisation, chrome precipitation and recovery and sulphide-oxidation[14]. A minor part of the tanneries employ complete treatment, i.e. including chemical and/or biological treatment.

A.2 BEAMHOUSE OPERATIONS

* Process description

The hides obtained from the slaughterhouse are cured by brining (replacing moisture by salt) or by refrigeration. For the production of leather the hides must regain their original moisture. The hides are therefore soaked, for a few hours to one day, in special containers (paddle-vats or vats) filled with water. ***Soaking*** removes dirt, salt and blood from the hides. Besides sodium carbomate, the soaking solution often contains enzymes, to increase the removal of dirt, salt and blood from the hides.

Subsequently the hides are ***limed*** and ***unhaired***. The epidermis, containing the hairs, is removed from the hide by a (bio)chemical reaction. The hides are placed in an alkali bath composed of, for example, lime, sodium sulphide, sodium sulphydrate and enzymes. The reaction is left to work for approximately half a day. The purpose of liming is to make the hide swell to make the fibre releasing process (unhairing) easier.

12 WGR, 1995
13 UNEP IE, 1994
14 CTIC, 1996: In Portugal, 80% of the tanneries are situated in Alcanena, where there is a common waste water treatment plant that receives the effluents of all these tanneries.

Fleshing is conducted to remove the residual flesh from the hides by mechanical means. In general, the hides are in a limed condition when they are fleshed; in some cases however, the fleshing process is conducted prior to the liming process.

Some individual tanneries perform ***lime splitting***. During lime splitting the hides are more precise adjusted to the required thickness; this process is however very hard to control on hides in a limed condition and is often carried out as a post-tanning operation.

The fleshed hides are still in a limed condition and contain high amounts of alkali reactive agents. To make the hides suitable for tanning, the pH must be brought back, down to a neutral level by ***deliming***. The pH adjustment is performed by soaking the hides in a solution composed of ammonium chloride and acids. This operation is carried out in rotating drums for 1 hour. The soaked hides are then being rinsed to remove excess chemicals.

Degreasing the hides is essential when sheep and pig skins are used[15]. Degreasing these hides results in improved quality of the final leather. The degreasing process is carried out with solvents or with water solutions containing surfactants.

* **Waste description**

- *Waste water sludge free of chromium and liming wastes*
  The major waste stream produced by the beamhouse operations is waste water, consisting of spent bath solutions and rinsing water. The waste water is commonly treated within the tannery itself, thus resulting in primary and secondary waste water sludge (free of chromium) which needs to be disposed as waste or by-product. The volume of the sludges produced by the primary treatment is approximately 90% of the total sludge volume (i.e. including secondary - biological - sludge, when a biological treatment step is included).
  The waste water produced at chrome tanning is generally pre-treated separately to remove chrome; the waste water is then combined with the rest of the effluent of the tannery.

  The liming process is responsible for the major part of the COD-load within the waste water. In addition, the ammonia salts used for deliming purposes, increase the nitrogen content of the waste water significantly, resulting in additional waste water sludge production.

  The waste water produced by the beamhouse operations also contains putrescible (organic) matters which are removed from the waste water by pretreatment with narrow screens. The putrescible matters consists of hair, dung, sand etc.

- *Fleshings and limed splittings*
  Fleshing also represents another important waste producing sub-process. When fleshing is performed on hides in a limed condition the removed material is called *fleshings*; the fleshings are very fatty and are strongly contaminated with liming chemicals. When fleshing is performed prior to the liming process, the removed material is called *"green" fleshings*. Green fleshings are considered as being a minor waste due to the fact that they are free of chemicals and serve as a valuable raw material for the animal feed producing industry.
  When limed splitting is conducted, the splitted material is called *limed splittings*.

- *Degreasing wastes*
  Solvent degreasing results in greasy residues remaining after solvent recovery. Non solvent degreasing results in waste water containing surfactants and dissolved grease, which has to be treated, thus producing waste water sludge.

15. Sub-process not performed within the cowhide tanning process

A.3 TANNING OPERATIONS

* **Process description**

Pickling is required prior to the tanning process. By ***pickling***, the pH of the hides is adjusted, thereby sterilizing the hides and improving penetration of the subsequent tanning material into the hides. Pickling is performed by bringing the hides in an acid and brine solution for approximately 3 hours. After pickling the hides are ready for the actual tanning process.

During the ***tanning*** process, chemical tanning agents are fixed on the fibres, in order to stabilize the hides by blocking reactive functions. Many products can be used as tanning agents, and different tanning systems are available. The most important tanning systems are described below:

- The majority of the leathers today are chrome tanned. Chrome tanning is conducted for 4 to 24 hours, using tri-valent chrome sulphate.
- Vegetable tanning has in general been eclipsed by chrome, but is still employed for sole and saddlery and some speciality leather[16]. The majority of the vegetable tanning agents consist of aqueously extracted bark or wood, in a sulphitated form.
- Syntans are increasingly employed alone or in association with chrome and vegetable tannins[17], either for re-tannage or as principal tanning agents for certain speciality leathers. Syntans are typically sulphonated products of phenol, cresol and naphthalene.
- A wide variety of alternatives are available for use as primary tanning material, or as a complement to chrome or vegetable tannins. These alternatives include: aluminium, titanium, and zirconium salts and glutaraldehyde. Alternative tanning materials are however, very seldom used, due to a lack of familiarity and, in some cases, reduced quality.

The tanning process is performed by immersion of the hides in a bath containing tanning agent and brine. It is very important that the tanning agents soak into the hide and settle correctly. Overtanning will result in unusable leather.

* **Waste description**

- *Spent tanning liquor and sludges, containing chrome*
  No solid wastes are directly derived from the tanning process, but as only a part of the chemical tanning "offer" is taken up by the hide, acidic effluents containing unused chemical tanning agents will be generated.
  These effluents containing spent tanning liquor, must be treated by a waste water treatment system before they can be discharged. This treatment results in waste water sludge; the sludge contains chrome when chrome tanning is employed.

16 WGR, 1995: 65% of German tanneries use chrome tanning agents and 35% vegetable tanning agents for the main tannage.
17 WGR, 1995: In Germany, the no-chrome ("wet-white") pre-tanning process is carried out partially at 24% of the German tanneries. Syntan tanning agents are mainly used. Some tanneries use also aluminium and aldehyde tanning agents.

A.4 POST-TANNING OPERATIONS

* **Process description**

After tanning, the hides are adjusted to the thickness desired by the customer, by ***splitting and shaving*** the tanned hides. Splitting is the process where the hide is split with a special machine, thus resulting in an external, grain side with a constant thickness and an internal, flesh side with a variable thickness. Splitting is followed by shaving. Shaving is the process where the thickness of the splitted hides is adjusted with more precision, using a plane.
Splitting can also be performed on hides being in a limed condition; accurate splitting in this condition is however more difficult.

In addition currying is performed on the tanned, splitted hides. The currying process involves ***retanning, fatliquoring and dyeing***. The purpose of currying is to:
- eliminate residual tanning agents and bring the hide to a neutral level
- dye the fibres with natural or synthetic dyes;
- adjust the quality of the tanned hides in terms of solidity, elasticity, density and swelling;
- lubricate the fibre with oils making the leather pliable.

All these operations are made one after the other in a drum. When the hides are retanned and fatliquored, all physical-chemical operations have been completed.

The hides are now ready for ***finishing***. Finishing gives the leather its definitive commercial look. Finishing can include drying, buffing, plating and a surface finish. Buffing is realised by rubbing abrasive papers over the crushed (dried) leather. Plating is pressing the leather to flatten it. The surface finish consists of the application of various solutions on the leather's surface such as dyes, paints and synthetic binders.

The result of the post-tanning operations is finished leather which is ready to be sold to manufacturers of leather products.

* **Waste description**

- *Waste tanned leather*
  The removed tanned splits and shavings are called wet white (chrome free) or wet blue (chrome containing), depending on the type of tanning process conducted: or chrome tanning, respectively. Wet white splittings can be used as a by-product suitable for gelatine production and pharmaceutical products. Wet white shaving can be used as a by-product for leather board production.

- *Waste water sludges*
  Retanning produces waste water, resulting in waste water sludge containing chrome or free of chrome depending on the type of retanning agent.

- *Spent dyes/solvents*
  Dyeing is commonly conducted, using spray pistols. The overspray can be considered as spent dyes. Minor waste are the excess ***lubricants***, used for fatliquoring. They also account for extra waste water sludge as the hides are washed after fatliquoring.

SECTION 5

TANNING AND DRESSING OF LEATHER

ANNEX B

PREVENTION OPTIONS

Contents:

Sector	Tanning and dressing of leather (NACE 19.1)
Process	Beamhouse operations / tanning / post-tanning
Waste stream	Waste water sludge

Prevention option	**Water conservation** [1]
Option No	5-1
Type	GOP / TC / RU
Group	1/2
Description	Variations in water consumption range from less than 25 l/kg of raw hide to greater than 80 l/kg for apparently similar technologies. A working figure of 50 l/kg is generally accepted[2]. The *efficiency of water use* can often be improved by: • increased volume control of processing waters • "batch" versus "running water" washes • low float modification of existing equipment and/or low float techniques using updated equipment • re-use of waste water in less critical processes • recycling of individual process liquors. Relatively clean rinse and wash waters can be *recycled* to other processes where the low concentration of residual chemicals will have little adverse impact. For example, after bate and neutralization and subsequent clean wash float, it is possible to recycle washwaters back to soak. Another possibility is the recycling of used lime washes for soaking. In addition, employing effluent as make-up for process liquors is a useful way of recycling such effluent. For example, several large bovine tanneries use a method where the residual liming float is restored to its initial composition and re-used after warming.
Remarks	Water conservation has important secondary benefits, in addition to waste reduction: it reduces the consumption of water; lower water consumption implies smaller sized waste water treatment plants, reduced consumption of chemicals and likely lower operating costs, including the costs of energy.
Economics	Re-using and recycling process liquors and waste water, can require high investment costs, due to the pipes, pumps and tanks needed. Savings result from lower discharge expenses of waste water and less costs for chemicals.
Potential	Re-using and recycling waste waters and process liquors can be considered as proven methods. Implementation is however still low, due to the investments required. The total prevention potential of water conservation has therefore been assessed as *moderate*.

1 Main sources: ARGELE 1992 and UNEP IE/PAC 1991.
2 UNEP IE/PAC 1991

Sector	Tanning and dressing of leather (NACE 19.1)
Process	Beamhouse operations
Waste stream	Waste water sludges free of chromium

Prevention option	**General methods for reduction of pollution load**
Option No	5-2
Type	GOP / IMC / TC
Group	1
Description	Reduction of the pollution load of raw waste water results in less waste water sludge production. General methods to reduce the pollution load can include [1]: • *Preventing of contamination* Contamination of the effluent can be prevented by removing solid particulates from the floor and equipment, prior to washing. This requires a clearly communicated code of practice for operators, when and how to clean floors and equipment. • *Pre-treatment* The produced amount of waste water sludge can be reduced by removing (suspended) organic matter (e.g. hair, fats) prior to the biological treatment. This can often be achieved by relatively simple pre-treatment techniques, like settlement. Fats, for example, can be separated from the effluent by flotation. Up to 30 to 40% of suspended solids can be removed from the raw waste stream by pre-treatment. • *Cleaner raw materials* Pollution of the raw materials (skins and hides) include dirt, dung, blood and insecticides. Cleaner skins and hides from meat-industry, reduces pollution load in the beamhouse waste water and facilitates adequate treatment. • *Separate treatment* Separate treatment of some effluents can also reduce the production of waste water sludge. Hair-save technologies and removal of hair by screening - as described in one of the following options - is an example of this approach.
Remarks	
Economics	Investment costs for the removal of organic matter from the effluent can range up to ECU 45 000 [2], depending on size and on type of removal. Savings occur due to lower costs for the discharge of waste water and/or the disposal of waste water sludge. In addition, organic matter collected has a potential for valorisation by external reclamation.
Potential	Although prevention, pre-treatment and other methods can be considered as good-operating practices, the waste prevention potential has been assessed as *moderate* because often still large amounts of solids are flushed with the effluent.

1 main sources: ARGELE 1992 and UNEP IE/PAC 1991.

2 EP3 1995

Sector	Tanning and dressing of leather (NACE 19.1)
Process	Beamhouse operations
Waste stream	Sludges free of chromium

Prevention option	**Alternative process methods for reducing salt pollution load**
Option No	5-3
Type	IMC/TC
Group	1/2/3
Description	With regard to waste water (sludges) and liming wastes, various low waste technologies have been developed for several sub-processes within the beamhouse operations [1]. These technologies focus mainly on reducing the salinity, the COD and/or ammonium (N) load or the sulphide content in the waste (water) streams. Methods for reducing *salt* and organic pollution from soaking of the hides, include: • Treatment of fresh or cooled skins. An adequate cooling process and storage temperature can permit storage of up to 3 weeks, thus replacing salt preservation. • Partial salt elimination and recovery. As only the undissolved fraction of the salt can be recovered, technologies have been introduced removing the salt in a dry condition of the hides. The quantity of salt that may be recovered through this process is around 30%. Upgrading recovered salt is considered only valid for large users. • Alternative preservation. Examples of proposed alternatives are e.g. preservation with antiseptics or irradiation sterilisation. • Soaking process accelerators. The soaking process is frequently speeded up by using enzymatic products.
Remarks	The suitability of these methods strongly depends on site-specific conditions and must be assessed on a case to case evaluation[2].
Economics	Investment costs for treatment of cooled skins can be considerable, due to the required cooled storage areas. The costs of alternative preservation are generally unfavourable. Further general cost information has not been obtained from available literature.
Potential	Some increase in industrial processing of fresh or refrigerated skin is expected in Europe (e.g. 35% of the raw materials processed by German tanneries consists of iced or chilled hides[3]). Some developments still are in an early stage where others are considered as being common-use, the prevention potential has been assessed as *moderate*.

1 main sources: ARGELE 1992 and UNEP IE/PAC 1991.

2 To facilitate this research, GERIC (Grouping of European Leather Research Institutes) has developed a Database of clean technologies applied Europe wide for the leather sector. This Database can be consulted through the GERIC Institutes or via Cotance: information from the Database can be used to support detailed individual studies on waste minimisation.

3 WGR 1995

Sector	Tanning and dressing of leather (NACE 19.1)
Process	Beamhouse operations
Waste stream	Sludges free of chromium / Liming waste

Prevention option	**Alternative liming/deliming methods for reducing pollution load**
Option No	5-4
Type	IMC / TC
Group	1/2/3
Description	With regard to waste water (sludges) and liming wastes, various low waste technologies have been developed for several sub-processes within the beamhouse operations [1]. Regarding the liming, unhairing and deliming processes, clean technologies for reducing *sulphide content or pollution load* include: • Sulphide substitution Much effort has gone into finding substitutes for sodium sulphide in the unhairing-liming step. Enzymatic preparations are commercially available and suitable as (partial) substitution of sulphide, but may not be universally applicable. • Hair-save unhairing processes Especially hair represents a large part of the total COD and nitrogen load. If hair-saving technologies are applied (preventing the hairs from being pulverised), the charge of hair can be detained by fine screenings and sieves. Hair-save methods for in-drum removal have been developed, relying on an initial protective treatment of the hairs before the final treatment destroys the hair roots and releases the hair fibre. A reduction of 50 to 60% of liming-dehairing pollution load can be achieved, corresponding with an overall reduction of pollution load of approximately 30% [2]. Hair-save methods demand precise operating conditions and control. • CO_2 deliming. Traditional deliming is performed using ammonium salts, bringing about considerable nitrogen pollution (up to 30% of total discharges). Deliming with CO_2 virtually avoids the application of the ammonium salts. This method is for long time available already but is not always suitable[3].
Remarks	The suitability of these methods strongly depends on site-specific conditions and must be assessed on a case to case evaluation[4].
Economics	Hair-save processes generally require higher costs for labour and chemicals, besides the additional investments for screens[5]. Recovered hairs can in some cases be valorised externally.
Potential	The use of these cleaner technologies increases. In Germany, 75% of the agents applied are partial and total substitution agents[6]. In addition, the results of CO_2 deliming should ensure its rapid development. As the pollution load from spent liming liquors is one of the major sources for waste water sludge production, the prevention potential has been assessed as *moderate to high.*

1 main sources: ARGELE 1992, Bles et al 1995 and UNEP IE/PAC 1991.
2 Bles et al, 1995
3 Bles et al, 1995
4 To facilitate this research, GERIC (Grouping of European Leather Research Institutes) has developed a Database of clean technologies applied Europe wide for the leather sector. This Database can be consulted through the GERIC Institutes or via Cotance: information from the Database can be used to support detailed individual studies on waste minimisation.
5 Bles et al, 1995
6 WGR 1995

Sector	Tanning and dressing of leather (NACE 19.1)
Process	Beamhouse operations
Waste stream	Fleshings and lime split waste

Prevention option	**Green fleshing** [1]
Option No	5-5
Type	GOP/TC/RC (external)
Group	1
Description	A technology has been developed that enables fleshing of the hides before the liming process. The "green" fleshings gained by this procedure are free from chemicals and serve as a valuable raw material for the animal feed producing industry. The method of green fleshings does not differ from the traditional fleshing process; the adipose tissue is mechanically removed from the flesh side of the hide.
Remarks	Green fleshing does not reduce the amount of fleshings removed but improves the quality of the waste, making the waste suitable to be reclaimed for advanced purposes. The suitability of this method depends on site-specific conditions and must be assessed on a case to case evaluation[2].
Economics	Green fleshing requires additional costs with regard to the traditional limed fleshing. Investment costs are required because the hides will have to be stored in a cold storage, before they can be fleshed, in addition the fleshing machine has to be modified or replaced when green fleshing is implemented. The higher economic value of the residues from green fleshing can however generate extra revenues.
Potential	Green fleshing is expected to be rapidly implemented or has already been implemented in many tanneries, but can presently not be presented as common use. It is estimated that approximately 45% of the German tanneries apply green fleshing[3]. Therefore the prevention potential has been assessed as *moderate*.

1 main sources: ARGELE 1992 and UNEP IE/PAC 1991.

2 To facilitate this research, GERIC (Grouping of European Leather Research Institutes) has developed a Database of clean technologies applied Europe wide for the leather sector. This Database can be consulted through the GERIC Institutes or via Cotance; information from the Database can be used to support detailed individual studies on waste minimisation.

3 WGR 1995

Sector	Tanning and dressing of leather (NACE 19.1)
Process	Beamhouse operations
Waste stream	Degreasing waste

Prevention option	**Alternative degreasers**
Option No	5-6
Type	IMC
Group	3
Description	Instead of using solvent based degreasers, enzymatic or aqueous degreasing can be conducted [1,2]. The type of enzymes, most suitable for degreasing, is being researched on an intensive scale. Enzymatic solutions are already available on a commercial basis; these enzymatic solutions are however in use in the soaking stage or in the liming and deliming stage. Current research focuses on further development of commercial available enzymatic solutions.
Remarks	The description does not account for degreasing bovine leather, since degreasing bovine leather is performed by liming, washing or bating. Degreasing of bovine leather can be performed by enzymatic solutions in the sub-processes mentioned [3]. The suitability of this method depends on site-specific conditions and must be assessed on a case to case evaluation[4].
Economics	At this stage no accurate figures can be given on the relative costs of enzymatic or aqueous degreasing.
Potential	The technology is still in a research phase. Sustainable efforts are given to make the technology ready for implementation on a large industrial scale. Recent research indicates that enzymatic degreasing has a *high* prevention potential [5].

1 Danish Technological Institute and the European Union 1995
2 COTANCE 1996
3 TME 1994
4 To facilitate this research, GERIC (Grouping of European Leather Research Institutes) has developed a Database of clean technologies applied Europe wide for the leather sector. This Database can be consulted through the GERIC Institutes or via Cotance: information from the Database can be used to support detailed individual studies on waste minimisation.
5 COTANCE 1996

Sector	Tanning and dressing of leather (NACE 19.1)
Process	Tanning
Waste stream	Spent tanning liquor and sludge, containing chromium

Prevention option	**High chrome exhaustion techniques**
Option No	5-7
Type	GOP / IMC / TC
Group	1
Description	The tanning process can be improved by establishing higher chrome fixation. The high chrome exhaustion techniques lead to less chrome in the residual floats from tanning and retanning. Nevertheless, generally the spent tanning liquor still has to be treated, resulting in sludge with a lower chrome concentration; the quantity of sludges will only be reduced slightly[1]. Chrome fixation during tannage is favoured by[2]: - short float; - increased temperature; - increased time of tanning; - increased basification; - decrease in neutral salts. With a combination of these techniques, and using self-basifying chrome compounds and dicarboxylic acid, which are commercially available, it is possible to raise apparent chrome fixation levels to 90%[3]. Experiments under optimized tanning conditions show chrome uptake of even about 96% of the chrome offer[4].
Remarks	The suitability of these methods depends on site-specific conditions and must be assessed on a case to case evaluation[5].
Economics	The savings in chrome salts are reported to offset the higher unit costs of the special tanning chemicals involved [6].
Potential	The application of high chrome exhaustion methods is increasing at tanneries. However, still significant potential is reported[7]. Therefore the prevention potential has been assessed as *moderate to high.*

1 Bles et al, 1995
2 UNEP IE/PAC, 1995
3 UNEP IE/PAC, 1995
4 WGR 1996
5 To facilitate this research, GERIC (Grouping of European Leather Research Institutes) has developed a Database of clean technologies applied Europe wide for the leather sector. This Database can be consulted through the GERIC Institutes or via Cotance; information from the Database can be used to support detailed individual studies on waste minimisation.
6 UNEP IE/PAC 1991
7 COTANCE 1996, WGR 1995 and Bles et al 1995

Sector	Tanning and dressing of leather (NACE 19.1)
Process	Tanning
Waste stream	Spent tanning liquor and sludge, containing chromium

Prevention option	**Alternative tanning agents** [1]
Option No	5-8
Type	IMC
Group	1/3
Description	A number of alternative (mineral and synthetical) tanning agents are developed, aimed at substituting chrome. Possible alternatives include aluminium, titanium, and zirconium salts and glutaraldehyde. Examples of characteristics of alternatives are[2]: - aluminium: producing a flat, hard leather with a whitish colour; it can be used alone or in combination with other traditional tanning agents; e.g. by using it as preliminary tanning, followed by a second step with traditional agents to adapt the physical qualities of the leather; - titanium: this also gives a whitish appearance to the leather and gives slightly different properties; - zirconium: producing a white leather which is flat and hard; it is more expensive than chrome and the tanning operation is more difficult to monitor. As discussed in Annex A, vegetable tannins constitute a well-known alternative for chrome tanning and are applied especially for sole and saddlery and some specialty leathers. It may also be used as part of a combination process.
Remarks	The mineral and synthetical alternatives mentioned, do not necessarily produce exactly the same leather product quality, therefore inhibiting widespread adoption. Besides technical dilemmas, much depends on market acceptance. The suitability of these alternatives must be assessed on a case to case evaluation[3]. Furthermore, it should be recognized that some alternative tanning agents can have significant environmental disadvantages[4]. For example aluminium, that is given special attention in waste water; on the other hand, titanium (as an example) is not considered disadvantageous from an environmental standpoint.
Economics	Cost specification could not be obtained from literature available.
Potential	Lack of familiarity with the mineral and synthetical alternatives, as well as the lower and different leather quality, has inhibited the general use of these alternatives. Vegetable tanning agents, on the other hand, are well-known and are often already applied where this is suitable[5] (especially sole and equipment leather). Considering these points, the prevention potential has been assessed as *low*.

1 main sources: ARGELE 1992 and UNEP IE/PAC 1991.
2 UNEP IE/PAC 1991
3 To facilitate this research, GERIC (Grouping of European Leather Research Institutes) has developed a Database of clean technologies applied Europe wide for the leather sector. This Database can be consulted through the GERIC Institutes or via Cotance: information from the Database can be used to support detailed individual studies on waste minimisation.
4 COTANCE 1996
5 WGR. 1995: 65% of German tanneries use chrome tanning agents and 35% vegetable tanning agents for the main tannage.

Sector	Tanning and dressing of leather (NACE 19.1)
Process	Tanning
Waste stream	Spent tanning liquor and sludge, containing chrome

Prevention option	**Chrome-recycling, recovery and re-use** [1]
Option No	5-9
Type	TC / RU
Group	1
Description	Re-use of chrome salts ban be achieved by direct or indirect recycling. Possibilities for *direct recycling* of used chrome liquors include: - recycling to tannage; after collection and sufficiently fine screening, the liquor is analysed (new chromium salts have to be added to restore bath strength) and re-used; this recycling method may be repeated several times on the same bath; - recycling to pickle; up to two-thirds of the float can be recycled after screening and cooling[2]. *Indirect recycling* involves chrome recovery and re-use: - in short, chrome-containing liquors are collected for treatment with alkali (e.g. sodium carbonate or magnesium oxide) to precipitate the chrome as hydroxide. The hydroxide sludge may be passed after sedimentation and thickening to a filter press or belt, after which the chromiumhydroxide is dissolved with sulphuric acid and re-used in the tanning process.
Remarks	In addition to some re-engineering of the plant, direct recycling requires regular control and monitoring. Some limitations are reported regarding product quality after repeated re-use[3]. The suitability of these methods must be assessed on a case to case evaluation[4].
Economics	Especially for larger plants, treating significant amounts of chrome, indirect recycling after precipitation is considered economically attractive. If in some region a high concentration of tanneries is present, then common treatment of collected residual baths may be viable. In general, the chrome recovery systems are considered less cost effective than a high fixation process[5].
Potential	Chrome recovery, as described above, is a well-known method and is introduced all over Europe. Still, in general, a *high* potential exists for both small and larger tanneries[6].

1 main sources: ARGELE 1992 and UNEP IE/PAC 1991.
2 UNEP IE/PAC. 1991
3 Bles et al, 1995
4 To facilitate this research, GERIC (Grouping of European Leather Research Institutes) has developed a Database of clean technologies applied Europe wide for the leather sector. This Database can be consulted through the GERIC Institutes or via Cotance; information from the Database can be used to support detailed individual studies on waste minimisation.
5 UNEP IE/PAC, 1991
6 COTANCE, 1996

Sector	Tanning and dressing of leather (NACE 19.1)
Process	Post-tanning operations
Waste stream	Waste tanned leather containing chromium

Prevention option	**Limed splitting** [1]
Option No	5-10
Type	TC
Group	I
Description	After liming, hides may be split in the limed condition. This avoids splitting after tanning, which yields chrome containing wastes that are more difficult to recover. However, as accurate splitting in limed condition is usually more difficult, splitting is often carried out in the tanned condition.
Remarks	The application depends on many factors, e.g. splitting at an early stage pre-determines end-uses and negates just-in-time concepts. The suitability of this method must therefore be assessed on a case to case evaluation[2].
Economics	Residues obtained from limed splitting can be reclaimed as valuable resource for split leather production and other industry (e.g. gelatin production). Limed splitting also reduces the amount of chrome salts needed for the tanning operations.
Potential	The technology has been implemented in the industry as far as the current accurateness of limed splitting is enough for the produced articles. Improved accurateness in limed splittings will develop new opportunities for the implementation of this technology. The prevention potential has therefore been assessed as *moderate*.

1 main sources: ARGELE 1992 and UNEP IE/PAC 1991.

2 To facilitate this research, GERIC (Grouping of European Leather Research Institutes) has developed a Database of clean technologies applied Europe wide for the leather sector. This Database can be consulted through the GERIC Institutes or via Cotance; information from the Database can be used to support detailed individual studies on waste minimisation.

Sector	Tanning and dressing of leather (NACE 19.1)
Process	Post-tanning operations
Waste stream	Spent dyes/solvents

Prevention option	**Alternative dyeing methods** [1]
Option No	5-11
Type	TC
Group	1
Description	Spray methods of various types for dyeing purposes may waste over 30% of the applied material. More advanced techniques, relying on direct contact application or improved spray applications, can reduce waste by a factor of 10. Examples of new technologies and methods are: • inking roller rotating machines or roller coaters with a foam finishing equipment; • high-volume-low-pressure (HVLP) spraying system; HVLP spraying systems can reduce the overspray from standard spray guns drastically from about 50% to 25 %. Alternative dyeing methods may also refer to changes within the dyeing equipment. Improvements in dyeing equipment have been made in the last decades, for example special stainless steel drums instead of classic wood drums.
Remarks	The major effect of the alternative methods mentioned is reduction of the emission of volatile solvents. However, as a side-effect, solvent wastes and spent dyes can be reduced as well. Inking roller systems offer additional advantages like a better surface covering, a higher softness of the finished leather and much more pronounced and long-lasting embossment[2]. The suitability of these methods depend on site-specific conditions and must be assessed on a case to case evaluation[3].
Economics	
Potential	The potential for clean technologies for dyeing purposes is considered high. However, the impact of these methods is basically on air emissions. The prevention potential for wastes has therefore been assessed as only *moderate*.

1 main sources: ARGELE 1992, UNEP IE/PAC 1991 and WGR 1995.

2 WGR, 1995

3 To facilitate this research, GERIC (Grouping of European Leather Research Institutes) has developed a Database of clean technologies applied Europe wide for the leather sector. This Database can be consulted through the GERIC Institutes or via Cotance; information from the Database can be used to support detailed individual studies on waste minimisation.

Sector	Tanning and dressing of leather (NACE 19.1)
Process	Post-tanning operations
Waste stream	Spent dyes/solvents

Prevention option	**Alternative finishing or dyeing agents** [1]
Option No	5-12
Type	IMC
Group	1
Description	The oldest methods for dyeing and finishing involved contact application of resins or aqueous liquids via a system of brushes and pads, which were substituted by solvent based finishing, applied often with spraying techniques. However, the application of aqueous or less solvent finishing systems, is now becoming common use (again). Examples of aqueous dyes are acrylic- or polyurethane-based dyes. The use of resins that can be fixed by UV-light has an additional advantage in that it also avoids the generation of aqueous pollutants.
Remarks	Application of water-based systems reduces directly solvent wastes. However, spent dyes, pigments etc. still may occur from water-based or low-solvent systems. The suitability of these methods depend on site-specific conditions and must be assessed on a case to case evaluation[2].
Economics	No information could be obtained from literature available on cost specification.
Potential	Non-solvent technologies are now developing very quickly. The implementation of aqueous finishing systems is increasing[3]. Based on the good technological results, the prevention potential has been assessed as *moderate.*

1 UNEP IE/PAC 1991

2 To facilitate this research, GERIC (Grouping of European Leather Research Institutes) has developed a Database of clean technologies applied Europe wide for the leather sector. This Database can be consulted through the GERIC Institutes or via Cotance; information from the Database can be used to support detailed individual studies on waste minimisation.

3 WGR 1995: 85% of finishing operations performed by German tanneries use exclusively water based finishes.

SECTION 6

MANUFACTURE OF WOOD AND WOOD PRODUCTS

SECTOR REPORT

Contents :

NACE sectors involved in the present sector report:

Retained for analysis:	20	Manufacture of wood and of products of wood and cork, except furniture; manufacture of articles of straw and plaiting materials
	36.1	Manufacture of furniture
Excluded from analysis:	-	

6.1 SECTOR CHARACTERISATION [1]

The European sector of NACE 20 comprises the production of wooden articles, such as semi-finished wood products (particle board, impregnated board etc), wooden building components (doors, window frames etc), wooden containers and pallets and other articles, such as plating materials, brushes and brooms etc[2].

The sector (including wooden furniture) is mainly made up by a large number of small companies. The total number of companies in the EU was about 244 000 in 1990, of which 94% employed less than 20. These smaller firms represent 48% of the total employment and 36% of turnover. The sector employs approximately 1.7 million people[3].

The wood processing industry underwent a crisis in the early 1980's. During the second half of the decade there was a rapid expansion in the demand for wood products. Companies reacted by substantial investments, causing rationalisation of the production process and an improvement in efficiency and productivity.

Major EU producers in 1993 are Germany, France, Spain, Italy and the UK. Within the EU, Portugal has the highest degree of specialization in the processing of wood, followed by Denmark and Spain.

6.2 PROCESSES AND WASTES

Within NACE 20, basically three groups of major waste generating processes can be distinguished. These groups are comprised of a number of different sub-processes. An enterprise can employ a certain mix of these (sub)processes or can be dedicated to one process only. The three processes are:
- machining operations
- preservation
- paint application

In machining operations, the raw timber is transferred in working pieces as poles, parquets, joineries, shingles, beams etc. Typical machining operations in the wood sector are sawmilling, chipping, grinding, calibrating, scouring, milling, boring etc.

Preservation processes, using oilborne or waterborne preservatives, are used at various stages of timber transformation. Wood is being preservated in order to prevent rotting when wood is exposed to water and as protection against termites and marine borers.

The application of paint (coatings) is practised within many wood products assembly workshops. Coating and painting are applied for cosmetic purposes or for preservation.

A further description of these processes is given shortly in Annex A.

Minor waste generating operations are assembly of wooden products, unpacking, packing, cleaning and maintenance.

---

1 Main source: European Commission, 1995

2 Because of large similarities in production, this sector report reviews waste minimisation options in the whole of Nace 20 sectors and in the part of NACE 36.1 (manufacture of furniture) that produces wooden furniture. Other sector reports within this study that are relevant for NACE 36.1 (manufacture of furniture), include manufacture of **textile** (section 4), **leather** (section 5), **plastic and rubber products** (section 10) and **metal products** (section 13).

3 The data provided in this chapter do not include Austria, Finland and Sweden. With the entry of these countries into the EU in 1995, the relative importance of the wood processing industry for the EU economy will have increased considerably.

In table 6.2.1 the different wastes are listed, together with their process origin; the table includes a tentative priority ranking, based on the amount and the hazardous character of the waste. Further details on wastes are provided in Annex A.

Table 6.2.1: Wood manufacture wastes

Process origin	Waste streams	Priority rank	Description and code according to EWC	
Machining operations	Wood losses	+	Waste bark and cork Shavings, cuttings, spoiled timber/particle board/veneer	03 01 01 03 01 03
	Wood dust	o	Sawdust	03 01 02
Preservation[1]	Preservated wood	o	Shavings, cuttings, spoiled timber/particle board/veneer	03 01 03
	Preservatives	+	Non-halogenated organic wood preservatives Organochlorinated wood preservatives Organometallic wood preservatives Inorganic wood preservatives	03 02 01 03 02 02 03 02 03 03 02 04
Paint application[2]	Paint and solvent waste	o	Wastes from the MFSU of paint and varnish	08 01 00

Priority rank: + : high significance, o : medium significance, - : low significance EurEco/Witteveen+Bos 1997

Waste streams of low significance, not included in the table, are:

- wastes that arise in assembly of wooden products (not including paint application)
- scouring materials
- sludges, produced in waste water treatment plants on site
- wood rejects and chemicals (such as glue) in manufacture of wooden products
- packing, cleaning and maintenance waste.

The major waste streams in the wood sector are wood waste (because of the large amounts) and preservatives, including paint and solvent waste (because of the hazardous character).

Almost all machining operations produce wood dust. The majority of the dust is hold back by filters or swept from floors. For wood dust good reclamation possibilities exist, such as use as cattle feed, in paper production, composting or as fuel.

Wood losses can add up to 60% of the incoming wood. Sources are rejects and machining operations, especially sawing. For non preserved wood, good recycling possibilities exist[3]. Preservated wood losses occur at machining operations after preserving. Other sources are rejects or filling pieces for the preservation process (filling pieces are used in order to create distance between the products that have to be preservated). Preservated wood has to be disposed of as chemical waste.

Most preservative waste is produced by drippings and spills out of treatment processes or from treated wood, surface runoff water and/or sludges. Treating with oilborne preservatives causes more waste water than waterborne processes. Furthermore, recycling possibilities are better for waterborne preservatives. Sludges from preservating consist of oil-water emulsions or polymers, bark, sawdust, dirt, wood chips and debris. Preservatives are very hazardous.

1 Preservation wastes (EWC 03 02 01 to 03 02 04) are hazardous wastes according to the European Hazardous Waste List.
2 Paint and solvents wastes (EWC 08 01 00) can include hazardous wastes.
3 Umweltbundesamt, Vorhaben 1988-1994 gives some future options.

Rough estimates on paint and solvent waste mention that circa 1/3 of the paint ends up on wood, 1/3 is emitted to the air and 1/3 ends up as paint losses. High costs are involved, because of lost raw materials and disposal.

Environmental aspects in the wood sector, apart from waste, are associated with deforestation of the tropics (in case of hard-wood), the hazardous character of preservatives and VOC-emissions in preservation.

6.3 WASTE PREVENTION

This section discusses waste prevention methods identified in literature. The major waste streams along with prevention options are summarized in the next table, following the division into three processes as made in the preceding chapter. The options are described in detail in Annex B.

Table 6.3.1: Overview waste prevention options for wood manufacture

Waste streams	Priority rank	Waste prevention method	Group	Potential
Machining operations				
Wood losses	+	6-1 Good housekeeping (GOP) 6-2 Recycling wood losses (GOP/RU)	1 1	o o
Wood dust	o	6-1 Good housekeeping (GOP) 6-3 Wood dust incineration (TC/RC)	1/2 1	o -
Preservation				
Preservated wood	o	6-4 Replacement wooden filling pieces (IMC)	1/2	..
Preservatives	+	6-5 Good housekeeping (GOP) 6-6 Alternative preservatives (IMC) 6-7 Alternative preservation methods (TC) 6-8 Recycling (RU/RC)	1/2 1/2 2/3 1/2	o - / o - o
Paint application				
Paint and solvent waste	o	6-9 Good housekeeping (GOP) 6-10 Catching of overspray (GOP/RU/RC) 6-11 Alternative paints (IMC) 6-12 Technological modifications (TC) 6-13 Alternative paint application methods (TC) 6-14 (Mobile) distillation solvent waste (RU)	1 1 1/2/3 2 1/2/3 1/2	o o o / + - / o o / + o / +

+ = high, o : medium, - : low, .. = insufficient data — EurEco/Witteveen+Bos 1997

Only few literature sources on waste prevention for *wood waste* have been identified. Waste minimisation of wood is an issue that is directly related to the competitiveness of companies, as wood is the main raw material input. Prevention options identified, involve mainly good housekeeping, like purchase and stock management, standardisation and maximizing re-use of losses. No options that involve technological changes are found. As the degree of implementation of good housekeeping measures is expected to be often high already for economic reasons, the prevention potentials for these options have been assessed as low to moderate.

Most literature available on environmental aspects in the wood sector concerns preservation. Reduction measures for *preservation wastes* include the whole range from good housekeeping to recycling. The prevention potential for the options varies from low to high, depending on aspects as age of the equipment and the attention that already is given to waste.

For *paint and solvent waste*, literature on prevention options concerning paint application on wooden surfaces is less common, but a transfer of options from other sectors where paint is applied is easily possible. Paint losses can still constitute considerable waste quantities; therefore the waste prevention potential of most options identified has been ranked as medium to high.

6.4 EVALUATION

Major attention on environmental issues in the wood products sector has been addressed towards the hazardous effects of preservatives, concerning especially emissions of volatile organics in preservation and waterborne emission in use. Much literature is available on these subjects. However, as comparative statistics on the application of techniques in preservation were in most cases not available, the prevention potentials are based on expert judgement. Considering the many opportunities available on the one hand, but on the other hand the attention that will be paid already to these options for economical reasons, the potential has been assessed generally as moderate, not high.

Wood wastes can involve considerable quantities. However, it does not constitute a hazardous waste stream and external reuse (fuel, cattle feed or fibre production) can be applied to a large extent. This may explain the limited number of (mainly good housekeeping) waste prevention options identified in literature. Furthermore, as wood is the main raw material input, waste minimisation of wood is an issue that is directly related to the competitiveness of companies.

Summarizing, it can be concluded that in the wood sector already attention has been given to the main waste stream (wood) because of economical reasons, whereas little environmental pressure is laid on this non-hazardous waste stream. However, as still large waste quantities are involved, further development and implementation of waste minimisation methods and dissemination of information are recommendable. In preservation, the environment has been an important issue for long. Major developments in new clean technologies or significant further implementation of existing methods, are not expected in the nearby future.

6.5 BIBLIOGRAPHIC REFERENCES

Bundesministerium für Umwelt (1994), "Branchenkonzept Holz", Bunderministerium für Umwelt, Sektion III, Wien, Österreich.

European Commission (1995), "Panorama of EC Industry 95/96", Bruxelles-Luxembourg.

Heidemij advies (1994), "Preventieproject timmerfabrieken, pilotstudie, Eindrapport", Nederlandse Bond van Timmerfabrikanten, Provincie Gelderland en Overijssel, Heidemij advies, Arnhem.

Infomil (1996), "Watergedragen lak en lijnolie in houten meubelbedrijf", KWS praktijksheet 1, Infomil, Den Haag.

TME, Instituut voor Toegepaste Milieu-Economie (1994), "Preventie afval en emissies Hout en meubelindustrie, Handleiding voor een systematische aanpak", Nationaal Milieucentrum, Woerden.

Provincies Gelderland en Overijssel (1994), " 'Voorkomen is verdienen' door preventie van afval en emissies in de Gelderse en Overijsselse meubelindustrie", Uitgave Provincie Overijssel, Zwolle.

Umweltbundesamt, Projektträgerschaft Abfallwirtschaft und Altlastensanierung, Vorhaben 1988-1994, Bundesministerium für Bildung, Wissenschaft, Forschung und Technologie; Projektträger: Umweltbundesamt:
- Remmers Chemie GmbH & Co (1993-1996); Förderkennzeichen: 1490908.
- Technische Universität Dresden (1991-1997); Förderkennzeichen: 1450780.
- Bundesforschungsanstalt für Forst- und Holzwirtschaft (1990-1993); Förderkennzeichen: 1450676.

UNEP IE Database:
- Thomson Crown Wood Products, USA, 1991
- Schecter et al, USA, 1989; Docno unep04: 112-003-A-282
- Verniland, France, 1990

UNEP IE/PAC (1994), "Environmental Aspects of Industrial Wood Preservation, A Technical Guide, Technical Reports series N°20", United Nations Publications, Paris, France.

US EPA (1993), "Guides to Pollution Prevention; Wood Preserving Industry", Office of Research and Development, Washington DC.

VROM (1992), "Circulaire betreffende werkprogramma milieumaatregelen bij houtimpregneerbedrijven", Ministerie van Volkshuisvesting, Ruimtelijke Ordening en Milieu, Directoraat Generaal Milieubeheer, 's-Gravenhage.

Warren Spring Laboratory (1994), "Reduction of volatile organic compound emissions from industrial coating and impregnation of wooden surfaces", Office for Official Publications of the European Communities, Brussels-luxembourg.

Witteveen+Bos (1995), "Bedrijfstakinformatie afvalpreventie. Handreiking bij de Leidraad preventie via de milieuvergunning", Ministerie van VROM, Den Haag.

SECTION 6

MANUFACTURE OF WOOD AND WOOD PRODUCTS

ANNEX A

PROCESSES AND WASTES DESCRIPTION

Contents :

A.1 OVERVIEW

As defined by code 20 of NACE, this sector comprises companies of the following categories:
- sawmilling and planing of wood, impregnation of wood;
- manufacture of veneer sheets; manufacture of plywood, laminboard, particle board, fibre board and other panels and boards;
- manufacture of builders' carpentry and joinery;
- manufacture of wooden containers;
- manufacture of other products of wood; manufacture of articles of cork, straw and plaiting materials.

Wooden furniture is excluded in NACE 20. In this report, wooden furniture is included in because of large similarities in production[1].

Typical raw materials are:
- timber
- preservatives
- paints.

Three major waste generating processes are distinguished. Each group itself is comprised of a number of different sub-processes. These processes are:
- machining operations
- preservation
- paint application.

Short descriptions of these processes and the wastes produced, are given in the next paragraphs.

Minor waste generating activities are assembly of wooden products, unpacking, packing, cleaning and maintenance.

A.2 MACHINING OPERATIONS

* Process description

In machining operations, the raw timber is transferred in working pieces as poles, parquets, joineries, shingles, beams etc. Typical machining operations in the wood sector are sawmilling, chipping, grinding, calibrating, scouring, milling, boring etc.

* Waste description

- *Wood dust*
  Almost all machining operations produce wood dust. The majority of the dust is hold back by filters or sweeped from floors. For wood dust, good reclamation possibilities exist, such as use as cattle feed, in paper production, in composting or as fuel.

- *Wood losses*
  Wood losses can add up to 60% of the incoming wood. Sources are rejects and machining operations, especially sawing. For non preservated wood good recycling possibilities exist.

---

1 Other sector reports within this study that are relevant for NACE 36.1 (manufacture of furniture), include manufacture of **textile** (section 4), **leather** (section 5), **plastic and rubber products** (section 10) and **metal products** (section 13).

A.3 PRESERVATION

* Process description

Preservation processes are used at various stages of timber transformation. Wood is being preservated in order to prevent rotting when wood is exposed to water and as protection against termites and marine borers. Major preservatives are:

- oilborne:
  - creosote;
  - pentachlorophenol (PCP);

- waterborne:
  - mostly chromated copper arsenate (CCA);
  - also: ammoniacal copper-zinc-arsenate (ACZA).

The actual trend is towards waterborne preservatives. Treatment of oilborne preservatives produces more waste water than treatment of waterborne processes. Furthermore, recycling possibilities are better for waterborne preservatives.

Most common processes are pressure treating processes; non-pressure treating processes are less common (not applicable for CCA). The pressure treatment involves the use of a pressure cylinder ("retort cylinder") in which the wooden material is placed and subsequently closed. Preservatives are transferred to the cylinder through piping from storage tanks. Pressure is applied until the preservative permeates the wood or until a desired retention time is obtained. After the treating processes, the wood is removed and placed on a drip pad where it remains until dripping has ceased. Waterborne drippings are collected in dilution water tanks and blended with additional concentrate to make fresh treating solution.

* Waste description

Preservation wastes (EWC 03 02 01 to 03 02 04) are hazardous wastes according to the European Hazardous Waste List.

- *Preservated wood*
  Preservated wood losses occur at machining operations after preserving. Other sources are rejects or filling pieces for the preservation process (filling pieces are used in order to create distance between the products that have to be preservated).

- *Preservatives*
  Most preservative waste is produced by drippings and spills out of treatment processes or from treated wood, surface runoff water and/or sludges. Process waste water includes waste water from conditioning, kiln drying, treated wood washing, accumulation in doors or retort sumps, preservative formulation recovery and rinsing. Sludges from preservating consist of oil-water emulsions or polymers, bark, sawdust, dirt, wood chips and debris.

A.4 PAINT APPLICATION

* **Process description**

Different forms of wet painting are spraying, immersion ("dip"), brushing and rolling. For spraying, use is made of spray guns that are manually operated or are automated. Spray guns can be pneumatic or airless (spray under pressure); in general, airless spraying generates less wastes. Spraying usually takes place in contained workplaces, i.e. a ventilated room or a paint spray booth.

Powder coating forms an alternative to solvent- or waterbased coatings. The process is simple in operation and can be done manually or by highly automated equipment. The low conductivity of wood can cause problems.

* **Waste description**

- *Paint and solvent waste*
  According to rough estimates on paint and solvent waste, circa 1/3 of the paint ends up on wood, 1/3 is emitted to the air as VOS and 1/3 ends up as paint losses. High costs are involved, because of loss of raw materials and for disposal. Solvent waste is especially produced at paint-spraying with reuse of paint.

SECTION 6

MANUFACTURE OF WOOD AND WOOD PRODUCTS

ANNEX B

PREVENTION OPTIONS

Contents :

Sector	Manufacture of wood and wood products (NACE 20)
Process	Machining operations
Waste stream	Wood losses

Prevention option	**Good housekeeping**
Option No	6-1
Type	GOP
Group	1

Description	Reduction of *wood losses* can be achieved by general good housekeeping measures, including[1]:
	• clustering orders;
	• optimizing/automizing nesting of wood-pieces (CAD/CAM);
	• optimizing stock-management:
	  - division in lengths;
	  - reduction of base-stock;
	  - first in/first out system;
	  - periodic control;
	  - acceptance control;
	• purchase management measures, such as:
	  - buying fixed lengths;
	  - buying the required lengths;
	  - using larger lengths;
	  - buying faultless wood; faults have been removed at suppliers by laminating and welding;
	  - buying high-quality wood.
	• standardisation; product change can be necessary;
	• building up work-pieces out of smaller half-manufactures.
	
	Reduction of *wood dust* can be achieved by purchase management measures, as these measures diminish the machinery processes which cause dust waste.

Remarks	Some of these measures (such as clustering orders and standardisation), are more fit for larger companies. Purchase management can increase waste amounts at suppliers. Nevertheless, it is to be expected that scale effects will cause a positive nett effect. Possibilities of purchase management depend on the sizes that suppliers deliver. Furthermore, lengths longer than 6 meter, in general give problems in handling.
Economics	Most options mentioned do not require investments. Usually, more labour is involved. Economic benefit further depends on the extra costs for purchase other raw materials. Some case studies indicate that in general these measures are promising.
Potential	A reduction of up to 20% with this group of measures is achievable. The prevention potential is estimated as *low to moderate.*

1 TME 1994, Heidemij advies 1994 and Provincies Gelderland en Overijssel 1994

Sector	Manufacture of wood and wood products (NACE 20)
Process	Machining operations
Waste stream	Wood losses

Prevention option	**Recycling wood losses**
Option No	6-2
Type	GOP/RU
Group	1
Description	Recycling of wood losses can be achieved by[1]: • active wood losses management, like: - central storage - segregation of sizes and types of wood - tell off one responsible person for collection, segregation and reuse • use of wood losses for other types of products.
Remarks	
Economics	Active management requires no investments and has short pay-back times. For using wood losses for other products usually new machines are necessary. One case studies mentions a pay back time of 3 years[2].
Potential	A reduction of circa 10% is achievable. The prevention potential has been estimated as *moderate.*

1 Heidemij advies, 1994
2 Heidemij advies, 1994

Sector	Manufacture of wood and wood products (NACE 20)
Process	Machining operations
Waste stream	Wood dust

Prevention option	**Wood dust incineration**
Option No	6-3
Type	TC/RC
Group	1/2
Description	Wood dust can be stored in a bunker from which it is transported to a special wood dust incinerator[1]. This measure will reduce wood dust waste largely, whereas the heat produced can be applied for heating the buildings.
Remarks	Emissions from this type of small-scale on-site incinerators can cause negative environmental effects if the combustion process is not controlled strictly. As in many EU-countries, wood dust waste will end up in a waste incineration plant and be burned under controlled conditions, it is doubtful whether the nett environmental effects of on-site incineration will be positive. Furthermore, other useful external applications for wood dust exist, like in paper production, in composting or in cattle feed.
Economics	Stricter regulations for airborne emissions from wood dust incinerators will make these incinerators less profitable.
Potential	A reduction of 100% can be achieved. Because of restricted airborne emissions and the fact that the waste problem is not strictly prevented, this prevention option has been assessed to have a *low* potential.

1 TME, 1994

Sector	Manufacture of wood and wood products (NACE 20)
Process	Preservation
Waste stream	Preservated wood

Prevention option	**Replacement wooden filling pieces**
Option No	6-4
Type	IMC
Group	1/2
Description	Filling pieces are used in order to create distance between the products that have to be preservated. Usually, wood is used for these filling pieces. This wood has to be disposed of as chemical waste. In case filling pieces are made of materials which do not absorb preservatives, the filling pieces are more fit for reuse. Furthermore, the filling pieces will not end up as chemical waste[1].
Remarks	A negative side-effect is the environmental effects of cleaning the filling pieces (water-pollution). Water treatment installations are available for this purpose.
Economics	No data have been found in literature. Saved costs are cost for the disposal of chemical waste. Costs have to be made for the alternative materials and for cleaning waste water.
Potential	Considerable reduction can be achieved. Economic data are not available, so a prevention potential can not be given.

1 Witteveen+Bos, 1995

Sector	Manufacture of wood and wood products (NACE 20)
Process	Preservation
Waste stream	Preservatives

Prevention option	**Good housekeeping**
Option No	6-5
Type	GOP
Group	1/2
Description	The following good housekeeping practices can decrease the amount of waste[1]: • vacuum or manually sweeping of floors • regularly inspection of equipment for spills and leaks • interception of any chemical dripping when unloading preservatives • good piling up of treated or untreated lumber to prevent damage • clearly marking of recycling bins and containers • regularly cleaning of filters, sump pits and drip pads • application of linings or coating on sumps to prevent sumpage • wall in of major process areas to prevent migration or overflowing of solutions • automation of lumber handling and mixing systems and remote monitoring as much as possible • triple rinse empty containers of waterborne preservatives and reuse of rinse water • daily inspection of storage yards; clean up of any drippage detected within 24 hours • use elevated drip pans on drip pads (under cylinder doors and treated wood) • cover or enclose treatment facilities and drip pads • good training of all personnel who handle or treat lumber and who manage, maintain or inspect hazardous waste. Preservation treatment practices: • good quality control: dirt on wood prior to treatment should be removed; unsalable, out-of-spec and damaged wood should be removed prior to treatment • application of high pressure over a period of 5 to 8 minutes, followed by a slow pressure release of 8 to 15 minutes • avoidance of excess pressure during treatment • application of a final vacuum • usage of strip pumps, which continuously return residual chemical solutions to the working tank • treating cylinder are to be tilted tightly towards the working tank • usage of dedicated forklift at drip pads or washing of the wheels before leaving the drip pads • construction of paved areas adjacent to drip pads • coverage of wood that is dried in open yards • application of good storage and handling practices (cover, lock, label, fence storage areas, detection systems for leakings).
Remarks	
Economics	Economic data on this variety of options differ strongly. In general, most options do not involve large investments and will be profitable.
Potential	The prevention potential has been estimated as *moderate*.

1 US EPA 1993 and VROM 1992

Sector	Manufacture of wood and wood products (NACE 20)
Process	Preservation
Waste stream	Preservatives

Prevention option	**Alternative preservatives**
Option No	6-6
Type	IMC
Group	1/2
Description	Preservative alternatives are[1]: • waterborne preservatives (producing less waste than oilborne preservatives because process water is reused) • borates (using pressure treatment or dip diffusion); because borates are highly susceptible to leaching, borates are not fit to preserve wood that will be in contact with the ground or water • ammoniacal copper/quaternary ammonium (ACQ) • copper-8-quinolinolate (Cu_8) • copper naphtenate • zinc naphtenate • quaternary NH_4 compounds (QAC) • zinc sulphate.
Remarks	Some options involve only qualitative waste reduction.
Economics	Economic data have not been found in literature.
Potential	The prevention potential has been estimated as *low to moderate.*

1 US EPA, 1993

Sector	Manufacture of wood and wood products (NACE 20)
Process	Preservation
Waste stream	Preservatives

Prevention option	**Alternative preservation methods**
Option No	6-7
Type	TC
Group	2/3
Description	Treatment processes vary in their ability to minimize waste[1]: • the empty-cell treatment process uses less carrier oil than the full-cell process for oilborne preservatives • the modified full-cell treatment process reduces the uptake of treating solution and minimizes the amount of dripping for waterborne solutions. Alternative preservation methods, still in research, are[2]: • thermic preservation of softer wood types requiring no preservatives • steam or chamber fixation for controlled application of preservatives.
Remarks	
Economics	No economic data have been found in literature. However, changes in technology involve large investments. In general, these options are suitable when old process equipment is to be renewed.
Potential	It is estimated that not many companies will change technologies only because of waste minimisation motives, so the prevention potential is *low*.

1 US EPA, 1993
2 Witteveen+Bos, 1995

Sector	Manufacture of wood and wood products (NACE 20)
Process	Preservation
Waste stream	Preservatives

Prevention option	**Recycling**
Option No	6-8
Type	RU/RC
Group	1/2
Description	• Components can be recovered out of preservatives residues or out of waste water[1]. Especially borates are suitable[2]. These components can be used for the manufacture of new preservatives. • Liquid waste generated at plants using waterborne preservatives can be reused as process solutions; all liquid waste should be directed to a sump. • Steam condensate from creosote treatment can be used as boiler feedwater. • Creosote sludge can be used as boiler fuel.
Remarks	
Economics	In general, recycling (especially waterborne preservatives) is probably the most cost effective means of minimizing waste[3]. However, recovery of borates is more expensive than buying new.
Potential	As literature indicates that recycling is economically effective, the prevention potential has been assessed as *moderate.*

1 UNEP IE Database: Thomson Crown Wood Products, 1991 gives a case of a chemical addition to separate the solids and liquid fractions of the waste.

2 VROM, 1992

3 US EPA, 1993

Sector	Manufacture of wood and wood products (NACE 20)
Process	Paint application
Waste stream	Paint and solvent waste

Prevention option	**Good housekeeping**
Option No	6-9
Type	GOP
Group	1
Description	Reduction can be achieved by good operational measures, such as: • reduction of spill-losses • clustering of paint orders • reduction of the painted surfaces; painting only visible parts • optimization of spray-techniques: - manufacture of minimal amounts - optimization of painting parameters, such as spray shape, spraying time and spraying device design.
Remarks	In wood industry, most attention is given to the aspect of overspray. Some of the options mentioned (such as clustering orders) are more fit for larger companies.
Economics	No economic data have been found in literature. However, no large investment costs are involved. Most options mentioned will have a pay back period of reasonable terms.
Potential	A considerable reduction of paint and solvent wastes is achievable by good operational measures. Therefore, the prevention potential has been estimated not as low, but as *moderate*.

Sector	Manufacture of wood and wood products (NACE 20)
Process	Paint application
Waste stream	Paint and solvent waste

Prevention option	**Catching of overspray**
Option No	6-10
Type	GOP/RU/RC
Group	1
Description	A fairly common recycling technique is to catch the overspray on rotating disks or moving belts from which the paint may be scraped and re-conditioned for re-use in the painting process. This is applicable only to certain paint types. Overspray and solvents in spray-booths are proved to be catched effectively with venturi-scrubbers, while with the use of coagulants like calcium-chloride, re-use of paints could be achieved[1].
Remarks	Paint sludge may be recycled for the production of lower-grade paint.
Economics	Generally, catching of overspray is economically feasible.
Potential	The prevention potential has been estimated as *moderate*.

1 Umweltbundesamt, Lack-Recycling GmbH 1986-1989; reference included in sector report 13 on manufacture of metal products.

Sector	Manufacture of wood and wood products (NACE 20)
Process	Paint application
Waste stream	Paint and solvent waste

Prevention option	**Alternative paints**
Option No	6-11
Type	IMC
Group	1/2/3
Description	Major alternatives[1] are: • higher solids coatings • waterborne coatings[2] • powder coatings • solvent-free liquid coatings • low reactivity solvent based products.
Remarks	The world-wide attention to reduce the emission of volatile organic compounds (VOC) has increased attention for opportunities to reformulate paints. Most alternatives will consequently reduce solvent wastes as well. Especially powder painting techniques have proved to be successful, providing a large reduction of VOC emissions, reduction of hazardous waste and improved work environment. However, the low conductivity of wood can cause problems. Barriers against widespread use of alternative formulations are: • performance characteristics are sometimes not as good as solvent-based paints; • reluctance towards experiments and time-consuming performance trials; • significant investment costs to change process equipment.
Economics	Significant investment costs are often involved to change process equipment.
Potential	In spite of the barriers mentioned above, general tendencies show a slow but steady process of change-over to alternative paints (principally as a result of the environmental pressure to reduce VOC emissions). Therefore, the prevention potential has been estimated as *moderate to high.*

1 A clear overview and discussion of these alternative types is to be found in: Giddings 1994 (reference included in sector report 13 on manufacture of metal products). As possibilities are industry specific, discussions relating to which customers are using/likely to use these alternative coating types is included in this document.

2 UNEP IE Database Verniland, 1990 and Schecter 1989, as well as Infomil, 1996 give case studies

Sector	Manufacture of wood and wood products (NACE 20)
Process	Paint application
Waste stream	Paint and solvent waste

Prevention option	**Technological modifications**
Option No	6-12
Type	TC
Group	2
Description	Modifications of painting equipment can reduce waste. Possibilities are: • minimizing system contents[1]: - using thin transport tubes; - minimizing temporal reservoirs; • emptying of tubes by a rubber ball or using exchangeable tubes[2]. • using a scour and seal-machine[3]; in most cases the use of primer will no longer be necessary; • using a colour mixing machine[4].
Remarks	
Economics	A scour and seal-machine requires an average investment of ECU 12 000. Benefits can add up to ECU 25 000. A colour mixing machine costs circa ECU 6 000[5]. No further economic data have been found in literature.
Potential	The prevention potential has been estimated as *low to moderate* (not high) due to required investments for technological modifications.

1 Witteveen+Bos, 1995
2 Heidemij advies, 1994
3 Provincies Gelderland en Overijssel, 1994
4 Provincies Gelderland en Overijssel, 1994
5 Provincies Gelderland en Overijssel, 1994

Sector	Manufacture of wood and wood products (NACE 20)
Process	Paint application
Waste stream	Paint and solvent waste

Prevention option	**Alternative paint application methods**
Option No	6-13
Type	TC
Group	1/2/3
Description	The following alternative painting techniques are in use[1]: • alternative painting technology using brushes and rollers; for example, when more coating of the material prior to assembling is applied, these efficient methods can be applied rather than spraying the finished product; • alternative spray-painting technologies (airless, electrostatic, high-volume-low-pressure)[2]; • dry spray cabin, i.e. airstream capture of paint spray and waste air filtration; • plunge-bath painting with minor amounts of sludge remaining from workpiece rinsing; • plunge-bath painting using water based paints, positioning electrodes within the painting bath to make use of physical-chemical effects; • use of water-soluble spray paints that can be recovered from the catching of the overspray; • moving the workpiece through a paint curtain.
Remarks	Not all these techniques will provide the requested quality of paint, so the applicability is restricted. Specific restrictions are the required high temperature for powder painting, the large paint particles and short spraying distance for vaporizing techniques, the very low conductivity of wood for electrostatic painting and the necessity of flat wood with no profile for rolling techniques.
Economics	The costs and benefits of the techniques mentioned are very site-specific. Generally, these techniques are economically feasible as significant savings on purchase of paints are obtained.
Potential	The waste reduction that can be achieved is considerable. It is estimated that these (partly good-operation) practices are not yet applied extensively sector-wide. Therefore, the prevention potential has been estimated as *moderate to high.*

1 Euroenviron 1993

2 Conventional manual air-atomised spray roughly produces the double amount of paint waste as compared to airless or high pressure spraying; electrostatic paint spraying produces about 20% of the waste compared to conventional spraying.

Sector	Manufacture of wood and wood products (NACE 20)
Process	Paint application
Waste stream	Paint and solvent waste

Prevention option	**(Mobile) distillation solvent waste**
Option No	6-14
Type	RU/RC
Group	1/2
Description	Methods for recovering of solvents from wastes are distillation processes, such as vacuum distillation or thin-film evaporation. *Batch-type distillation units* are commercially available in ranges from 20 to 200 litre units. Commercial *continuous-feed distillation* equipment is available for large volumes of contaminated solvents waste production[1]. Good housekeeping measures facilitate solvent recovery: • keep different solvents separated • minimise solids for efficient solvent reclamation • control solvent concentration • label waste and specify its origin
Remarks	In-house recycling of halogenated solvents is often possible for larger units[2] For small quantities, off-site reclamation is well suited.
Economics	Initial investment ranges from 2 000 ECU for a 20-litre batch distillation unit to more than 20 000 ECU for a 200-litre unit[3]. Benefits are related to lower solvent purchase costs and reduced hazardous waste management expenses.
Potential	For large enterprises with high consumption rates of solvents, recycling is a feasible and economically attractive option, that reduces this waste stream significantly. It is estimated that most of these larger enterprises do not operate on-site distillation. Therefore, the waste prevention potential has been assessed as *medium to high.*

1 Warren Spring Laboratory 1994 and Heidemij advies 1994
2 In literature (US EPA reference included in sector report 13 on manufacture of metal products) is indicated that recycling is economical when at least 10 m^3 solvent is generated per year.
3 US EPA reference included in sector report 13 on manufacture of metal products.

SECTION 7

MANUFACTURE OF PAPER AND BOARD

SECTOR REPORT

Contents :

NACE sectors involved in the present sector report:

Retained for analysis:	21.12	Manufacture of paper and paperboard
Excluded from analysis:	21.11	Manufacture of pulp
	21.2	Manufacture of articles of paper and paperboard

7.1 SECTOR CHARACTERISATION [1]

This sector is covered by code 21 of NACE, Rev.1 (1991), and includes the manufacture of pulp and paper (NACE 21.1) and the manufacture of articles of paper and paperboard (NACE 21.2) - both including cardboard production. The information presented afterwards in this section is related largely towards the manufacture of paper and paperboard (NACE 21.12)[2].

The major raw material (85%) for paper-making is wood-fibre, which includes both virgin fibre and waste paper. Recycling of waste paper is important and increasing. Waste paper utilisation represented 56% of all fibrous material furnished in 1993 and is growing annually[3]. The products of the sector can be divided into different grades of paper and board. In annex A the main grades are described, accounting for roughly 93% of both total EU production and consumption.

Over the last decades, the manufacture of paper and board shows a continuous tendency towards consolidation into large corporate and production units. This tendency is coupled with the closure of smaller, less efficient mills. However, in many market niches is a growing need for small, flexible production units which are close to their markets. A decline of the number of non-integrated mills is foreseen as integrated mills operate much more efficiently[4]. Non-integrated mills may therefore develop more into specialties in order to stay competitive. From 1989 to 1993 the sector faced increasing over-capacity; however, domestic demand and prices have since then recovered, providing favourable outlooks for at least 1997.

Average capacity of the 1 034 EU-12 paper mills in 1993 was 46 000 t/y, compared with 205 000 t/y for the 112 Nordic mills (Sweden and Finland). In general, large paper mills (over 100 000 t/y production) accounted for approx. 10% of the total number of mills in 1988, yet representing 40 to 45% of total Community production. The number of small mills (under 5 000 t/y) was approx. 250, whereas medium-sized mills account for approx. 665. Total paper and board production in 1993 (including Sweden, Finland and Austria) was approx. 70 million tonnes. Total employment nowadays is estimated at 150 000.

7.2 PROCESSES AND WASTES

There are two major steps in the production of paper and board:

- preparation of the fibre ('stock preparation'), based on pulp or on waste paper ('recycled or waste fibre')
- manufacturing of the paper itself ('paper machine').

A short decription of processes and products is provided in Annex A.

---

1 Main source: European Commission, 1995

2 The manufacture of articles of paper and paperboard (NACE 21.2) and the production of pulp (NACE 21.11) are excluded from further analysis:
The paper and board converting industry (NACE 21.2) is considered to produce waste streams (waste paper and board) of relatively low significance. The industry is mainly composed of small and medium-sized companies and employs about 380 000 persons within the Community in about 5 000 companies. The converting sector's total added value is higher than that of the pulp, paper and board sector. A large variety of products and articles in paper and board is manufactured; major products are packaging products (especially board and corrugated board), household and hygienic paper goods and stationery and office supplies (CITPA, 1996).
The production of pulp (NACE 21.11) as 'market pulp' (pulp dried and sold to third parties) is comprised of less than 100 mills EU-wide, with a total employment of approximately 11 000. It is not considered as typical SME level. Most pulp production (more than 60%) however is integrated to paper and board production (integrated mills). The number of integrated mills in the Community is about 300.

3 Waste paper recovery represented 41% of total domestic paper consumption in 1993 compared with 39% in 1992.

4 Evenblij, 1995; efficiency is higher since dewatering and drying of the pulp can be avoided between pulp and paper production.

In table 7.2.1 the different wastes are listed, together with their process origin and composition; the table includes a tentative priority ranking, based on the amount and the hazardous character of the waste. Further information regarding these wastes is provided in Annex A.

Table 7.2.1: Paper and board manufacturing process wastes

Process origin	Waste streams	Priority rank	Description and code according to EWC [5]	
Recycled fibre preparation	De-inking sludges	+	De-inking sludges from paper recycling	03 03 05
	Rejects	o	Rejects from paper and cardboard recycling	03 03 07
Paper machine	Waste water treatment sludge	o	Fibre and paper sludge Sludges from the treatment of industrial waste water	03 03 06 19 08 04
	Coating residues	-/o	Wastes not otherwise specified	03 03 99

Priority rank: + : high significance, o : medium significance, - : low significance EurEco/Witteveen+Bos 1997

Waste streams of minor significance only, not included in the table, are:
- ashes and slags (from the incineration of waste (bark, sludge) and from power boilers)
- scrap iron and other metals (from packings and from repair and maintenance)
- plastics (cans, bags and foils from packings)
- various waste (spill oils, wood, concrete, bricks, glass, etc.).

In general, standard data regarding waste generation at paper mills cannot be established; most figures show large variations between mills. The amounts of wastes depend strongly on the types of paper produced, applied processes and raw materials used.

Major waste streams can arise when de-inking is applied within the recycled fibre preparation (e.g. for tissue and printing grades paper) *(de-inking sludges)*. The average amount is about 0.3 ton dry solids/ton paper produced[6]. In addition, waste fibre preparation produces *rejects* from the various screening and cleaning stages in the process. These rejects consist of other contaminants of the waste paper, like nails, staples, paper clips, plastics, wires and wood pieces.

The principal waste stream from paper making is *waste water treatment sludge*, mainly consisting of primary treatment sludge; when biological (secondary) treatment is applied, also secondary sludge arises (roughly 10 - 20% of the amount of primary sludge). The average total amount is about 0.03 ton dry solids/ton paper produced[7]. At mills producing coated paper, temporary discharges of *coating residues* may occur.

Generally, the dry solids content of the waste sludges is about 20 to 40%. Sludges can be incinerated (for energy at the mill or externally) or deposited to landfill. Often, external re-use is possible, like soil-conditioning; minor applications are for example cement or brick production.

Environmental issues addressed to paper and board production are principally water pollution and waste (sludge) production. As a high energy-consuming sector, air pollution from paper mills originates primarily from various types of power plants; the mill itself does normally not give rise to significant air emissions[8].

5 Paper and board production does not generate major waste streams that are hazardous according to the European Hazardous Waste List.
6 Huizinga, 1992
7 Huizinga, 1992 and CEPI, 1996
8 Pöyry, 1994

7.3 WASTE PREVENTION

This section discusses waste prevention methods identified in literature. The major waste streams along with prevention options are summarized in the next table, following the division into processes as made in the preceding chapter. The selected options are described shortly in Annex B.

Table 7.3.1: Overview waste prevention options for paper manufacturing

Waste streams	Priority rank	Waste prevention method	Group	Potential
Recycled fibre preparation				
De-inking sludges	+	7-1 Optimisation of de-inking process (RU/TC) 7-2 Promotion of alternative inks (IMC)	1/3 1	-/o -
Rejects	o	7-3 Reduction of fibre losses with rejects (GOP)	1	-
Paper machine				
Waste water treatment sludge	o	7-4 Reduction of fibre and filler losses (GOP/RU/TC) 7-5 Fibre recovery from waste water (TC/RU) 7-6 Additional anaerobic waste water treatment (TC) 7-7 Limitation of accidental discharges (GOP)	1/2/3 1/2 2 1	- - - -
Coatings	-/o	7-8 Recycling of coating colours (RC)	2	o

+ = high, o : medium, - : low, .. = insufficient data — EurEco/Witteveen+Bos 1997

As *de-inking sludges* from recycled fibre preparation often contain good fibres, waste prevention is generally directed towards the recovery of these fibres, thus reducing the amount of waste sludge. Fibre-recovery itself is a state-of-the-art method; the prevention methods selected refer to a further optimisation of this process[9]. According to these sources, a certain extent of optimisation may still be achieved; therefore, the potential has been assessed as low to medium.

The level of contaminants in waste paper used for recycled fibre processing depends on external factors; therefore, the amount of *rejects* can not be reduced by the mills itself. Some waste prevention, however, can be achieved by further reducing the amount of fibres that are lost with the rejects. The potential of this optimisation method is low, because the major part of the waste stream (the rejects) is not reduced.

In general, prevention options for *waste water treatment sludges* are directed to the reduction of fibre and filler losses to the excess water[10]. However, for many years already, a great number of methods is implemented to optimise fibre recovery processes. Often, only the very small (and less usable) fibre particles may still be lost with the waste water. The prevention potential can therefore be assessed as low[11].

At mills for coated paper, reduction of *coating residues* is not yet very common for technical and, especially, economical reasons. The prevention potential depends on opportunities and developments in cost effective prevention methods. Opportunities may especially occur in new

9 Regaining of fibres from de-inking sludge, however, may give problems when paper is produced for special applications (for example hygienic and special paper).

10 Again, integrated mills offer more opportunities for waste prevention. In a non-integrated paper mill, the excess water is led to the waste water treatment, producing treatment sludges. In an integrated mill, this *excess water* can sometimes be used as a substitute for fresh water in the pulp mill. Part of the rejects from the paper machine consists of fibre material. In an integrated plant, at least part of this *reject flow* can be pumped back to the pulp mill for fibre separation.

11 For example: personal comments of KNP LEYKAM Maastricht (1996) and Özepa, 1995.

situations, for example when new production units are planned that involve extension of waste water treatment; recovery of specific waste streams may then become viable as this may reduce the costs of the (extension of) central waste water treatment. As opportunities and developments will continue to occur, the prevention potential has been estimated as medium.

7.4 EVALUATION

Low waste technology has been used widely for a long time in paper industry for reasons of competitiveness. Recovery of valuable fibres and consequent reduction of waste water treatment sludges, have been issues for many years because of the economic benefits. In the last decade, clean technology development has been directed as well to further reduction of the water consumption. Most board production can nowadays be operated with complete recycling of water. Paper production water use has decreased significantly.

The discerned importance of low waste technology and consequently its high degree of implementation sector wide, can explain the number and potential of the prevention options identified in literature: relatively few options are discussed in literature, most of them being 'state of the art' (group 1). Generally, the prevention potentials of these options have been assessed as low. Besides, as it appeared, literature provided little or no information on costs of prevention. The reason is often that the options are intimately related to the processes itself, so costs can hardly be separated.

Summarizing, it can be concluded that the outlook for clean technologies in the paper industry lies for some part in the field of reducing water consumption. Waste prevention has been an issue for many years, resulting in a high degree of implementation of prevention methods. Waste strategies are further directed towards improving external use of waste streams.

7.5 BIBLIOGRAPHIC REFERENCES

CITPA (1996), "Annual and statistical report of the European Paper and Board Converting Industry, 1994 and 1995", The International Confederation of Paper and Board Converters in Europe (CITPA), Frankfurt, Germany.

COWIconsult (1989), "The Technical and Economic Aspects of Measures to Reduce Water Pollution caused by the Discharges from the Pulp and Paper Industry", COWIconsult, Lyngby, Denmark.

Elzenga H.E., et al. (1994), "Preventie van industrieel afval; een verkenning van het potentieel aan kwantitatieve preventie van industrieel afval", RIVM, Bilthoven, 181 p.

Euroenviron (1993), "Industrial Waste Management, R&D Needs and Market Opportunities", Euroenviron Working Group on Industrial Wastes, Eureka, Euroenviron Umbrella Project

European Commission (1995), "Panorama of EC Industry 95/96", Bruxelles-Luxembourg.

Evenblij M. (1995), "Papier hier ?" Milieustrategie 5-95, Amsterdam, 4 p.

FEFCO (1996), "European Database for Corrugated Board Life Cycle Studies"; Fefco, Paris; Groupement Ondulé, Darmstadt; KRAFT institute, Stockholm.

Haskoning (1992), "Technical & Economic Study on the Reduction, Based on Best Available Technology, of Industrial Emissions (Water, Air & Solid Wastes) from the Pulp Industry - Selection of the most suitable parameters to determine limit values for emissions to air and water", Commission of the European Community, Bruxelles.

Huizinga K., et al. (1992), "Papier- en kartonindustrie, Samenwerkingsproject Procesbeschrijvingen Industrie", RIVM, Bilthoven, 15 p.

Muilwijk, E., et al. (1995), "New technology for the reuse of process water in the pulp and paper industries" (EV5V-CT92-0243), summary paper of European Workshop on Technologies for Environmental Protection, 1995 Trade Fair Bilbao Spain; published by the European Commission DG XII, L-2920 Luxembourg.

Oschatz (1992), "Entwicklung einer Feststoffverbrennung mit Rostfeuerung für Fang- und Reststoff aus der Karton- und Papierindustrie", Abschlussbericht Umweltbundesamt, Projektträgerschaft Abfallwirtschaft und Altlastensanierung; Förderkennzeichen: 1450577

ÖZEPA and AFC Aforma Consult (1995), "Branchenabfallwirtschaftskonzept Zellstof- und Papierindustrie", Bundesministerium für Umwelt, Wirtschaftskammer Österreich, Austropapier - Vereinigung österreicher Papierindustrieller; Bundesministerium für Umwelt, Sektion III, Wien, Österreich.

Pöyry, J. (1994), "Techno-economic Study on the Reduction Measures, Based on Best Available Techniques of Emissions (Water, Wastes, Air) from the Paper and Board Manufacturing Industry", Commission of the European Community, Bruxelles, 397 p.

SME (1996), "Inventarisatie preventiemaatregelen papier- en kartonindustrie", Bureau SME Milieubeleidsadvisering, Nijmegen, 48 p.

Scott (1989), "Efficiency and effluent improvements in a paper company", case-study originally appeared in a UK Department of the Environment booklet "Clean Technology" (ref. no D119NJ Nov. 1989). Reviewed and edited by UNEP IE database (July 1995).

St Regis Paper Co Ltd, United Kingdom, (1990), "De-inking process for waste paper", case-study was originally published in the UNEP IE document "Cleaner Production Worldwide"; later, the case study underwent a technical review; UNEP IE, Paris.

Umweltbundesamt, Projektträgerschaft Abfallwirtschaft und Altlastensanierung, Vorhaben 1988-1994, Bundesministerium für Bildung, Wissenschaft, Forschung und Technologie; Projektträger: Umweltbundesamt, Deutschland:
- Hartman-Druckfarben (1989 - 1995); Förderkennzeichen: 1470604/3
- Henkel KGaA (1989 - 1995); Förderkennzeichen: 1470604/2.

Waering, J. (1995), "R&D Needs for Progressive Systems Closure in the Pulp and Paper Industry" (Pulp and Paper Research Institut Canada), summary paper of European Workshop on Technologies for Environmental Protection, 1995 Trade Fair Bilbao Spain; published by the European Commission DG XII, L-2920 Luxembourg.

The Confederation of European Paper Industries (CEPI) has provided general information for the report as well as valuable comments on the draft version of the present sector report, for which we are very grateful. We have taken account of their remarks, within the possibilities given by the scope and budget of the study.

SECTION 7

MANUFACTURE OF PAPER AND BOARD

ANNEX A

PROCESSES AND WASTES DESCRIPTION

Contents :

A.1 OVERVIEW

The paper and board manufacturing is described independently from pulp manufacturing. There are two major steps in the production of paper: the manufacturing of the fibre out of pulp or collected paper wastes ('stock preparation') and the manufacturing of the paper itself (sheet forming).

The products of the sector can be divided into different grades of paper and board. Each grade requires different raw materials and machine design. The following seven paper and board grades account for roughly 93% of both total EU production and consumption.

- *Newsprint*
  Newsprint is mainly used for printing newspapers. As a commodity paper grade, production units are large, amounting to an average of 175 000 t/y in Finland and Sweden and 145 000 t/y in total Western Europe. Typical raw materials are:
  - unbleached (mechanical) pulp
  - semi-bleached softwood pulp or unbleached sulphite pulp
  - de-inked recycled fibre.
  The increased use of waste paper has shifted industry from the Nordic countries to the large consumption centres, such as Germany.

- *Coated printing and writing paper (graphic papers)*
  This is a fast growing grade sector in the EU. It includes coated wood-containing printing papers and coated wood-free papers. Typical new machines for this sector have a capacity of around 200 000 t/y. Typical raw materials are:
  - bleached mechanical pulp
  - bleached softwood Kraft
  - coating, composed of coating clay as pigment and latex and starch as binders.

- *Uncoated printing and writing papers (graphic papers)*
  This grade also includes wood-containing and wood-free papers. Developments in the production of uncoated woodfree papers is directed to the integration of pulp production with large-scale paper-machines (up to 250 000 t/y). Typical raw materials are:
  - bleached mechanical pulp
  - semi-bleached softwood Kraft or unbleached sulphite
  - clay filler.

- *Packaging papers*
  Packaging papers can be made from all grades of pulp or waste paper or any combination of these. Typical raw materials are:
  - unbleached softwood kraft pulp
  - recycled paper.

- *Packaging paperboards*
  This sector includes white-lined chipboard, folding boxboard, liquid packaging board and so-called grey-board. Production capacity consists of rather small mills and machines, the average machine capacity being 33 000 t/y, except for Finland and Sweden, with average of 110 000 t/y. Folding boxcard and liquid packaging board (used to make carton packs for milk etc.) are made with virgin fibre, mainly from Sweden and Finland. The other types are made EU-wide, making use of in general lower grades of wastepaper. Typical raw materials for multi-layer folding boxboard are:
  - bleached softwood or hardwood (for topliner)
  - mechanical or recycled paper pulp (for middle layer).

- *Liner and fluting*
  Liners, like Kraftliner and testliner, are paper grades used for the surface of corrugated board. Fluting, like Wellenstoff or semichemical fluting, are paper grades used for the interior of corrugated board. Major producers of linerboard and fluting are Germany and France. Kraftliner and semichemical fluting are virgin fibre based; Wellenstof and testliner are corrugated base papers from recovered waste paper. Typical raw materials are:
  - kraft pulp (for Kraftliner)
  - unbleached pulp (for semichemical fluting)
  - recycled fibre (for Wellenstoff and testliner).

- *Tissue (hygienic and sanitary paper)*
  These papers for sanitary and household uses may be made from virgin fibres, generally bleached, and with varying amounts of secondary fibres ranging up to 100%. Major tissue producers are Italy and Germany. The average machine size is very small, approximately 19 000 t/y. Virtually all production is converted at the mills into the consumer products. Typical raw materials are:
  - chemical softwood and hardwood pulp
  - mechanical pulp or de-inked pulp
  - recycled paper.

A.2 FIBRE PREPARATION

* Process description

Paper making starts with fibre preparation ("stock preparation"). The major raw materials for paper making are pulp (virgin fibres) or waste paper (recycled fibres).
Stock preparation involves screening and refining of the virgin fibres or repulping of the recycled fibres. When recycled fibres are applied, additional steps in stock preparation are necessary, related to the removal of impurities from the recycled material[1].

Further general steps in stock preparation involve the addition of various chemicals and fillers and dissolution of chemicals and mixing of all ingredients. Typical chemicals are inorganic filler materials (china clay, kaolin, talc, calcium carbonate) and binders (starch and latex), accounting for 12 to 15% of total raw material input. Inorganic fillers or coating pigments have two main functions: they improve the printing characteristics of the paper surface; and they reduce cost as they are less expensive than fibre.

* Waste description

Waste streams from fibre preparation occur mainly at *recycled fibre* processing and involve rejects and de-inking sludges. These streams are discussed further below.

- *Rejects from paper and cardboard recycling*
  In European countries the water content of recovered paper is generally assumed to be about 10%. The content of other materials than fibres in the recovered paper varies between 8 and 12 %. It is estimated that 25% of these materials originates from the former use of the paper, such as tacks, labels etc.[2] The remaining 75% has no relation with the former use of paper.

---

1 These steps may involve removal of mechanical impurities and/or chemical impurities (e.g. de-inking), as well as the optional step of bleaching.
Different paper types based on recycled fibre require different cleanliness and brightness of the stock. For example, many board grades do not require de-inking, whereas high-speed, thin paper machines require extensive multi-stage pre-treatment. For tissue and household products based on recovered fibres, the de-inking process is often followed by bleaching.

2 Fefco, 1996.

After repulping of the dry waste papers, removal of the mechanical impurities has to take place. The removal of rejects is based on the differences in physical properties between fibres and contaminants. Methods used are screening or centrifuging in hydro-cyclones or centrifuges, applied at various stages in the process and depending on the requirements of the paper grade.

Impurities typically contain sand and stones, fillers, glues, plastics and metal parts, such as staples. The rejects contain also some valuable fibres (data for the Netherlands indicate fibre contents of 15-20% [1]).

Some typical waste amounts of rejects reported are about 3 - 6% of the amount of stock produced[2], 2,5%[3], and 2%[4] of waste paper input.

Disposal of these solid wastes is generally to landfill.

- *De-inking sludges from paper recycling*
  The largest amount of reject-waste is generated by de-inking[5]. Ink removal is necessary for paper grades where brightness is important (newspaper, graphic paper, tissue, liners of waste-based cartonboards). For tissue production also the fillers have to be removed.

  Available de-inking methods are based on flotation or washing techniques. Before de-inking, the printing ink must be released from the fibre and kept in dispersion. The sludge is dewatered separately in a centrifuge or wire press to 30 - 50% dry solids content. Additional washing is required to remove the finest and largest ink particles[6]. If removal is based largely on washing, the de-inking sludge amount is higher than compared to flotation de-inking. Various reports give different figures of total de-inking sludge production. For example 22% of input waste paper (0,3 ton/ton paper produced)[7]. For tissue production, material loss is in the order of 25 - 30%[8].

  The de-inking sludges are generally disposed of to landfills or externally incinerated, e.g. in the ceramics and brick industry.

Stock preparation from *virgin fibre* pulp, does also involve a reject waste stream that is generated by cleaning of the pulp furnish before the paper machine. These rejects contain various impurities, like shives, bark, sand, and also some good fibres. Normally, these rejects are led to the effluent stream and will end up in the sludge from effluent treatment. This is why the rejects are not separately accounted for in this waste description.

---

1 SME, 1996.
2 Pöyry, 1994.
3 Huizinga, 1992.
4 SME, 1996.
5 According to <Pöyry, 1994> the presence of heavy metals (in the ppm range) in rejects, waste water sludge and paper is particularly related to the content of heavy metals in printing inks and varnishes - in spite of today's tendency towards using non-metal-containing printing inks. In some countries, e.g. France, heavy metals appear not to be a problem anymore for many years <CEPI, 1996>.
6 Pöyry, 1994
7 Huizinga, 1992.
8 Pöyry, 1994,

A.3 PAPER MACHINE

* Process description

For production of paper and board in paper machines, the prepared fibre (stock) is added to the paper machine in low concentrations (< 1% dry solids). During the process of sheet-forming by pressing and drying, the water is removed through wires and screens. This so-called white water, which still contains fibres, is filtered and largely recirculated in the process.

Generally, a paper or board machine consists of:
- wire section
- press section
- dryer section
- reeler.

Most common additional units (depending on the paper and board grade) are:
- calenders (on- and off-machine types)
- winders and rewinders
- coaters (on- and off-machine types)
- coating emulsion preparation
- finishing and roll wrapping equipment
- roll core handling systems

* Waste description

- *Waste water treatment sludge*
  Excess water from the paper machine becomes contaminated with fibres and fillers because part of the material passes through the holes in the wire when paper is dewatered: the retention of the material on the wire is less than 100%, varying between 50 and 90% depending on paper quality. The main part of the white water is recycled, passing through a fibre recovery unit. The fibre and filler materials recovered, are pumped back to stock preparation. The excess of white water is discharged as waste water. Final waste thus is produced as sludge from the waste water treatment.

  The treatment sludge consists in general of two types:
  - primary sludge, from the mechanical pretreatment of waste water (primary clarification), consisting of fibres and of inorganic material at mills using fillers;
  - biological (secondary) sludge at mills that use biological waste water treatment; this sludge has a high level of organic material. The amount of secondary sludge is roughly 10 - 20% of the amount of primary sludge[1].

  The sludges consist mainly of fibres that are too short in order to be useful for recycling in paper production. However, for certain paper grades, e.g. board production, all primary sludge can be recycled internally[2].

  The re-use of sludge in production is reported to be decreasing, for the following reasons[3]:
  - lower fibre content in the final sludge will reduce interest in re-use;
  - when biological waste water treatment is used, dewatering of sludge becomes more difficult, as fibres in sludge provide for acceptable dewatering properties.

---

1 CEPI, 1996
2 Özepa, 1995
3 Pöyry, 1994

Generally included in the sludges as well, are rejects from pulp cleaning before the paper machines. The dry solid content is low (1 - 2%) and these rejects are normally led to the waste water stream and consequently end up in the treatment sludge.

Data regarding the generation of primary and secondary sludge are found mostly in a range from 10 to 40 kg dry solids/ton paper produced.

Waste water treatment sludges are not regarded as particularly hazardous and are most commonly dumped at landfills. External recycling options are available for sludge wastes. Especially soil-conditioning material may find an increasing use in areas where there is demand for such material[1]. Besides, several applications are investigated for other use of waste water treatment sludge, for example additives in the production of building stones, ceramic products and insulating material, cement production and cat's box fillers[2].

The possibility of sludge incineration has been demonstrated, although on-site incineration is only economically viable for large amounts of sludge (thus for very large mills only).

- *Coatings*
  At mills producing coated papers, discharges of coating colour may occur. These discharges may have a high dry solids content (approx. 50%) or may be a diluted effluent[3]. The first type of discharge can be handled as a solid waste; the diluted stream is stored in a surge tank and discharged to the waste water treatment plant.

- *Various*
  Waste streams of minor significance include:
  - ashes and slags (from the incineration of waste (bark, sludge) and from power boilers)
  - scrap iron and other metals (from packings and from repair and maintenance)
  - plastics (cans, bags and foils from packings)
  - various waste (spill oils, wood, concrete, bricks, glass, etc.).

1 Pöyry, 1994.
2 Huizinga, 1992.
3 Pöyry, 1994.

SECTION 7

MANUFACTURE OF PAPER AND BOARD

ANNEX B

PREVENTION OPTIONS

Contents :

Sector	Manufacture of paper and board (NACE 21.12)
Process	Recycled fibre preparation
Waste stream	De-inking sludges

Prevention option	**Optimisation of de-inking process**
Option No	7-1
Type	RU/TC
Group	1/3
Description	As de-inking sludges contain good fibres, waste prevention is generally directed towards recovery of the fibres, thus reducing the amount of sludge. *Proven methods* for optimisation of de-inking processes involve: • application of pressure screens for filtrate from the washer[1], in order to retain larger valuable fibres[2]; • multi-stage cleaning principles, that is to have a second flotation stage for fibre recovery from the de-inking sludge-layer[3]. *New developments* involve: • fine sorting of medium-density waste paper intended for de-inking to remove adhesive impurities; • fibre recovery by advanced cellulose filtration system (Turboscreen) [4]; • treatment with oxygen enriched water[5] to reduce fibre waste (pulp whiteness could be improved simultaneously); • development and pilot-plant testing of improved bio-degradable chemicals for de-inking flotation of conventional inks, as well as of new chemicals for de-inking of new generation water-based newspaper inks[6]; • new flotation processes to increase the quality of de-inked waste paper[7]; • improvement of separating small print particles from the paper fibre in order to increase de-inking efficiency from approximately 80% to 90% [8].
Remarks	Regaining of fibres from de-inking sludge may give problems when paper is produced for special applications (for example hygienic and special paper). Increasing of the amount of short fibres and fillers in the product must be combined with adjustment of wires, cleaners, filters etc.
Economics	Specific costs are not defined in literature available.
Potential	According to the literature sources mentioned, fibre recovery from de-inking sludge is a state-of-the-art method; however, some optimisation is reported to be possible[9]. Therefore the prevention potential has been assessed as *low to moderate*.

1 The filtrate from the washing steps, containing ink and filler particles, holds smaller amounts of good fibres.

2 Pöyry, 1994

3 Pöyry, 1994 and St Regis Paper Co Ltd, 1990 (UNEP IE):
In the case of the St Regis Paper Co Ltd, additional dispersion is carried out between the first and second flotation stage, contributing substantially to the reduction of dirt particles in the finished paper and allowing the processing of a wider range of available waste papers to be converted to high quality printing paper. Process design includes low usage of chemicals (no chlorine bleaching is necessary) and energy (operating at the lowest acceptable temperatures).

4 In Euroenviron 1993: Eureka 831: Stork Screens, Netherlands, Scan-Sult, Norway.

5 Centre Technique de Papier/Societé des Pates a Papier Savoie Dauphine, France (in: Euroenviron, 1993)

6 Umweltbundesambt, Henkel, 1989 - 1995

7 Papierfabrik Hermes, Darmstadt Institute for Paper Manufacture, Dresden Technical University, Munich Technical Academay, Germay (in: Euroenviron, 1993).

8 Papiertechnische Stiftung, Dresden Technical University, Munich Technical Academay; Germay (in: Euroenviron, 1993).

9 E.g. according to SME, 1996

Sector	Manufacture of paper and board (NACE 21.12)
Process	Recycled fibre preparation
Waste stream	De-inking sludges

Prevention option	**Promotion of alternative inks**
Option No	7-2
Type	IMC
Group	1
Description	The promotion of no-metal-containing inks and varnishes will improve the opportunities for re-use of de-inking sludge. In Sweden, taxing is being announced for the use of metal containing inks and of UV-hardened inks and varnishes. Further, the de-inkability of the printed product and the ecological impact of de-inking wastes can be affected through careful selection of ink raw material, such as printing ink resins and oils which are based on tall oil, the removal of which requires less chemicals under less restrictive conditions[1]. Water-based newspaper inks are developed and tested in full-scale newspaper printing runs[2]. Waste paper containing these water-based inks can be de-inked much easier than conventional inks. The de-inking test results indicate high brightness of de-inking sludge and high removal efficiency. Other on-going and planned R&D concerns re-design of inks and additives in order to ease recycling[3].
Remarks	This prevention option lies not within the control of individual companies, but is of interest for public authorities, official associations and federations.
Economics	Individual companies can greatly benefit from this development.
Potential	As developments are still in an early stage, the prevention potential has been assessed as *low.*

1 United Paper Mills, Finland (in: Euroenviron, 1993)
2 Umweltbundesambt, Hartmann-Druckfarben, 1989 - 1995
3 Papiertechnische Stiftung, Germany (in: Euroenviron, 1993)

Sector	Manufacture of paper and board (NACE 21.12)
Process	Recycled fibre preparation
Waste stream	Rejects

Prevention option	**Reduction of fibre losses with rejects**
Option No	7-3
Type	GOP
Group	1
Description	The level of contaminants in waste paper used for recycled fibre processing depends on external factors; therefore, the amount of rejects can not be reduced by the mills itself. Some waste prevention, however, can be achieved by further reducing the amount of fibres that are lost with the rejects. Optimisation options of waste paper fibre processing consist of: • increase of the residence time of waste paper fibres in the re-pulper, reducing the amount of particle-formation[1]; • optimising of the separation engineering (e.g. increased number of cleaning stages for the rejects and intermittent reject discharge of the high-density centrifugal cleaners, to reduce fibre loss)[2]; • recirculation of the rejects to the pulp mill (for integrated mills).
Remarks	-
Economics	Costs for optimising existing operations are estimated to be high in the literature source mentioned.
Potential	By optimizing the fibre processing, it is estimated that a reduction of the amount of fibres (15 - 20%) in the rejects of 75% can be achieved[3]. Taken into account that this reject flow is a minor part of total fibre sludge waste, the prevention potential has been assessed as *low*

1 SME, 1996
2 Pöyry, 1994
3 SME, 1996

Sector	Manufacture of paper and board (NACE 21.12)
Proces	Paper machine
Waste stream	Waste water treatment sludge

Prevention option	**Reduction of fibre and filler losses**
Option No	7-4
Type	GOP/TC/RU
Group	1/2/3
Description	Reduction of fibre and filler losses with waste water will reduce the amount of waste water treatment sludge produced. There are several measures to reduce these losses: • *Optimisation of fibre recovery from excess white water* At most paper mills there is a special fibre recovery system from circulating waters and waste waters. For example, (vacuum) disc filters will often provide an efficient recovery[1]; some methods to improve retention on the filter surface include: - adding a sweetener pulp from the stock preparation to the white water ahead of the filter; the best pulp for this purpose is usually unrefined long-fibre pulp; - adding retention chemicals to the incoming water. Micro-filtration at the water circuit of paperboard machines is still developing[2]. • *Retention aids* To increase the retention of material in the paper machine, chemicals ('retention aids', usually poly-electrolytes) are used that bind smaller particles to the larger fibres. An effective retention aid can increase the retention with 10-15%. Many retention aids are affected by dissolved material in white water. To overcome this problem, chemicals should be selected which are unaffected by contaminants but still meet the intended function. One such example is polyethylene oxide[3]. • *Reject handling and reject cleaning* Rejects[4] from the incoming raw materials contain a large amount of good fibre material. Improved recovery of this material can be achieved by increasing the number of cleaning stages for the rejects (adding several pressure screens or centicleaners in series)[5]. In this way considerable amounts of raw material can be saved and the fibre load to the waste water treatment reduced. Three to five cleaner stages are optimal for most systems.
Remarks	
Economics	Specific costs are not defined in literature available.
Potential	Fibre recovery methods for white water are generally state-of-the-art, according to literature mentioned; therefore the prevention potential has been assessed as *low*.

1 Pöyry, 1994

2 SME, 1996; further applications of micro filtration are reported in Muilwijk, 1995:
This reported research programme is aimed at developing high-flux ceramic microfiltration systems as an alternative for disc filters and other traditional filter systems in paper industry. Micro-filtration total operational costs at 1992 summed up to roughly ECU 5,00 per m^3; a reduction in costs to around ECU 1,00 brings this treatment within acceptable limits for the paper industry. The project claims current operational costs of ECU 2,00 per m^3, and means to reach the final goal are developed to be tested in 1995 .

3 Waering, 1995

4 Rejects in the raw material (pulp) for paper making include fibre material not suitable for paper-making and contaminants like bark, sand and shives.

5 Pöyry, 1994

Sector	Manufacture of paper and board (NACE 21.12)
Proces	Paper machine
Waste stream	Waste water treatment sludge

Prevention option	**Fibre recovery from waste water**
Option No	7-5
Type	RU/TC
Group	1/2
Description	Primary treatment (by settling ponds) of waste water from a major manufacturer of tissue paper products, resulted in still high levels of suspended solids (mainly fibres) in the effluent. Fibre recovery from this effluent was improved by the application of Dissolved Air Flotation (DAF)[1]. Efficiency is claimed to be higher than traditional methods like sedimentation or filtration. The recovery process also includes adding polymeric flocculating agents to the waste stream.
Remarks	The majority of the fibre recovered from the effluent stream is currently recycled in low-grade products, such as industrial wipes, made of 100% recycled fibre.
Economics	The capital costs of the DAF plant was considerably more than the cost of an extended water treatment plant. The payback period depends on the company's ability to use the fibre that is collected. If it is possible to reuse the maximum amount of fibre, the payback period is of the order of five years.
Potential	In the case study, wastes generated were reduced from 260 tons per week to 200 tons per week. Information on the EU-wide application and feasibility is not available. A waste prevention potential can therefore not be given.

1 Scott, 1989

Sector	Manufacture of paper and board (NACE 21.12)
Proces	Paper machine
Waste stream	Waste water treatment sludge

Prevention option	**Additional anaerobic waste water treatment**
Option No	7-6
Type	TC
Group	2
Description	If biological (secondary) waste water treatment is applied, the common treatment method is generally an aerobic process. The secondary sludge from this process can be reduced by preceding the aerobic process with an anaerobic waste water treatment. Aerobic waste water treatment gives generally a sludgegrowth of approximately 50% of the organic influent load. Anaerobic treatment gives only a sludgegrowth of 5%. By installing an anaerobic water treatment before the traditional aerobic treatment, a secondary sludge reduction of 85% can be achieved[1].
Remarks	Important additional benefits from anaerobic treatment are savings on the aerobic process (less pollution load, requiring less energy), energy savings when biogas from the anaerobic process is utilized and improved final effluent quality.
Economics	High investment costs are involved.
Potential	As (additional) investments are high, implementation of anaerobic pre-treatment is expected to take place on a limited scale; besides, the amount of waste reduction is only moderate because the major amount of sludge originates from primary treatment; therefore, the prevention potential has been estimated as *low*.

1 SME, 1996.

Sector	Manufacture of paper and board (NACE 21.12)
Proces	Paper machine
Waste stream	Waste water treatment sludge

Prevention option	**Limiting accidental discharges**
Option No	7-7
Type	GOP
Group	1
Description	Sludge production is increased if accidental discharges take place due to upsets in the processes. To reduce their frequency and effects, the following areas are of interest[1]: • white water system design and control: - appropriate storage volume - control of fresh water intake and white water discharge - separation of production lines • broke system design: - optimal storage volume for broke - application of different broke systems for different types of broke - mimimal material loss (rejects) with broke screening • improved training and motivation of the operators • sewer recovery system.
Remarks	-
Economics	Investment costs for storage volumes can be minimized by proper analyses of production rates of machines, frequency and extent in time of peak-flows and web breaks, dilution factors for fibres, chemicals and fillers, shower system etc.
Potential	As accidents can cause significant extra volumes of waste sludges, the prevention potential of accident control measures has been assessed as *moderate*.

1 Pöyry. 1994

Sector	Manufacture of paper and board (NACE 21.12)
Proces	Paper machine
Waste stream	Coatings

Prevention option	**Recycling of coating colours** [1]
Option No	7-8
Type	RC
Group	2
Description	Recirculation of coating colour (diluted spills in waste water) back in the process is considered difficult. However, with membrane techniques at a full-scale plant in Sweden, good results have been obtained with recycling of coating colour since 1992. The recovered coating colour is recycled back to the coating kitchen, where it is proportioned to the fresh coating colour. The permeate from the membranes is used in coater showers instead of fresh water.
Remarks	If coated paper grades are produced it is common to have a separate sewer for coating discharges. This prevents possible setups in the treatment system and prevents possible obstruction of dewatering properties and eventually the incineration of the sludge. A succesfull trial has also been made in a French mill with a similar system[2].
Economics	Specific costs are not defined in literature available.
Potential	Literature reports good results, but costs for membrane systems are expected to be significant; the prevention potential has been estimated as *moderate*.

1 Pöyry, 1994
2 Pöyry, 1994 and CEPI, 1996 (: Cascades-Blendecques mill in France)

SECTION 8

PUBLISHING, PRINTING AND REPRODUCTION OF RECORDED MEDIA :

PRINTING

SECTOR REPORT

Contents :

NACE sectors involved in the present sector report:

Retained for analysis:	22.2	Printing and service activities related to printing
Excluded from analysis:	22.1	Publishing
	22.3	Reproduction of recorded media

8.1 SECTOR CHARACTERISATION [1]

Printing and publishing, as defined by code 22 of NACE (1991), includes all activities to reproduce an original image on or into a product, such as books, the press, maps, packaging and CD's. It is a mature sector of moderate and steady growth. The following chapters of this section focus on printing (NACE 22.2), which includes photoprocessing, as major wastes occur within these processes[2].

Total production of the EU based printing and publishing companies amounted 91 billion ECU in 1993, with a value added of 39 billion ECU. The average real annual grow rate over the period 1984-1993 was 3.8%. Employment in the sector grew steadily from 1984 until the recession in 1991, falling to an estimated number of 817 000 persons in 1994. A gradual recovery is foreseen for the coming years.

Most of Europe's printing and publishing sector constitutes small companies serving specific local or regional markets. For example, 85% of the printing industry employs less than 20 persons, while most of the remaining 15% employ between 20 and 500 workers. Besides, a small number of large printing and publishing companies exist, often dominating national markets. A general trend towards concentration by acquisition and merger can be observed. Due to small scale production technologies and geographically defined niche markets, however, small firms are expected to continue to provide the bulk of industry, particularly in printing.

The sector is characterized by strong value added and a high dependence on skilled personnel. It is a modern, high-technology industry, remaining so by investing heavily in new machinery and manufacturing processes. The growth of computer applications and strength further assists these trends.

In the short and medium term, the economic upturn and increasing demands for information in Europe are expected to sustain a growth in output of the sector as a whole. In the longer term, new technologies such as CD-based publishing are challenging paper-based production.

8.2 PROCESSES AND WASTES

The two processes considered in this sector report on NACE 22.2 are:

- printing
- photoprocessing

Printing may be further subdivided into lithography, gravure printing, flexography, letter press and screen printing. Printing process steps include image processing, proof making, plate processing, make-ready, printing and finishing.

The photoprocessing industry consists of business which develop and finish photographic film. It includes color (print and slide) and black/white processing.

More details on printing and photoprocessing can be found in Annex A.

---

1 Main source: European Commission, 1995

2 Publishing (**NACE 22.1**) is the major output market for the printing sector. The publisher accepts and edits the author's manuscript. The publisher is responsible for determining the number of copies to be printed and is responsible for taking care of unsold copies. Some large printing firms incorporate their own publishing department to keep marketing in their own hands. As publishing itself does not constitute a production industry, only marginal waste streams are generated. The only exception would be the unsold copies, which are often recycled, though.
Reproduction of recorded media (**NACE 22.3**) includes copying of sound recordings, video recordings and computer media. The activities typically occur on demand. The associated waste streams are assessed to be negligible.

Table 8.2.1 lists the identified waste streams, together with their process origin. The table includes a priority ranking, based on a sector wide tentative evaluation of the amount and the hazardous character of the waste streams.

Table 8.2.1: Wastes of the printing industry

Process origin	Waste streams	Priority rank	Description and code according to EWC [3]	
Printing	Waste ink containers	-	Wastes not otherwise specified	08 03 99
	Solvent and ink residues	+	Waste ink containing/free of halogenated solvents	08 03 01 / 02
	Waste ink	+	Ink sludges containing/free of halogenated solvents	08 03 05 / 06
	Dirty cleaning rags	-	Wastes not otherwise specified	08 03 99
	Chrome sludges	-	Wastes not otherwise specified	08 03 99
	Waste paper and cardboard	+	Wastes not otherwise specified	08 03 99
	Used plates	o	Wastes not otherwise specified	08 03 99
Photo-processing	Waste paper and film	o	Photographic film and paper, containing/ free of, silver or silver compounds	09 01 07 / 08
	Waste cartridges, cassettes and spools	-	Wastes not otherwise specified	09 01 99
	Silver containing bath overflows	+	Water based developer, activator/offset plate developer/fixer/bleach and bleach fixer solutions	09 01 01 / 02 / 04 / 05

Priority rank: + : high significance, o : medium significance, - : low significance EurEco/Witteveen+Bos 1997

The photoprocessing industry primarily generates aqueous wastes from process operations. The most significant contaminant is silver, but other contaminants occur as well. Technology exists to recover silver and certain other chemicals. The drying phase of photoprocessing does not generate a specific waste.stream.

Solid wastes are primarily waste paper and film, waste ink and used plates from printing and waste paper and film from photoprocessing.

Other environmental issues than waste in printing and photoprocessing are:

- emission of Volatile Organic Compounds (VOC's) to air through evaporation (printing);
- waste water containing silver or other contaminants (photoprocessing);
- noise and vibration nuisance from heavy equipment (printing).

These topics are only marginally discussed here, but are relatively important for this sector, with many prevention options realised.

3 Printing wastes that are hazardous wastes according to the European Hazardous Waste List and included in table 8.2.1. are EWC 08 03 01 / 02 / 05 and 06; hazardous photoprocessing wastes included in the table are EWC 09 01 01 / 02 / 04 and 05.

8.3 WASTE PREVENTION

This section discusses waste prevention options identified in literature. The major process waste streams along with prevention options are summarised in table 8.3.1, following the division into processes and waste streams as made in the preceding paragraph. A more detailed description of the various options can be found in Annex B.

Table 8.3.1: Waste prevention options for the printing industry

Process origin	Waste stream	Priority rank	Waste prevention method		Group	Poten-tial
Printing	Waste ink containers	-	8-1-1	Use of recyclable bulk ink containers (GOP)	1	- / o
	Solvent and ink residues	+	8-1-2 8-1-3 8-1-4 8-1-5	Alternative solvents (IMC) Electrostatic powder painting (TC) Electronic picture production (TC) Recycling of solvent (RC)	1 2 2 2	- o + o
	Waste ink	+	8-1-6 8-1-4 8-1-7	Overnight sprays (GOP) Electronic picture production (TC) Re-use of printing ink (RU)	1 2 1	- / o + -
	Cleaning rags	-	8-1-8	Use washable cleaning rags (RU)	2	- / o
	Chrome sludges	-	8-1-9	Ceramic or plastic gravure printing cylinders (TC)	3	o
	Waste paper and cardboard	+	8-1-10 8-1-4	Good operating practice (GOP) Electronic picture production (TC)	1 2	- / o +
	Used plates	o	8-1-4 8-1-11	Electronic picture production (TC) Re-use aluminium plates (RU)	2 1	+ -
Photo processing	Waste paper and film	o	8-2-1 8-2-2 8-2-3 8-2-4	Good housekeeping (GOP) High utilization of paper and film area (GOP) Material substitution (IMC) Re-use/recycling of water and waste (RU/RC)	2 2 2 1	o - - -
	Waste cartridges, cassettes, spools	-	8-2-5	Recycling of cartridges, cassettes and spools (RU)	1	-
	Silver containing bath overflows	+	8-2-4	Re-use/recycling of water and waste (RU/RC)	1	-

Priority rank: + : high significance, o : medium significance, - : low significance — EurEco/Witteveen+Bos 1997

The prevention methods identified provide only a broad outline and should not be seen as limitative. The industry is characterized by a large diversity of printing processes, each with specific wastes and specific limitations on the applicability of the options mentioned. The prevention options, as reported shortly, are therefore not universally applicable. Further studies on waste minimisation should typically be performed on an individual company level.

For printing, several waste prevention options involve technological change, which matches the high-tech character of the industry. Two of these options are defined in group 2, meaning they have so far been applied in limited cases, and one option is defined in group 3. Electronic picture production (option 8-1-4) is attributed high potential, because of its possible future impact on several process steps. This option is still young and may see further development and implementation in the nearby future. This option will also create the introduction of printing on demand, which will eliminate the waste arising from unsold copies in the applied cases. Handling unsold copies is the responsibility of the publisher, or the combined printing and publishing firms which are slowly evolving.

Several options for printing involve good operating practice. All these activities are considered more or less common practice and have therefore been defined in group 1 with medium to low potential.

In photoprocessing, most options find moderate to widespread application. This has lead to general low potential for waste prevention in photoprocessing, because substantial prevention has already been realised. Contrary to printing, no options involving technological change have been found.

The major waste streams from photoprocessing are wastewaters containing silver or other contaminants. Silver recovery from these wastewaters by a variety of methods are normal practice, as are the regeneration of in particular bleach and fix solutions. The waste(water) prevention thus realised is large, but considerable further improvement seems difficult.

Solid waste from photoprocessing is primarily waste paper and film, to which most prevention options refer. Good operating practice still provide opportunities to reduce waste paper and film. Re-use and recycling are quite normal to the extent that further major waste reduction through this way does not seem likely.

8.4 EVALUATION

Printing is a modern, high-tech industry. Printing yields several solid waste streams, for which promising prevention options exist, mostly involving technological change, which matches the high-tech character of the industry. Electronic picture production, at this moment still limited to small scale processes, can have important future waste prevention potentials. The outlook for clean technologies within the printing industry is therefore promising.

Photoprocessing generates primarily aqueous wastes, but some solid waste reduction can still be achieved by good operating practice. No major clean technologies developments have been identified. As traditional waste streams have been recognized for many years already, existing waste prevention methods are generally considered common practice. Summarizing it is concluded that the photoprocessing industry faces modest outlooks for clean technologies introduction on the short and medium term.

8.5 BIBLIOGRAPHIC REFERENCES

BECO (1995), "Inventarisatie preventiemaatregelen Grafische Industrie", BECO Milieumanagement & Advies BV, Rotterdam, 1995

Booij H. (1992), "Procesbeschrijvingen industrie: Fotografische industrie", RIVM rapportnr. 736301137, Bilthoven, 1992, 13 p.

Cramer Y. (1996), "Het einde van het drukinkt-tijdperk", Intermediair, 1996 (32), 30, p. 21-23

CUWVO (1989), "Afvalwaterproblematiek zeefdrukkerijen, aanbevelingen met betrekking tot de sanering van afvalwaterlozingen door zeefdrukprocessen", CUWVO werkgroep VI, the Hague, Netherlands, 1989

European Commission (1995), "Panorama of EC Industry 95/96", Bruxelles-Luxembourg, 1995

Provincie Overijssel (1995), "Grootste winst is toegenomen bewustzijn binnen het bedrijf", Nieuwsbrief Afvalpreventie, Provincie Overijssel, Zwolle, Netherlands, November 1995, p. 8-9

Quarles van Ufford C.H.A. and Gels H. (1994), "Procesbeschrijvingen industrie: Grafische industrie", RIVM rapportnr. 773006161, Bilthoven, 1994, 15 p.

UNEP (1994a), "Internal recycling in a flexographic printing facility reduces effluents", case study submitted to UNEP IE in 1994, Valance d'Agen, France, 1992

UNEP (1994b), "The French firm Thermocolor S.A., specialized in lacquering by electrostatic powdering, replaced its chemical stripping device by a thermal stripping of its handling tools", case study submitted to UNEP IE in 1994, Luce, France, 1993

UNEP (1995a), "Substitution of organic solvent-based flexographic printing ink on polyethylene to water based flexographic printing ink", case study submitted to UNEP IE by the Swedish Foundation of TEM, Landskrona, Sweden 1991

UNEP (1995b), "Internal recycling at a photographic processing facility", abstracted from US EPA 'Pollution Prevention Information Clearing House' and technically reviewed and edited by UNEP IE in 1995, Raleigh NC, United States of America, 1985

UNEP (1995c), "Recycling of printing ink to be re-used by newspapers as black printing ink reduces waste disposal to treatment plant by seven tons", abstracted from US EPA 'Pollution Prevention Information Clearing House' and technically reviewed and edited by UNEP IE in 1995, Denmark, 1980

UNEP (1995d), "Reduction of waste and emissions of photographic chemicals at a commercial printing company", original article translated, reviewed and edited by UNEP IE in 1995, Oslo, Norway, 1993

UNEP (1996a), "Ecoprofit: Cleaner Production in a City-based Project", elaboration of UNEP IE document "Cleaner Production Worldwide", Graz, Austria, 1991

UNEP (1996b), "Recycling water and waste in the photographic industry", elaboration of UNEP IE document "Cleaner Production in the ASIA and Pacific Economic Coorporation (APEC) Region", Marlkam, Ontario, Canada, 1993

US EPA (1990), "Guides to Pollution Prevention - The Commercial Printing Industry", Washington, DC, Office of Research and Development, 1990, 45 p.

US EPA (1991), "Guides to Pollution Prevention - The Photoprocessing Industry", Washington, DC, Office of Research and Development, 1991, 61 p.

'The European Newspaper Publishers Association (Enpa) and the International Confederation of Printing and Allied Industries (Intergraf) have been asked to comment the draft sector report. We were very grateful for their reactions: ENPA confirmed that they had no comments to make; Intergraf made comments on the general character of the report, and indicated that this can give false impressions in such a divers industry as printing industry. We agree with this remark and have tried to take account of it by generalising to a minimum, but could not go much more into detail than for other industrial sectors of study, as the study's objective is to provide a comparative overview of several industrial sectors.'

SECTION 8

PUBLISHING, PRINTING AND REPRODUCTION OF RECORDED MEDIA :

PRINTING

ANNEX A

PROCESSES AND WASTES DESCRIPTION

Contents :

A.1 PRINTING

* **Process description**

Printing process steps include, image processing, proof making, plate processing, makeready, printing and finishing.

The original artwork is photographed to produce the image. Image making is in essence a photographic process, for which reason it is not detailed in this paragraph but covered by paragraph A.2. A proof is made to compare with the printed product and make adjustments to the press. The image is transferred to the plate, on which the image areas are made ink receptive. The press is adjusted under operating conditions to achieve the reproduction quality desired. Paper (as web or sheets) is fed into the printer and printed. Depending on the printing process and the ink solvent, the printed paper may pass a drying step. Finally, the product is trimmed, folded, binded, laminated and/or embossed.

The main printing processes are characterized by the type of the plate used.
In **lithography printing**, image and non-image areas are on the same plane. Surface plates are most commonly used nowadays, because other types such as deep-etch and bimetal plates result in serious heavy metal toxicity and water pollution problems. Common surface plates are made of aluminium.
Gravure printing evolves around a copper plated printing cylinder of steel, in which the image is engraved mechanically with a diamond stylus or etched chemically with ferric chloride. Etching requires a resist for the non-image areas, which is stripped off after etching. Following testing and reworking (if necessary), the cylinder is chrome plated. Before the next image is applied, the cylinder is machined and polished for a smooth surface.
Flexography and letterpress employ plates with raised images. Metal plates are etched after developing; plastic plates, which are typically applied in flexography for packaging, do not need etching.
In **screen printing**, the (negative) image is transferred to the screen, which consists of a woven fabric. The ink is pressed mechanically through the image areas of the screen with a scraper onto the object to be printed.

* **Waste description**

The major wastes from printing are waste ink containers, solvent and paint residues, waste ink, dirty cleaning rags, chrome sludges and baths, waste paper and cardboard and used plates.

- *waste ink containers*
  Even large users of ink normally have the ink delivered in small containers, resulting in large number of empties. These have to be disposed of as hazardous waste because of contamination with ink.

- *solvent*
  Solvent in ink or cleaning liquids largely evaporates, but also ends up in cleaning rags and collection trays under the printing equipment, particularly in screen printing.

- *waste ink*
  Waste ink is liberated at the printing process as waste from color mixing or as left over from cleaning rolls and fountains. It is collected in trays under the printing machine or sticks to cleaning rags. Ink not properly stored may form skins leading to unnecessary early replacement.

- *dirty cleaning rags*
  Cleaning equipment is a necessary step between different process runs or before close down at the end of the working day. Spills have to be cleaned up. Cleaning rags are used for this purpose. Dirty rags contain solvent, waste ink, oil, dust, dirt and other contaminants.

- *chrome sludges and baths*
  The preparation of gravure printing cylinders involves at least several galvanic treatment steps, including removal of the used and applying of a new chrome layer in a bath treatment. The resulting wastewater contains chrome, which is chemically precipitated yielding a chrome-hydroxide sludge.

- *waste paper and cardboard*
  Waste paper accounts for more than 90% of the total waste from printing industries. It originates mainly from rejected print runs and scrap from finishing operations. Most paper is recycled, incinerated or disposed of as trash.

- *used plates*
  Lithographic printing plates wear out (or rather the coated image areas on it) and have to be replaced after a certain number of press runs. This may generate a waste stream, depending on the type of plate used. Aluminium surface plates, which are most commonly used, can be recycled.

A.2 PHOTOPROCESSING

* Process description

The photoprocessing industry consists of business which develop and finish photographic film. Nearly all of the consumer oriented films are based on silver as the photo-active material, usually available in a gelatine emulsion on a paper or plastic carrier film. The processing of photographic film and paper requires the use of a number of chemicals to develop and produce finished photographic goods.

Photoprocessing consists of two successive operations. Firstly a film is prepared from the image. Secondly a photo-sensitive medium is exposed to light through this film, after which this medium is subsequently processed in a similar fashion as the film, to obtain the end product.
The basic steps in **color processing** are developing, stopping, bleaching, fixing, washing, stabilizing and drying. Depending on the end product, one or more series of bleach and fix treatments may be passed and more or less treatments are followed by a wash treatment before passing on to the next step.
Black/white processing includes developing, stopping, fixing and washing, which applies for preparation of both the film image and the photographic end product.

* Waste description

Wastes generated by photoprocessors are primarily aqueous effluents, in particular process bath wastes, color developer wastes, bleach/fix wastes and spent rinse water. Most aqueous effluents contain silver in one form or another. Bath overflows that contain dissolved silver are commonly recovered. Spent bleach and bleach-fix baths are usually regenerated.

Silver bearing solid wastes include paper and film, and items like film cartridges, cassettes and spools. Photographic paper and film may be wasted because of expiry and/or unfavourable storage conditions. Waste paper and film also originates from trimmings, test strips, incomplete use of paper and film area, and rejected prints. Silver from scrap paper and film may be recovered.

SECTION 8

PUBLISHING, PRINTING AND REPRODUCTION OF RECORDED MEDIA : PRINTING

ANNEX B

PREVENTION OPTIONS

Contents:

Sector	Publishing, printing and reproduction of recorded media (NACE 22)
Process	Printing
Waste stream	Waste ink containers

Prevention option	**Use of recyclable bulk ink containers**
Option No	8-1-1
Type	GOP
Group	1
Description	Small ink containers are widely used. For large printers, this results in many empty containers to be disposed of [1,2]. Recyclable bulk ink containers can be returned to the ink supplier for refilling.
Remarks	Small printers should not use large ink containers due to storage problems.
Economics	There are no cost details on these measure available. The measures require no large investments and are easy to introduce.[3]
Potential	Use of recyclable containers seems fairly widespread. Because further application has no particular obstacles and should lead to more reduction of waste ink, the potential is rated *medium/low*.

1 US EPA, 1990, p. 14-15
2 UNEP, 1996a
3 BECO, 1992

Sector	Publishing, printing and reproduction of recorded media (NACE 22)
Process	Printing
Waste stream	Solvent and ink residues

Prevention option	**Alternative solvents**
Option No	8-1-2
Type	IMC
Group	1
Description	Solvents based on Volatile Organic Compounds (VOC's) lead to serious air emissions. A variety of fountain solutions, cleaning solvents and inks are available based on vegetable cleaning agents, reducing the emissions of VOC's[1,2], and reducing solvent based waste streams.
Remarks	
Economics	
Potential	Because of the widespread use of alternative solvents, the potential is rated *low*.

1 BECO, 1995
2 US EPA, 1990, p. 20

Sector	Publishing, printing and reproduction of recorded media (NACE 22)
Process	Printing
Waste stream	Solvent and ink residues

Prevention option	**Electrostatic powder painting**
Option No	8-1-3
Type	TC
Group	2
Description	Solvent based painting yields large amounts of waste solvent. Electrostatic powder painting greatly reduces these amounts.[1, 2]
Remarks	Electrostatic powder painting is a recognized painting technology in e.g. xerography (laser printers), but is increasingly applied in commercial printing companies.[3]
Economics	For commercial printing, electrostatic powder painting as an alternative for or complementary to conventional printing processes, seems for the moment suitable for orders of small numbers, because of financial and technical limitations of the machinery.
Potential	In desk top publishing this option is already standard. For commercial printing, further application on a large scale does not seem likely, but gradual further application on a small scale feasible. Hence the potential is rated *medium*.

1 UNEP, 1995a
2 UNEP, 1994b
3 Cramer, 1996

Sector	Publishing, printing and reproduction of recorded media (NACE 22)
Process	Photoprocessing
Waste stream	Solvent, waste paper, used plates, waste ink

Prevention option	**Electronic Picture Production**
Option No	8-1-4
Type	TC
Group	2
Description	With electronic techniques, the image is received and processed in digital format. Computer to plate technologies skip the image processing step by placing the digital image directly on the plate. In direct engraving, the use of a plate is abolished and the image printed directly on the object. The latest development is digital printing, with advanced equipment that produces the end product folded and binded in one step straight from the digital image.
Remarks	Electronic Picture Production is a very young technique and seems for the moment interesting for smaller orders because of the low speed of the equipment[1]. Digital printing is applied in small companies only, but expectations are that larger printing companies will soon use this technique in addition to conventional printing processes[2]. Digital printing allows printing on demand, which almost eliminates unsold copies and related waste. This coincides well with the recent trend towards more books in small numbers with high rates of return.[3]
Economics	Reports on costs vary. According to BECO (1995), the technique is relatively expensive. Other sources claim that the costs of upgraded equipment is affordable[4].
Potential	Although initial application is not estimated highly by all sources, the technology is still young. Further technological developments and possible related price decrease may lead to further introduction. Because the technique itself implies a virtual abolishment of one or more complete process steps, the prevention potential is rated *high.*

1 BECO, 1995
2 Cramer, 1996
3 European Commission, 1995
4 UNEP, 1995d

Sector	Publishing, printing and reproduction of recorded media (NACE 22)
Process	Printing
Waste stream	Solvent and ink residues

Prevention option	**Recycling of solvent**[1]
Option No	8-1-5
Type	RC
Group	2
Description	Cleaning the screen of screen printing with toluene based solvents yields considerable amounts of waste solvent. Although most cleaning solvent evaporates (giving an air pollution problem), spent solvent residues may be recycled. For large printing companies, distillation of used cleaning solvent may be feasible. *Batch-type distillation units* are commercially available in ranges from 20 to 200 litre units. Commercial *continuous-feed distillation* equipment is available for large volumes of contaminated solvents waste production. Special closed cleaning units with automatic cleaning solvent recovery are available.
Remarks	
Economics	Initial investment ranges from 2 000 ECU for a 20-litre batch distillation unit to more than 20 000 ECU for a 200-litre unit[2]. Benefits are related to lower solvent purchase costs and reduced hazardous waste management expenses. The use of cleaning solvent may be reduced by as much as 80% through closed cleaning units.
Potential	Closed cleaning units are already increasingly applied and may provide, like in company distillation, considerable savings on the use of cleaning solvent. The potential is rated *medium*.

1 BECO. 1995

2 US EPA reference included in sector report 16, option 16-3.

Sector	Publishing, printing and reproduction of recorded media (NACE 22)
Process	Printing
Waste stream	Waste ink, dirty cleaning rags

Prevention option	**Overnight sprays**[1]
Option No	8-1-6
Type	GOP
Group	1
Description	Overnight sprays are sprayed onto ink fountains to prevent overnight drying, so that the ink can be left in the fountain without cleaning and the waste that would come with that cleaning at the end of the day.
Remarks	
Economics	The savings on ink, waste ink disposal and cleaning labour easily outweigh the low costs of the spray.
Potential	Overnight sprays can be easily introduced, but are already reasonably commonly applied. Because of the large benefit against a small effort, the potential is nevertheless rated *medium/low*.

1 US EPA, 1990, p. 20

Sector	Publishing, printing and reproduction of recorded media (NACE 22)
Process	Printing
Waste stream	Waste ink

Prevention option	**Re-use of printing ink**
Option No	8-1-7
Type	RU
Group	1
Description	Waste ink from the printing process and color changes is collected, purified and re-used as black printing ink in newspaper production. The recycling can be carried out by the printing company itself, or by the ink manufacturer. The former is more advantageous for large companies, the latter for small companies.
Remarks	Recycling to black ink is generally more practical than to another (original) colour. The ink after recycling is of some lower quality, such as newspaper ink. This option can only be applied in company if the amount of black ink used is large compared to the amount of coloured ink used by the company. 'Carbon black' may be added to improve the blackishness of waste coloured ink. Advanced equipment for mixing colouring agents reduces coloured ink losses.[1]
Economics	With a capital cost of Dk 37 000 and O&M of 1.23 Dk/ton paper, the net savings were reported at 24.5 Dk/ton paper in 1980, for a discarded printing ink treatment unit of 7 ton/year.[2] Another source reports that major operating cost savings are reductions in raw materials and waste disposal.[3]
Potential	The options are generally used for newspaper printing and hence given *low* prevention potential.

1 BECO, 1995
2 UNEP, 1995c
3 US EPA, 1990, p. 20

Sector	Publishing, printing and reproduction of recorded media (NACE 22)
Process	Printing
Waste stream	Dirty cleaning rags

Prevention option	**Use washable cleaning rags**
Option No	8-1-8
Type	RU
Group	2
Description	Most clean-up is done with rags wetted with solvent or by pouring solvent over the equipment and then wiping it off with a rag.[1] Washable cleaning rags are rented and returned to the industrial laundry for cleaning or dry cleaning of solvent, waste ink and other contaminants. Rags can be re-used for 20 times on the average.
Remarks	The rags should be stored in closed tins to avoid evaporation of solvents. Use of washable cleaning rags transfer the solid waste problem of the rags to a wastewater problem.
Economics	One source reports the costs of one washing at Dfl 0.35 compared to Dfl 1.15 for each new cleaning rag.[2]
Potential	The reported degree of implementation is moderate to high. The measure is easy to introduce and results in a clear reduction of waste rags, but increases a wastewater problem. The overall prevention potential is therefore rated *low/medium*.

1 US EPA, 1990, p. 13
2 BECO, 1995

Sector	Publishing, printing and reproduction of recorded media (NACE 22)
Process	Printing
Waste stream	Chrome sludges

Prevention option	**Ceramic or plastic gravure printing cylinders**
Option No	8-1-9
Type	TC
Group	3
Description	Removing the chrome layer of the gravure printing cylinder results in chrome waste yielding chrome sludges. The use of gravure printing cylinders of ceramics or plastic replaces these waste by less hazardous ones.[1]
Remarks	
Economics	Change of printing cylinders requires considerable investments, which makes is feasible for large scale applications only.
Potential	Despite the financial obstacles to wide scale introduction, real waste reduction of this particular waste stream may be achieved. The prevention potential is therefore rated *medium*.

1 BECO, 1995

Sector	Publishing, printing and reproduction of recorded media (NACE 22)
Process	Printing
Waste stream	Waste paper and cardboard

Prevention option	**Good operating practice**
Option No	8-1-10
Type	GOP
Group	1
Description	Various options for reduction of waste paper and cardboard exist. Although some of these require the use of small parts of equipment, these parts are so readily available that the use has been labelled good operating practice instead of technological change. • Proof losses can be decreased by using overproduction of previous orders, and by applying lower speed. Also paper from previous proof runs may be used again in a next proof. Proof runs do not require the use of high quality paper.[1] • Covering the carriers of forklift trucks will protect paperwebs and reduce damage loss. • Speed adjusters at the cutting machine allow most of the last stretch of the paper web to be used. • A well functioning counting system should be combined with exact counting by the operator of the number of copies required, particularly for orders with more than one series to have equal copies of each series. • The use of high quality cardboard will reduce rejection of unacceptable products.[2]
Remarks	
Economics	Generally low cost measures.
Potential	Because many of the options mentioned above are already being used more or less commonly, the potential has been rated *medium/low*.

1 Provincie Overijssel, 1995
2 BECO, 1995

Sector	Publishing, printing and reproduction of recorded media (NACE 22)
Process	Printing
Waste stream	Used plates

Prevention option	**Re-use of aluminium plates**
Option No	8-1-11
Type	RU
Group	1
Description	Aluminium plates are the most common type in lithographic printing. By external re-use, almost 100% recovery can be achieved. Use of double side plates may further reduce the need for plates.[1]
Remarks	Reuse of aluminium plates is normal practice. The use of double side plates is unknown.
Economics	
Potential	The option is considered normal practice and the potential rated *low*.

1 BECO. 1995

Sector	Publishing, printing and reproduction of recorded media (NACE 22)
Process	Photoprocessing
Waste stream	Waste paper and film

Prevention option	**Good housekeeping**
Option No	8-2-1
Type	GOP
Group	2
Description	Paper and film storage at optimum room temperature and humidity; refrigerator or freezer for long storage periods.[1] First in first out storage management: avoid exceeding expiration dates. Good inventory control to reduce los of raw material due to damages.[2]
Remarks	
Economics	
Potential	Measures are easily introduced and give direct results, hence the potential is rated *medium*.

1 US EPA, 1991, p. 13
2 UNEP, 1995d

Sector	Publishing, printing and reproduction of recorded media (NACE 22)
Process	Photoprocessing
Waste stream	Waste paper and film

Prevention option	**High utilization of paper and film area**
Option No	8-2-2
Type	GOP
Group	2
Description	Improving the use of paper and film area results in more orders per given paper or film area, which decreases the amount of waste paper or film.[1]
Remarks	The extent to which this option can be applied depends on the nature of the orders. The organization of image processing becomes more complicated when more than one order is put on one paper or film.[2]
Economics	
Potential	Due to the restraints on widespread introduction of this option, the potential is rated *low*.

1 UNEP, 1995d
2 Booij, 1992

Sector	Publishing, printing and reproduction of recorded media (NACE 22)
Process	Photoprocessing
Waste stream	Waste paper and film

Prevention option	**Material substitution**[1]
Option No	8-2-3
Type	IMC
Group	2
Description	Use of alternative chemicals or films to reduce the associated toxic waste streams. Replacement of ferricyanide bleach by ferric EDTA resulted in a less toxic waste stream. Using non-silver instead of silver based films reduces silver containing waste streams.
Remarks	In general, alternative materials may be unavailable, more expensive or lead to unacceptable product quality.
Economics	
Potential	Because the option is only applicable in specific cases due to the limitations described under 'Remarks', the potential is rated *low*.

1 US EPA, 1991, p. 14

Sector	Publishing, printing and reproduction of recorded media (NACE 22)
Process	Photoprocessing
Waste stream	Waste paper and film

Prevention option	**Re-use/recycling of water and waste**
Option No	8-2-4
Type	RU/RC
Group	I
Description	Aqueous wastes come about as bath overflows from most photoprocessing steps, containing silver and potentially a variety of other chemicals. Several processes are used to recover silver and other chemicals from these flows, often enabling re-use of process water to high extents as well. Reported[1] processes include chemical precipitation, countercurrent rinsing, evaporation, membrane filtration[2], ion exchange[3] and electrolytic processes[4].
Remarks	
Economics	In general, cost savings on raw chemicals, in particular silver, outweigh investment costs for treatment facilities.
Potential	Applications of chemical recovery are common, and the option is therefore given *low* priority.

1 US EPA, 1991, p.14-19
2 UNEP, 1996b
3 UNEP, 1995b
4 UNEP, 1995d

Sector	Publishing, printing and reproduction of recorded media (NACE 22)
Process	Photoprocessing
Waste stream	Waste cartridges, cassettes and spools

Prevention option	**Recycling of cartridges, cassettes and spools**[1]
Option No	8-2-5
Type	RU
Group	1
Description	Films are normally delivered to the photoprocessor in housings such as cartridges, cassettes and spools. These housings constitute a waste stream after processing of the film, but can be recycled several times before they wear out.
Remarks	
Economics	
Potential	Although limited information is available about this option, application seems fairly normal practice, so the prevention potential has been rated *low*.

1 US EPA, 1991, p. 13

SECTION 9

MANUFACTURE OF CHEMICALS AND CHEMICAL PRODUCTS

SECTOR REPORT

Contents :

NACE sectors involved in the present sector report:

Retained for analysis:
24.1 Manufacture of basic chemicals
24.2 Manufacture of pesticides and other agro-chemical products
24.3 Manufacture of paints, varnishes and similar coatings, printing ink and mastics
24.4 Manufacture of pharmaceuticals, medicinal chemicals and botanical products
24.5 Manufacture of soap and detergents, cleaning and polishing preparations, perfumes and toilet preparations
24.6 Manufacture of other chemical products
24.7 Manufacture of man-made fibres

Excluded from analysis: --

9.1 SECTOR CHARACTERISATION

The chemical industry is one of the most successful and diverse sectors of manufacturing industry. Its main activities consist of chemically transforming materials into diverse substances, giving them new physical and chemical properties. The range of chemical products is enormous and these products make an invaluable contribution to the quality of our lives.

The EU is a leading producer of chemical products with an added value of 126 311 ECU/a in 1995. EU production (EU-15) stands at 128% of US production, and at 188% of Japanese production (figures of 1995)[1]. After several years of solid growth in the mid to late eighties, depressed prices and overcapacity have characterised the performance of the EU chemical industry since 1990. Despite an improvement in profitability in 1994, a high cost structure is anticipated to undermine European profitability in the medium term. The strategy of major chemicals companies hinges therefore on the creation of strategic alliances and joint-ventures to achieve rationalisation in research, production and access to markets[2].

A high number of large enterprises are involved in chemical industry: the enterprises with 100 or more employees represent 79% of the turnover. Large multinational companies operate world-wide and are responsible for most of the research and development (R&D), that is a crucial competitive factor in all sectors and that represents high percentages of the turnover. There are nevertheless many smaller companies that are in general active in one or more market niches and are often limited to local markets.

Germany is by far the largest EU producer of chemicals, accounting for about 27% of EU turnover in this sector. Other large EU producers are France (18%), the United Kingdom (13%), Italy (11%), Belgium (8%), Spain (7%) and the Netherlands (7%).

9.2 PROCESSES AND WASTES

Chemical industry utilises a vast array of complex continuous and batch-type processes and technologies in the manufacture of chemical products.

Three common methods used in the manufacture of chemical products are considered :

- chemical synthesis
- ancillary processes (e.g. storage, transport, heating, cooling)
- cleansing

Annex A gives further details on these processes.

Table 9.2.1 lists the identified waste streams, together with their process origin. The table includes a priority ranking, based on a sector-wide tentative evaluation of the amount and the hazardous character of the waste streams.

1 Estimates. Source: CEFIC 1996a.
2 European Commission 1995

Table 9.2.1: Major waste streams of the chemical industry				
Process origin	**Waste streams**	**Tentative priority rank**	**Description and code according to EWC [3]**	
Chemical synthesis	Process wastes	+	Wastes from inorganic chemical processes Wastes from organic chemical processes	06 00 00 07 00 00
	Solvent wastes	+	Organic solvents, washing liquids and mother liquors (halogenated and halogen free)	07 01 03/04 - 07 07 03/04
	Off-spec product	o	Wastes from inorganic chemical processes Wastes from organic chemical processes	06 00 00 07 00 00
Process ancillaries	Process wastes	o	As above	
Cleansing	Cleansing wastes	o	Aqueous washing liquids and mother liquors Organic solvents, washing liquids and mother liquors (halogenated and halogen free)	07 01 01 - 07 07 01 0701 03/04- 0707 03/04

Priority rank: + : high significance, o : medium significance, - : low significance EurEco/Witteveen+Bos 1997

Waste streams from chemical industry are complex due to the varied operations and reactions employed. They arise from a variety of sources which are associated with the chemistry and plant; they may arise from the preparation of feed stocks; the reaction / reactor itself; from product separation; from the utility system and from cleansing processes.

Process wastes are the major waste stream and directly related to the chemical synthesis. They contain unconverted reactants, reaction by-products, residual products, raw material impurities and auxiliary chemicals (as solvents and catalysts).

Solvent wastes are another major waste stream. Solvent use is high and many different solvents are applied, for product recovery, purification, and as reaction media.

Off-specification products are produced as a result of changing conditions during start-up and shut-down or alterations in conditions during normal processing. Insufficient quality control and process operation are another factor.

Cleaning wastes are also a significant waste stream. Especially in batch processes and multi-product plants, but also in continuous processes, there is an obvious need to clean the process equipment in order to meet reaction and product specifications.

Further details on wastes are provided in annex A.

The chemical industry is involved in other environmental issues than waste. Industry is working with substances which can have harmful effects when released into water bodies and into the air. As a big energy user, the industry is a big emitter of CO_2, one of the gases contributing to the greenhouse effect. There is further the possible pollution linked to the use of certain chemical products (such as the contamination of water tables by fertilisers and pesticides and the pollution due to the use of solvents in paints and adhesives).

3 Chemical industry waste streams are hazardous wastes according to the European Hazardous Waste List.

9.3 WASTE PREVENTION

This section discusses waste prevention options identified in literature. The major waste streams along with prevention options are summarised in table 9.3.1, following the division into processes and waste streams as made in the preceding chapter. Because of the highly specific and often confidential nature of the processes of chemical industry, only very general discussions on options can be given. The intent is to stimulate the thinking of manufactures about their processes. The selected options are described in detail in Annex B.

Table 9.3.1: General waste prevention options for chemical industry

Process	Waste streams	Priority rank	Waste prevention method	Group	Potential
Chemical synthesis	Process wastes	+	9-1 Good housekeeping (GOP)	1	-
			9-2 Changes in process chemistry (TC)	1/3	o / +
			9-3 Changes in reactor design (TC)	1/3	o / +
			9-4 Integrated process development (TC)	1/3	o / +
			9-5 Process optimisation (GOP)	1	o
			9-6 Advanced process control (GOP)	1	o
	Solvent wastes	+	9-7 Solvent selection (IMC)	1/3	o / +
			9-8 Solvent recovery (RC / RU)	1	o
	Off-spec	o	9-9 Reprocessing of off-spec product (RC)	1	-
Process ancillaries	Process wastes	o	9-10 Minimisation of losses during storage / transport (GOP)	1	-
			9-11 Minimisation of losses in heating / cooling processes (GOP)	1	-
			9-12 Minimisation of losses in piping (GOP)	1	-
Cleansing	cleansing wastes	o	9-13 Reduction of the need for cleansing (GOP)	1	o
			9-14 Optimisation of the cleansing process (GOP)	1	-

+ = high, o : medium, - : low, .. = insufficient data — EurEco/Witteveen+Bos 1997

As both a significant consumer of materials and energy as well as a major generator of wastes, the chemical industry is well placed to benefit from waste minimisation measures. Chemical industry has recognised this and has developed several waste minimisation options. Most of the options mentioned above have been developed and/or are applied in chemical industry.

Two types of waste minimisation options have been identified in literature. On the one hand, the options concern *highly innovative new reaction design and process development* with emphasis on waste minimisation (options 9-2 to 9-4, 9-7). These options can have considerable long term financial benefits and are the key to substantial minimisation of wastes, but require high R&D expenditure and high investments. As chemical industry is used to solve problems by innovation, the prevention potential of these options has been evaluated as between *moderate* and *high*.

On the other hand, many options are *good operating practices*. These options are based on conventional chemical engineering principles and their introduction, particularly at times of plant refurbishment, do not necessarily require large capital investments. However, the options are anticipated to be already implemented to a large extent or to generate low reduction possibilities in relation to the options mentioned above. Potentials are therefore evaluated as between *low* and *moderate*.

9.4 EVALUATION

The drive towards clean technology in the chemical industry with an increasing emphasis on the reduction of waste at source will require a level of innovation and new technology that the chemical industry has not seen in many years. It will go beyond the traditional approach of product recovery and by-product re-use of industry. The costs of running chemical plants more cleanly and safely will be high and will increasingly make it important to use the best technology. Research and development will be crucial for the successful introduction of new and more environmentally friendly products and processes.

Chemical industry is for safety reasons in general rather conservative and depends on tried and trusted processes and procedures. Waste minimisation options implemented until now follow often this line and are good housekeeping measures. Projects to minimise waste in production concentrate on tidying up the existing operations. The real benefits for waste minimisation can be seen in the production processes where fundamental change to the process is often required to achieve cleaner operation. The fact that chemical industry is research based and is among the most innovative sectors of manufacturing industries (second after electronic industry), can therefore be very beneficial. Fundamental solutions need to be found and it is in this area that new chemistry residing in research and development departments in chemical industry and academic laboratories is continuously converted to cleaner, more profitable processes to the benefit of all.

Chemical industry (CEFIC) has launched an initiative under the name of SUSTECH, which is intended to promote collaboration within the chemical and related processing industries on the theme of cleaner manufacturing. In comparison with other sectors as the oil industry, collaboration is still at an early stage; the chemical industry has traditionally been less inclined to collaborate on technical developments because R&D is a major competition factor.

With the SUSTECH initiative, the transfer of waste minimisation techniques from one sector of chemical industry to another can bring considerable improvements within a relative short term. This is of particular importance to the fine chemicals sector, where catalysis has traditionally played a relatively minor role and where chemical products are often produced in batch processes and in several reaction steps. For process innovation in the longer term, the SUSTECH initiative is anticipated to facilitate co-operation between industry on strategic process development necessitating particularly high R&D expenditure.

Rapidly advancing technology makes it important that companies continually educate themselves about improvements that are waste reducing and pollution preventing. Information distribution on waste minimisation - in the form of general strategy building information and of information on process specific applications - is vital for this. Information sources to help inform companies about such technology include trade associations and journals, chemical and equipment suppliers, equipment expositions, conferences, and industry newsletters. By keeping abreast of changes and implementing applicable technology improvements, companies can often take advantage of the dual benefits of reduced waste generation and a more cost efficient operation.

9.5 BIBLIOGRAPHIC REFERENCES

Berkel van C.W.M., et al. (ed.) (1991), "Business Examples with Waste Prevention: Ten Case Studies from the Dutch PRISMA-project", "Prevention of waste and emissions at DSM resins", Amsterdam, Ministry of Economic Affairs, 1991

BKH (1991), "Descriptive analysis of the technical and economical aspects of measures to reduce water pollution caused by discharges from the fertilizer industry and other industries entailing nutrient discharges", Commission of European Communities, 1991,

Bundesministerium für Bildung, Wissenschaft, Forschung und Technologie / Umw eltbundesamt (1995), "Projektträgerschaft Abfallwirtschaft und Altlastensanierung, Vorhaben 1988-1994", Berlin, May 1995, 448 p.

Bundesministerium für Umwelt (1994), "Branchenstudie Abfälle halogenfreier Lösemittel", Wien, ENTEC, 136 p

Byrne O Cléirigh (1991), "Technical & Economical Study on the Reduction (based on best available technology not entailing excessive costs) of Industrial Emission from the Pharmaceutical and Cosmetics Industry", Dublin, Commission of the European Communities, 1991, p. 84

CEFIC (1990), "CEFIC Guidlines on Waste Minimisation", Bruxelles, CEFIC, 1990, 20 p

CEFIC (1996a), "Facts and Figures - the European chemical industry in a worldwide perspective", Brussels, November 1996, 80 p.

CEFIC (1996b), personnel communications, Brussels, July and December 1996.

ChemInform (1992), "Identification and brief description of the emissions (water, air & wastes) from the different sectors of the organic chemical Industry", Richmansworth, Commission of the European Communities, 1992,

Christ C. (1996): "Integrated environmental protection reduces environmental impact", in 'Chemical Technology Europe, May/June 1996.

Clark J.H. (ed.) (1995), "Chemistry of Waste Minimization", Blackie Academic & Professional, London, 1995, 554 p

DTI/DOE (1996), "Saving money through waste minimisation", Environmental Technology Best Practice Programme, examples related to chemical industry (GC 16, GC 20, GG 25/6, GG 26/4 and 26/7, GG 27/2 and 27/9), London, March 1996.

Ecotec (1995), "New clean and low waste products, processing and services and ways to promote the diffusion of such practices to industry", report on case studies, Bruxelles, study commissioned by the European Commission DGIII and DGV, 280 p.

ERL (1993), "Identification and brief description of the emissions (water, air, wastes) from the different sectors of the manufacture of basic inorganic chemicals and non-metallic mineral products", published by the EC Off. for Off. Pub., Luxembourg, 1996, 95 p.

EurEco (1990), "Hazardous waste prevention", Luxembourg, STOA, 1990, p. 23

Eureka (1993): "Industrial Wate Management R&D Needs and Market Opportunities", Berlin, Federal Environmental Agency, 1993, 200 p

European Commission (1995), "Panorama of EC Industry 95/96 - an extensive review of the situation and outlook of the manufacturing and service industries in the EU", Bruxelles-Luxembourg, Office for Off, Pub. of the EC, 1995

Haskoning (1994), "Techno-economic study on the reduction measures based on best available techniques of emissions (water, wastes, air) from the pesticides manufacturing industry", Bruxelles, Commission of the European Communities DG XI, 1994,

ITU (1992), "Materialien zum Landesabfallentsorgungsplan Hessen, Teilplan 2: Abfälle aus Industrie, Gewerbe und Dienstleistungsbereichen, Erfassung und Mobilisierung von Vermeidungs- und Verwertungspotentialen", Dieburg, erstellt für den Hessischen Ministerium für Umwelt, Energie und Bundesangelegenheiten, 204 p.

Ministerie van Economische Zaken / Ministerie van Volkshuisvestiging, Ruimtelijke Ordening en Milieu (1992): "Handboek voor de preventie van afval en emissies in de bestrijdingsmiddelen formulerende industrie", Den Haag.

Price B. (1995): "Waste minimisation - a cross-industry review of current practices and trends", FT management report, London, November 1995.

UNEP IE (1995) database, ICPIC diskette publication, selected case studies:
no. 29:Glycerin recovery through process improvements, Philippine
no. 37:Good housekeeping at Rhone Poulenc Chemicals Ltd, Leeds UK, 1994
no. 57:New technology in polypropylene polymer production, Ferrara Italy, 1990
no. 59: New technology in olefins polymerization technology, Milano, 1994
no. 82: Process modification in acrylate dispersion manufacturing, Rohm and Haas Nordic Sweden, 1990
no. 145: Process modification in resins manufacturing industry, US, 1987
no. 155:Solvent waste recycling and re-use, US, 1987
no. 253:Process modification in a terpene manufacturer, DRT France, 1994
no. 266:Process modification to reduce discharges in a French pharmaceutical company, 1990.

US EPA (1991), "Guides to Pollution Prevention - The Paint manufacturing Industry", Washington, DC, Office of Research and Development 1991, 67 p.

US EPA (1991), "Guides to Pollution Prevention - The Pesticide formulating Industry", Washington, DC, Office of Research and Development 1991, 53 p.

US EPA (1991), "Guides to Pollution Prevention - The Pharmaceutical Industry", Washington, DC, Office of Research and Development 1991, p.74

Witteveen+Bos (1995), "Bedrijfstakinformatie afvalpreventie - Uitwerking van de Leidraad preventie via de milieuvergunning" (copy), Deventer, Ministerie van VROM, 1995

The European Chemical Industry Council (CEFIC) has provided general information for the study and has commented the draft version of the present sector report. We are very grateful for their constructive remarks and have integrated their remarks into the text.

SECTION 9

MANUFACTURE OF CHEMICALS AND CHEMICAL PRODUCTS

ANNEX A

PROCESSES AND WASTES DESCRIPTION

Contents :

A.1 OVERVIEW

The characteristic activity of chemical industry consists of chemically transforming materials into diverse substances, giving them new physical and chemical properties.

Chemical industry utilises a vast array of complex continuous and batch-type processes and technologies in the manufacture of chemical products. Because of the highly specific and often confidential nature of the processes of chemical industry, processes and wastes are only discussed in general. The intent is to provide background information for the identification of prevention options; for further information is referred to literature[1]. Three common methods used in the manufacture of chemical products are considered :

- chemical synthesis
- ancillary processes (e.g. storage, transport, heating, cooling)
- cleansing

These methods and their waste streams are described hereafter.

A.2 CHEMICAL SYNTHESIS

* Process

A typical chemical synthesis plant consists of one or more reactors, in which the chemical reactions take place, and one or more separation and purification steps to make the desired end product. Numerous types of chemical reactions, recovery processes, and chemicals are employed in order to produce a wide variety of chemical products, each conforming to its own rigid products specification.

Depending upon the scale and the condition of the chemical reaction, continuous processes or batch processes are applied. This can be done in single-product plants, where reaction vessels and ancillary equipment are arranged into separate, dedicated process units, or in multi-product plants, where chemicals are manufactured in product campaigns. During such campaigns, operators or computerised controllers add the required reagents and monitor process functions. At the end of a campaign, process equipment is thoroughly cleaned.

Chemicals used in chemical synthesis operations range widely and include organic and inorganic reactants, catalysts and solvents.

* Waste description

Process wastes[2]

Waste streams from chemical synthesis operations are complex due to the varied operations and reactions employed. They arise from a variety of sources which are associated with the chemistry and plant; they may arise from the preparation of feed stocks; the reaction / reactor itself; from product separation; and from the utility system.

---

1 e.g. BKH 1991 (fertilizer industry), Byrne O Clérigh 1991 (pharmaceutical and cosmetic industry), ERL 1993 (basic inorganic chemicals manufacturing), Haskoning 1994 (pesticides industry).

2 The main source for this chapter is Clark 1995

There are several ways in which the chemistry of a process can cause a waste problem. Reactions which cause particular difficulties are those which give stoichiometric amounts of waste :

A + B -> C + D

where C is the desired product and D a waste by-product; for each molecule of C one of D is produced. The only solutions are to employ a different synthesis route or to find a use for the by-product. Sometimes the two are combined by changing the synthesis route so that the waste by-product becomes a saleable by-product.

By-products are also generated by secondary reactions, occurring in parallel with the desired reaction. These may be represented as:

A + B -> C (desired reaction)
A + B -> D (side reaction)

In this case it may be possible to adjust the reaction conditions to maximise conversion to C.

Another problem arises when reactions do not stop at the desired product:

A + B -> C -> D

Once again, modifying the reaction conditions may offer score for improvements, one option being to settle for low conversion and recycle reactants a number of times. The cost of separating reactants and recycling them will usually be an issue.

The position can be complicated in the presence of impurities in the feed, which may undergo a range of reactions with reagents or products; by the presence of solvents which may not be inert or by catalysts which are less than perfect in their selectivity. Furthermore reactions may not go to completion, with the result that there is unconverted starting material present which it may, or may not, be practical to recycle. Reaction related possibilities for waste generation are summarised below.

Main reactants	->	Process	->	Desired products
Auxiliary chemicals e.g. catalysts, solvents				By-products
Impurities in main reactants				Unchanged main reactants
Impurities in auxiliary chemicals				Unchanged impurities
				Unchanged auxiliary chemicals

Wastes also arise from the product isolation parts of a process. Solvents may be used to extract or wash the product, acid or base to neutralise reaction products, catalysts, particularly homogeneous ones may escape, or be unsuitable for re-use.

Various aspects of plant operations also contribute. Alterations in conditions to give different grades of product and changing conditions during start-up and shut-down are likely to result in wastes.

There are differences in terms of process wastes between the bulk chemical and the fine chemicals sector. The former are generally much more efficient at putting atoms of reagent into product. In fine chemicals industry there is much less use of neat catalytic routes to products.

Solvent wastes

A wide variety of solvents are used, for product recovery, purification, and as reaction media. Typically, the spent solvents are recovered on-site by distillation or extraction, which generate solvent recovery wastes such as still bottom tars.

Off-specification products

Off-specification products are produced as a result of poor process control and operation, as well as during start-up and shut-down operations.

Wastes from chemical industry are classified in EWC categories 06 00 00 (inorganic processes) and 07 00 00 (organic processes); many of these wastes are classified as hazardous according to the European List of Hazardous Wastes.

A.3 ANCILLARY PROCESSES

* **Description**

A major ancillary process is the storage of raw materials and products. Storage can take place in different manners, depending upon scale and nature of the stored materials:

- *bulk liquid tank storage*: tank farms designed to store a complete range of liquids. The range of liquids and the extent of the tank farm required can be large depending on the chemistry involved. It is common to have separate tankage for fresh and recovered liquids (e.g. solvents) and to have 'in-process' tanks dedicated to each synthesis building. This increases the number of tanks and potential waste sources because of leakage and cleansing.

- *liquid storage in drums*: many plants use a wide range of chemicals in quantities which are to small for bulk storage. These are stored in (external) drum storage areas.

- *warehousing*: raw materials stored in separate building with segregated compartments for compatible materials.

Another ancillary process concerns the transfer of reagents and product. Liquids are generally pumped from bulk storage into a charge vessel prior to loading into a synthesis reactor vessel. Piping systems are designed to this purpose.

Heating and cooling are other major ancillary processes. Chemical synthesis plants often have their own furnaces for provision of heat and electrical power.

* **Waste description**

The wastes that arise during ancillary processes can contain all substances used or generated in chemical industry and can be considered as process wastes.

Particular waste streams (filter dusts, furnace slacks, etc) are related to combustion emissions associated with provision of heat and electrical power. These are not dealt with in this sector report.

A.4 CLEANSING

* **Process description**

Cleansing is particularly important in batch processes in multi-product plants, where process equipment is thoroughly cleaned at the end of a campaign. Cleansing in continuous processes takes place before start-up and in specific installations.

Cleaning is in many cases performed by rinsing or flushing the equipment with water or solvent. Once through flushing, repetitive flushing and counter current rinsing are examples of automated cleansing techniques applied. Manual cleaning also occurs.

If powders or other "dry" materials are processed, cleansing can also be accomplished using a dry, inert material, such as clay or sand. These inert materials are passed through the system where they pick up traces of powder. In some cases this flush material can be saved and used in the next production run of the same product.

The cleanup of spills and area wash down often contributes significantly to the total waste volume produced at chemical plants. Spills are caused from accidental discharges during transfer operations or equipment failures such as leaks. Area wash downs, e.g. with water hoses, are performed routinely at some plants, and are necessary in the event of contamination of the working area.

* **Waste description**

Depending on the cleansing agent, cleansing wastes are composed of solvent or aquatic waste streams, contaminated with reaction products, reagents and auxiliary chemicals. Dry cleansing wastes occur rarely.

SECTION 9

MANUFACTURE OF CHEMICALS AND CHEMICAL PRODUCTS

ANNEX B

PREVENTION OPTIONS

Contents :

Sector	Manufacture of chemicals and chemical products (NACE 24)
Process	All types of processes
Waste stream	All types of wastes

Prevention option	**Good housekeeping**
Option No	9-1
Type	GOP
Group	1
Description	In addition to the specific measures presented afterwards, basic good housekeeping procedures are used to reduce waste. Poor maintenance can cause unexpected equipment failures, contamination of product, leaks leading to losses and the departure op operating conditions from the optimal. Poor stock control of materials, careless handling and general lack of care and attention can also have serious consequences. Good housekeeping with respect to waste minimisation includes[1] : • Material handling and inventory control • Records system for waste streams • Spill prevention and control • Maintenance procedures • Waste stream segregation • Production scheduling • Waste management cost allocations • Personnel training • Supervision practices
Remarks	
Economics	Many of these measures are used in industry to promote operational efficiency. They can often be implemented at little or no cost to the facility. When one considers the effects of reduced waste, increased efficiency, and little or no implementation cost, good operating practices usually provide a very high return on investment.
Potential	It is anticipated that these measures are already largely applied. A *low* prevention potential has therefore been estimated.

1 as to CEFIC 1990, US EPA 1991, DOE / DIT 1996

Sector	Manufacture of chemicals and chemical products (NACE 24)
Process	Chemical synthesis, product isolation
Waste stream	Process wastes

Prevention option	**Changes in the chemistry of the process**
Option No	9-2
Type	TC
Group	1/3
Description	The chemistry of the process is the starting point and is a major area for waste minimisation. Examples of goals of waste minimisation in this area are to increase process selectivity by applying other reaction paths and to enable easy and efficient recovery of reagents and catalysts. An increase of process selectivity can for example in many cases be obtained by catalysts, notably in processes in the fine and speciality chemical industries where catalysis has traditionally played a relatively minor role. In other processes the selectivity of catalysts has always been studied with a view to improving the yield of the desired product but could also be tuned to reduce the generation of particularly hazardous wastes. Literature[1] addresses some of the most significant recent developments in catalysis that will have an impact on inefficient chemical processes, such as : • use of inorganic solids as catalysts or supports for other reagents; • phase transfer catalysis; • application of polymers and polymer supported reagents in reaction synthesis; • use of enantioselective catalysts or chiral intermediates to produce the pure active form instead of mixtures of two optical isomers.
Remarks	
Economics	The drive towards new clean processes requires a high level of innovation and new technology. The cost of clean processes will be high but must be put in balance to environmental damage, public image and expenditure for end-of-pipe technologies.
Potential	Changes in the chemistry of a process can have significant long term financial benefits and is the key to substantial minimisation of wastes. Because investments are in general high and because the long term is involved, the prevention potential is assessed as between *moderate* and *high.*

1 Clark 1995

Sector	Manufacture of chemicals and chemical products (NACE 24)
Process	Chemical synthesis, product isolation
Waste stream	Process wastes

Prevention option	**Changes in reactor design**
Option No	9-3

Type: TC

Group: 1/3

Description

Reactor design is also critical with respect to waste minimisation and innovative thinking can reap rewards.

Reactor choice is one of the aspects. Continuous reactors, for example, can be more effective in waste minimisation than batch reactors. A process operated continuously with integrated recycling of solvents, excess raw materials, by-products and energy is in many cases most easily optimised with respect to waste minimisation. Depending on the level of output required, a plant can be appropriately scaled and the capital investment matched to the product economics. Even small volume, high value chemicals can be produced cost-effectively on a dedicated continuously operated plant. The batch process reactor system, on the other hand, adds more flexibility because several products can be manufactured in the same reactor.

Another example concerns plug flow reactors versus stirred tank back mix reactors. Plug flow reactors can be more effective in optimising yield and minimising by-product formation than conventional stirred tank back mix reactors.

Further reactor design can also contribute to waste minimisation. Examples of crucial factors are the efficiency of mixing between reaction materials, the appropriateness of catalysts and the design of inlets to ensure even distribution of reactants in a catalytic bed.

Remarks

Economics

The nett benefits of the continuous process over the batch process are summarised below by means of indicative figures that are a generalisation rather than a specific example[1]:

	batch	*continuous*
• relative process costs	100%	50%
• yield from raw materials	70-80%	> 90%
• product purity	90-92%	> 98%
• plants down time	35%	20%

Potential

Changes in reactor design can have significant long term financial benefits and is the key to substantial minimisation of wastes. Because investments are in general high and because the long term is involved, the prevention potential is assessed as between *moderate* and *high*.

1 Clark 1995

Sector	Manufacture of chemicals and chemical products (NACE 24)
Process	Chemical synthesis, product isolation
Waste stream	Process wastes

Prevention option	**Integrated process development**
Option No	9-4
Type	TC
Group	1/3
Description	The scale-up of processes from the laboratory bench to pilot plant, and eventually to full scale plant, is an empirical step of process development with major implications for waste arising[1]. The laboratory process is taken as a starting point for scale-up but changes in the chemistry or process path may occur to optimise output. Important for waste minimisation and other purposes is that optimisation is more than maximising the yield of the desired product. An integrated approach must be considered, e.g. taking account of : • the chemistry of the reaction; • the physical parameters such as mixing, solubility, heat transfer characteristics, pressure of reaction, boiling points, melting points etc.; • the price, availability and specifications of raw materials; • the utilisation of energy; • the generation of wastes and their ability for recycling or re-use and disposal costs; • the toxicity of the process chemicals. As far as product isolation techniques are concerned, they are usually governed by the physical properties of component parts of the reaction mixture and often, if processes are designed backwards from the isolation stage, as opposed to matching isolation techniques to process chemistries, more optimum material management is possible. Choice of solvent is also to be considered (see option 9-7).
Remarks	In the bulk chemicals business, where dedicated plants producing only one product are the norm, process development is much more straightforward than in fine chemicals industry where multi-product plants are the norm.
Economics	The drive towards new clean processes requires a high level of innovation and new technology. The cost of clean processes will be high but must be put in balance to environmental damage, public image and expenditure for end-of-pipe technologies.
Potential	Integrated process development can have significant long term financial benefits and is the key to substantial minimisation of wastes. Because investments are in general high and because the long term is involved, the prevention potential is assessed as between *moderate* and *high.*

1 Clark 1995

Sector	Manufacture of chemicals and chemical products (NACE 24)
Process	Chemical synthesis, product isolation
Waste stream	Process wastes

Prevention option	**Process optimisation**
Option No	9-5
Type	GOP
Group	1
Description	Process optimisation is also an area where waste minimisation can be achieved. Process optimisation starts with a thorough understanding of the mechanisms of the process through detailed analysis of the components. Only by understanding how by-products are formed can the process be modified to eliminate or minimise them[1]. This is often followed by a mass balance exercise constructed around a process flow diagram. Changes made to the process and their impact on the efficiency of the process can so be made visible. This exercise can be based around three elements: raw materials/energy inputs, process steps, materials/energy outputs. The overall strategy to waste minimisation through process optimisation can be summarised as follows : 1. identification, characterisation, and quantification of all reaction products 2. recognition of key interactions forming by-products 3. minimisation of by-product formation by changing process components (raw materials, auxiliaries, solvents, temperatures, pressures etc. 4. recovery, recycling and reuse of all components.
Remarks	While process modification can result in significant waste reduction, there may be major obstacles to this approach to waste minimisation. Extensive process change can be expensive; downtime will occur when production is stopped for new equipment installation; and new processes must be tested and validated to ensure that the resulting product is acceptable.
Economics	Process optimisation is considered as a good operating practice that does not involve excessive costs.
Potential	Process optimisation is in many cases continuously taking place and can lead to significant waste minimisation. It has been estimated that there is a *moderate* potential for prevention.

1 Clark 1995

Sector	Manufacture of chemicals and chemical products (NACE 24)
Process	Chemical synthesis, product isolation
Waste stream	Process wastes

Prevention option	**Advanced process control**
Option No	9-6
Type	GOP
Group	1
Description	Process control, in all its manifestations, is a vital aspect of waste minimisation and one in which computer technology can achieve considerable savings[1]. On-line control optimises operating conditions and sensitive instrumentation can provide the data needed by the controlling computer (advanced process control). Computers can also be used to automate shutdowns, start-ups and product changeovers, times at which waste and off-specification materials can be produced in disproportionate quantities. The effects of unplanned trips and shutdowns can also be minimised by the use of computerised control systems.
Remarks	
Economics	Process control in general can be considered as a good operating practice that does not involve excessive costs. The costs of automating process control can however be significant.
Potential	Computerised process control can lead to significant waste minimisation. It has been estimated that there is a *moderate* potential for prevention.

1 Price 1995

Sector	Manufacture of chemicals and chemical products (NACE 24)
Process	Chemical synthesis, product isolation
Waste stream	Solvent wastes

Prevention option	**Solvent selection**
Option No	9-7
Type	IMC
Group	1/3
Description	Solvents are of vital importance in batch processes for the manufacture of many fine chemicals, chemical intermediates and other high-value products. These processes normally run in solvents and often involve solvents in the work-up and separation stages. As the major component in such processes, solvents are also likely to be the major source of waste. Waste considerations, but also controls on the release of VOCs and the restrictions on the use of chlorinated and some other solvents make solvents an important issue for chemical industry. A careful selection of the solvent, on the basis of the nature of the solvent effects, the solvent power and the role of solvents in the chemical reaction, is therefore of vital importance to many chemical companies. Substitutions that my be suited to chemicals manufacturing include the use of aqueous-based cleaning solutions instead of solvent-based solutions and the replacement of chlorinated solvents with non-chlorinated solvents. Waste minimisation should be introduced at the R&D phase because of reformulation difficulties encountered in the production phase. Careful examination of all materials which can be used in manufacturing a chemical with the aim to reduce toxicity of residuals should be an integral part of R&D activities. Because of the specificity of most chemical processes, solvent selection must take place on a case-by-case basis. Detailed guidelines for solvent selection can be found in literature[1].
Remarks	
Economics	The drive towards the use of less hazardous solvents requires a high level of innovation and new technology. The cost of a solvent change may be high but must be put in balance to environmental damage, public image and expenditure for end-of-pipe technologies.
Potential	Solvent changes necessitate considerable research but can have significant long term financial benefits and is the key to substantial minimisation of wastes. Because investments are in general high and because the long term is involved, the prevention potential is assessed as between *moderate* and *high*.

1 e.g. in Clark 1995

Sector	Manufacture of chemicals and chemical products (NACE 24)
Process	Chemical synthesis, product isolation
Waste stream	Solvent wastes

Prevention option	**Solvent recovery**
Option No	9-8
Type	RC/RU
Group	1
Description	In fine chemical batch processes using organic solvents, it has been routine practice for most manufacturers to attempt to recover some of the value of the solvents. This has been achieved mostly by selling contaminated solvent mixtures to third party processors who have regenerated saleable quality solvents or solvent mixtures. Very rarely are such regenerated solvents reusable in the process from which they arose. In fact 'Good Manufacturing Practice' guidelines would lead manufacturers to use only virgin solvents to avoid the possibility of cross-contamination. However, it is possible to recycle and reuse solvents in e.g. pharmaceutical industry as demonstrated in literature[1]. The strategy of identifying, optimising, recovering and minimising (see option 9-5) is generally at the basis of successful solvent recovery programmes.
Remarks	
Economics	The investments on solvent recovery have in general low pay-back times but should be determined on a case-by-case basis.
Potential	Solvent recovery is a key to substantial minimisation of wastes that can be implemented in a short term. It is anticipated that many companies already apply some form of solvent recovery but that there is still room for improvement. The prevention potential is assessed as *moderate.*

1 e.g. in US EPA 1991, Byrne O Cléirigh 1991, Clark 1995.

Sector	Manufacture of chemicals and chemical products (NACE 24)
Process	Chemical synthesis, product isolation
Waste stream	Off-specifications product

Prevention option	**Reprocesssing of off-specifications product**
Option No	9-9
Type	RC
Group	.1
Description	In batch process, e.g. in pesticide or paint formulation, off-specification batches can often be reformulated to an acceptable quality. The reformulation can e.g. take place by[1]: • executing a correction on the off-specification product in order to meet the specifications • a progressive re-use of the off-specification batch in batches with the same or similar composition.
Remarks	
Economics	These measures can often be implemented at little or no cost to the facility. When one considers the effects of reduced waste, increased efficiency, and little or no implementation cost, good operating practices usually provide a very high return on investment.
Potential	It is anticipated that these measures are already largely applied, given the costs of the raw materials and product loss. A *low* prevention potential has therefore been estimated.

1 Min. v. EZ / VROM, 1992

Sector	Manufacture of chemicals and chemical products (NACE 24)
Process	Process ancillaries
Waste stream	Process wastes

Prevention option	**Minimisation of losses during storage and transport**
Option No	9-10
Type	GOP
Group	1
Description	Transport of raw material and product from source to the factory site and from the factory to the consumer can be significant areas for losses, hence waste, as well as storing of raw materials and products. Simple good housekeeping techniques, embedded in overall waste minimisation or product stewardship programmes, can in most cases be applied. The scale of operation will in many cases dictate the feasibility of these techniques. Examples of applied techniques are[1]: • *Self-draining pipes and tanks.* Proper pipe and tank design in any liquid processing operation should be self draining and free of pockets. The use of Teflon lined tanks can be used to reduce adhesion and improve drainage. • *Use of mechanical devices such as rubber wipers* After a tank has been drained, some residual material remains clinging to the walls. To remove this cling age and to reduce the subsequent level of cleaning, mechanical wipers can be employed. For facilities where tanks are wiped with rags, use of wipers would reduce or eliminate waste rags. Use of wiper and squeegees usually requires manual labour, hence, the extent of waste reduction depends on the operator. • *Mechanise and automate scraping.* Since the benefits will be offset by increased labour, mechanisation/automation could be considered. Mixers designed with automatic wall scrapers are available. These mixers can be used with any cylindrical mix tank (flat or conical bottom). • *Use of a pig to clean lines.* Many industries use pigs (fluid propelled pipe inserts) to clean piping. The pig is forced through the pipe from the mixing tank to the filling machine hopper. The pig pushes ahead product left clinging to the walls of the pipe. This, in turn, increases yield and reduces to subsequent degree of pipe cleaning required. Inert gas is used to propel the pig and minimise drying of product inside the pipe. The equipment (launcher and catcher) must be carefully designed so as to prevent spills, sprays, and potential injuries, and the piping runs must be free of obstructions so that the "pig" does not become stuck or lost in the system. • *Use of returnable bulk containers*: can be applied if production is automated and if a limited number of ingredients is applied.
Remarks	
Economics	These measures can often be implemented at little or no cost to the facility. When one considers the effects of reduced waste, increased efficiency, and little or no implementation cost, good operating practices usually provide a very high return on investment.
Potential	It is anticipated that these measures are already largely applied, given the costs of the raw materials and product loss. A *low* prevention potential has therefore been estimated.

1 US EPA 1991a 1991b 1991c

Sector	Manufacture of chemicals and chemical products (NACE 24)
Process	Process ancillaries
Waste stream	Process wastes

Prevention option	**Minimisation of losses in heating and cooling processes**
Option No	9-11
Type	GOP
Group	1
Description	The area of heating and cooling is a crucial one because of the energy conservation possibilities available as well as the potential for waste minimisation. Heat transfer should be effective and uniform since by-products and decomposition products tend to form at hot spots[1]. Examples of techniques applied include using lower pressure steam, desuperheating steam before it enters a process or heat exchanger, and installing a thermocompressor to mix high and low pressure steam. These techniques have the effect of reducing the tube wall temperature in heat exchangers thereby reducing the breakdown of heat sensitive materials and consequent tube fouling. On-line cleaning devices such as reversing brushes can keep that exchanger tubes clean, thereby permitting lower operating temperatures and energy savings, while scraped-wall exchangers can be used to recover material which would otherwise foul surfaces and be wasted. The staged heating of heat-labile materials can reduce degradation and this can begin with the use of waste heat - another opportunity for energy conservation.
Remarks	
Economics	These measures can often be implemented at little or no cost to the facility. When one considers the effects of reduced waste, increased efficiency, and little or no implementation cost, good operating practices usually provide a very high return on investment.
Potential	It is anticipated that these measures are already largely applied. A *low* prevention potential has therefore been estimated.

1 Price 1995

Sector	Manufacture of chemicals and chemical products (NACE 24)
Process	Process ancillaries
Waste stream	Process wastes

Prevention option	**Minimisation of losses in piping**
Option No	9-12
Type	GOP
Group	1
Description	Modifications to pipework will often prove worthwhile and the first consideration should be the recovery of individual waste steams. Combining several streams in the same pipeline may prevent one or more from being recycled or used for another purpose and means that all will have to be handled by a treatment plant. Consideration of each stream individually may indicate where simpler treatment, such as filtration, could make a waste or the water carrying it usable. Other aspects of piping worth consideration include its metallurgy - changing the material or lining the pipe can prevent waste-producing catalysis, leak elimination, and the prevention of line overheating. The pipe sizes should also be checked to ensure that the optimum bore is used, since undersized pipe and obstructions to flow can waste energy through excessive pumping[1].
Remarks	
Economics	These measures can often be implemented at little or no cost to the facility. When one considers the effects of reduced waste, increased efficiency, and little or no implementation cost, good operating practices usually provide a very high return on investment.
Potential	It is anticipated that these measures are already largely applied. A *low* prevention potential has therefore been estimated.

1 Price 1995

Sector	Manufacture of chemicals and chemical products (NACE 24)
Process	Cleansing
Waste stream	Cleansing wastes

Prevention option	**Reduction of the need for cleansing**
Option No	9-13
Type	GOP
Group	1
Description	Options that reduce the need for cleansing are particularly relevant in batch production, where cleansing is operated between batches. Major options are[1]: • *Maximise production runs.* Production runs of a given product should be scheduled together so as to reduce the need for equipment cleaning between batches. • *Scheduling families of products in sequence.* While some cleanup is still needed between batches, it can be minimised by considering the potential for scheduling families of products in sequence. • *Separate installations.* The need for cleaning is reduced if separate installations are installed for different (families of) products. A better quality ensuring and process efficiency are other reasons to install separate installations. An GOP option that applies to both batch and continuous production is the following : • *Immediate cleaning.* Cleaning equipment, tanks and reactors before the liquid remnants dry is the best way to minimise the need for aggressive cleaning agents and solvents.
Remarks	
Economics	These options can often be implemented at little or no cost to the facility. When one considers the effects of reduced waste, increased efficiency, and little or no implementation cost, the options usually provide a very high return on investment.
Potential	Many companies will already have adapted their production planning in order to minimise waste arising. Nevertheless, waste minimisation audits often identify that there are still opportunities for further improvement. The prevention potential is therefore evaluated as *moderate.*

1 US EPA 1991a 1991b 1991c

Sector	Manufacture of chemicals and chemical products (NACE 24)
Process	Cleansing
Waste stream	Cleansing wastes

Prevention option	**Optimisation of the cleansing process**
Option No	9-14
Type	GOP
Group	1
Description	The cleansing process, extensively applied in batch production, must be regularly optimised. This can significantly reduce the quantity of cleansing waste. Major optimisation options are[1]: • *Counter current rinsing sequence.* This technique uses recycled dirty solution to initially clean the tank. Following this step, recycled clean solution is used to rinse the dirty solution from the tank. Since the level of contamination builds up more slowly in the recycled clean solution than with a simple re-use system, solution life is greatly increased. Counter current rinsing is more common with CIP systems, but can be used with all systems. • *Repetitive flushing with a smaller volume of diluent.* Waste arising is minimised if cleansing between batches is changed from once through diluent flushing to repetitive flushing with a smaller volume of diluent. This recommendation may involve the installation of dedicated holding tanks for the used diluents, and could also include the use of two stage flushing. • *Use of dry cleanup methods for liquid spills.* Ratter than cleaning spills with water or solvents and producing a hazardous waste, many plants use dry absorbents for spill cleanups. This greatly decreases the waste volume associated whit the cleanup. In addition, floor sweeping, moping and use of squeegees can collects pills for product reformation. • *Use of low-volume high efficiency cleaning systems.* In the case of water cleansing, high pressure spray nozzles can be used in place of the standard rinsing hoses. Water consumption can be cut by 80-90% when high pressure rinsing systems are used. Other types of low-volume high efficiency cleaning systems include water knifes and (portable) steam cleaners. The resulting waste water would be more concentrated and might be re-used in the process. The use of wiper blades to physically wipe down the inside of the tanks could also be envisaged.
Remarks	
Economics	There are no detailed data on the costs and benefits of the given options. They can often be implemented at little or no cost to the facility.
Potential	Many companies will already have optimised their cleaning system. The prevention potential is therefore evaluated as *low.*

1 US EPA 1991a 1991b 1991c

SECTION 10

MANUFACTURE OF PLASTIC AND RUBBER PRODUCTS

SECTOR REPORT

Contents :

NACE sectors involved in the present sector report:

Retained for analysis:	25.1	Manufacture of rubber products
	25.2	Manufacture of plastic products
Excluded from analysis: --		

10.1 SECTOR CHARACTERISATION [1]

This sector report concerns the processing of plastic and rubber, that is a particular dynamic sector of the European industry and has been so for many years. Long times it has benefited from an ever-increasing demand, thanks to the regular appearance of new products which frequently opened up new fields of application. Prices and profits became under pressure in the 1980s for rubber products and in the 1990s for plastic products.

The plastics processing and rubber industry are related because both process polymeric material based on hydrocarbons. The larger enterprises in the sector of rubber products are often also active in plastics processing industry. The processing machinery for both sectors is similar.

In 1993 the processing of plastics created a value added of 29 billion ECU. With a value added of 12 billion ECU, the manufacture of rubber products is a modest-sized industry compared with plastics processing industry.

The plastic processing industry is mainly composed of SMEs. Only a dozen plastic processing companies employ more than a thousand persons. Rubber industry, and particularly the tyre market, is dominated by large multinational companies. Specialised SMEs dominate in the market segment of technical rubber products and rubber products for end-consumers.

Competition in the plastic processing sector has become more intense recently, resulting in low profit margins. Rationalisation of production capacity resulted in a decline of employment of 5% over 1993 and 1994. Environmental legislation and shifts in consumer preferences contribute to the substitution of materials, the development of new product designs and the introduction of plastic recycling schemes. Prospects for plastic processors are nevertheless favourable.

In rubber industry, the economic downturn has caused a difficult period for most European manufacturers, leading to disinvestments and job losses in Europe. For the coming years a modest recovery in demand and production is expected. Industry is expected to continue its current strategy of cost reductions and development of new product and processing technologies.

10.2 PROCESSES AND WASTES

Many different processes are involved in plastics and rubber industry. For the use of this report, the processes have been regrouped in three overall sectors :

- *Plastic processing.*
  Plastic processing consists of a compounding, a processing and a finishing step. Examples of techniques applied for processing are extrusion, moulding and calendering. Finishing is done by machining, decorating and/or assembly.

- *Fibre-reinforced and composite plastics (FRC/P) processing.*
  The basic step of FRC/P processing involves the combination of polymerising resin and reinforcing material, resulting in a product with an excellent strength-to-weight ratio.

- *Rubber processing.*
  As plastics processing, rubber processing consists of a compounding, a processing and a finishing step. Techniques as calendering and extrusion are applied for processing, in combination with laminating (with textile and metal layers for tyres) and vulcanisation. Trimming, washing and/or surface treatment are techniques used in finishing.

1 Main source: European Commission, 1995

Annex A gives further details on processes of the plastic and rubber industry.

Table 10.2.1 lists the identified waste streams, together with their process origin. The table includes a priority ranking, based on a sector-wide tentative evaluation of the amount and the hazardous character of the waste streams.

Table 10.2.1: Wastes of the plastic and rubber processing sector

Process origin	Waste streams	Priority rank	Description and code according to EWC [2]	
Plastic processing	Compounding scrap	o	Wastes not otherwise specified	07 02 99
	Rejected or excess plastic material	+	Plastics particles	12 01 05
	Solvent wastes	o	Halogenated and halogen-free organic solvents, washing liquids and mother liquors	07 02 03 07 02 04
FRC/P processing	Resin residues and resin / solvent mixtures	+	Still bottoms, reaction residues (halogenated and halogen-free)	07 02 07 07 02 08
	Solvent wastes	+	Halogenated and halogen-free organic solvents, washing liquids and mother liquors	07 02 03 07 02 04
	Scrap material	-	Wastes not otherwise specified	07 02 99
Rubber processing	Compounding scrap	o	Wastes not otherwise specified	07 02 99
	Rejected or excess rubber material	+	Wastes not otherwise specified	07 02 99
	Solvent wastes	o	Halogenated and halogen-free organic solvents, washing liquids and mother liquors	07 02 03 07 02 04
	Scrap material	-	Wastes not otherwise specified	07 02 99

Tentative priority rank: + : high significance, o : medium significance, - : low significance EurEco/Witteveen+Bos 1997

Product loss in the form of rejected and excess material is an important source of waste in all three sectors. Literature reports a waste arising of 3,5% of the processed material for plastic processing industry, 7% for FRC/P industry (particularly in the form of resin residues) and 5-10% for rubber industry[3].

Solvent wastes are an important source of waste in FRP/C industry because of the extensive use of solvents in equipment cleaning. Solvent wastes are relatively less important in plastic and rubber processing industry, where equipment cleaning is less significant. Wastes streams of low significance, not included in the table, are packaging wastes, oily wastes, office wastes, paint and ink wastes. Further details on wastes are provided in annex A.

The plastic and rubber processing industry is involved in other environmental issues than waste. Major issues are air pollution with VOC and particles, recycling and re-use of end-products, use of brominated flame retardants, energy use, cooling water and waste water.

2 Hazardous wastes according to the European Hazardous Waste List included in this table are EWC 07 02 03 / 04 / 07 and 08.
3 Eijssen 1993, Huizinga 1993.

10.3 WASTE PREVENTION

This section discusses waste prevention options identified in literature. The major process waste streams along with prevention options are summarised in table 10.3.1, following the division into processes and waste streams as made in the preceding chapter. Within the scope of the study, only general discussions on options can be given, with the intent to stimulate the thinking of manufacturers about their processes. The selected options are described in Annex B.

Table 10.3.1: Waste prevention options for plastic and rubber processing industry

Waste streams	Priority rank	Waste prevention method	Group	Potential
Plastic processing				
Compounding scrap	o	10-1 Use of powder-free concentrates (IMC / TC)	1	o
Rejected and excess plastic material	+	10-2 Re-use of thermoplastic process wastes (GOP / IMC /RU)	1	+
Solvent wastes	o	10-3 Solvent recovery (RU)	1	+
FRC/P processing				
Resin residues and resin / solvent mixtures	+	10-4 Modify resin pan geometry (TC) 10-5 Reduce transfer pipe size (TC) 10-6 Change material application process (TC)	1 1 1/2	+ o o
Solvent wastes	+	10-7 Good house keeping measures (GOP) 10-8 Replace solvents with emulsifiers (IMC) 10-9 Changing resin formulation (IMC) 10-10 Alternative solvents (IMC) 10-3 Solvent recovery (RU)	1 3 1 3 1	+ o - o +
Scrap material	-	10-11 Re-use of scrap material (RU)	1	-
Rubber processing[4]				
Compounding scrap	o	10-1 Use of powder-free concentrates (IMC / TC)	1	o
Rejected or excess rubber material	+	10-12 Good housekeeping in tyre manufacturing (GOP) 10-13 Good housekeeping in extrusion (GOP) 10-14 Substitution of vulcanised rubber through rubber thermoplastics (IMC) 10-15 Re-use of vulcanised used rubber (RU)	1 1 3 3	+ + - -
Solvent wastes	o	10-16 Alternative adhesives and paints (IMC) 10-3 Solvent recovery (RU)	3 1	- +
Scrap material	-	10-11 Re-use of scrap material (RU)	1	-

+ = high, o : medium, - : low EurEco/Witteveen+Bos 1997

Detailed and comprehensive information on options in plastic and rubber industry was scarce. Brief information was available in Eijssen 1993 and NMC 1995, for plastic industry, and in Huizinga 1993 and DTI / DOE 1996, for rubber industry. More detailed information was available for FRC/P industry : an extensive review of options was found in US EPA 1991 and confirmed in NMC 1995.

---

4 For options related to metal operations, e.g. within tyre manufacturing, the reader is refered to sector report 13 on metal product manufacturing (options 13-1-1 to 13-1-5).

For *rejected* and *excess materials* arising in plastic and rubber processing, several options with a high potential were identified. These options are in general considered as good operating practices and do not require excessive extra costs.

For *resin residues* and *solvent wastes* arising in FRC/P industry, other high potential options were identified, in form of good housekeeping, solvent recovery or simple technology change measures. A further potential is available in technology change and input material change measures but these measures still have financial or technological constraints.

10.4 EVALUATION

The *minimisation of product loss* is an issue that receives traditionally much attention in the plastic and rubber sector, given the good possibilities for re-use of rejected and excess thermoplastics and unvulcanised rubber. The process of cutting costs going on these last years has reinforced attention for waste minimisation and has showed that there is a potential for further prevention.

Waste prevention for solvent wastes and solvent / residue mixtures are relatively new in the sector. Cost reduction programmes are surely an important cause for the new attention for this issue, but also the increasing emphasis world-wide on VOC emissions and the rising hazardous waste management expenses. Good possibilities for prevention have also been identified for these wastes.

Technologies are rapidly advancing in the sector, particularly in the FRC/P industry. It is for this reason that companies should continually educate themselves about improvements of waste reduction and pollution prevention if they desire benefiting from these improvements. There appears however to be little comprehensive, sector-specific, practical and recent review information on the issue of waste minimisation. Only few SME-specific activities were identified. The dissemination of accessible information is therefore anticipated to be interesting for both large- and small-scale industry and might result in a further reduction of waste streams of the plastic and rubber industry, with both environmental and economic benefits.

10.5 BIBLIOGRAPHIC REFERENCES

BLIC - Liaison office of the rubber industry in the EU (1996), "Annual activity report 1995", Brussels, 16 p.

Bräutigam A. (1995), "Reststoffvermeidung und -verwertung am Beispiel von Vulkanisieranlagen", in Entsorgungspraxis nr 10, October 1995, pp 22-27.

Bundesministerium für Umwelt (1994), "Branchenstudie Abfälle halogenfreier Lösemittel", Wien, ENTEC, 136 p

DTI / DOE (1996), "Saving money through waste minimisation - raw material use", GG25 guide of the Environmental Technology Best Practice Programme, industry examples 2 and 4, London, March 1996.

Du Pont de Nemours (1996), "Protection de l'environnement; usine de Luxembourg; rapport annuel 1995", Luxembourg, 1996, 20 p.

Eijssen P.H.M., Duesmann H.B., Poel P. van der & Koot J.E. (1993), "Procesbeschrijvingen industrie: Kunststofverwerkende industrie", Bilthoven, RIVM, 1993, 20 p.

Eureka (1992/1993): "Industrial Waste Management R&D Needs and Market Opportunities", draft report-1992, final report-1993, Berlin, Federal Environmental Agency, 1993, 200 p.

European Commission (1995), "Panorama of EC Industry 95/96" Bruxelles-Luxembourg, Office for Off, Pub. of the EC, 1995

European Commission (1996), "Techno-economic study on the reduction of industral emission to air, discharges to water and the generation of wastes from the production, processing and destruction (by incineration) of brominated flame retardants", Bruxelles-Luxembourg, Office for Off. Pub. of the EC, 1996, p. 112

Ganapini W. and Jacia E. et. al. (ed.) (1992), "Technological innovation in the plastics industry and its influence on the environmental problems of plastic waste - Report on substitution of virgin plastics by recycled materials", Bruxelles-Luxembourg, Commission of the European Communities, 1992, p. 104

Huizinga K., Verburgh J.J. and Matthijsen A.J.C.M. (1992), "Procesbeschrijvingen industrie: Rubberverwerking", Bilthoven, RIVM, 1992, 8 p.

ICPIC (1996), "data base on cleaner production methods", UNEP IE database, extracts on publications and case studies related to plastics and rubber industry, Paris, June 1996.

Infomil (1996), KWS praktijksheets no. 8 "LSE-hars en Good Housekeeping bij produktie kunststof opslagtanks" en 10 "LSE-hars en Good Housekeeping bij produktie glasvezel versterkt polyester", Den Haag, 4 p.

NMC (1995), "Preventie in kunststofverwerkende bedrijven", Preventie informatie brochure, Den Haag, February 1996.

Provincie Overijssel (1996), "Voorkomen is verdienen", Eindrapport Afvalpreventie IKT-2, part concerning Vredestein Banden b.v. (rubber industry), p 27 - 29.

US EPA (1991), "Guides to Pollution Prevention - The Fiberglass-Reinforced and Composite Plastics Industry", Washington, DC, Office of Research and Development 1991, 58 p.

The European Plactic Converters (EuPC) and the Liaison Office of the Rubber Industry (BLIC) have been contacted for information and for comments on the draft sector report. BLIC has provided general information for the study, for which we are very grateful. We did not receive comments on the draft sector report.

SECTION 10

MANUFACTURE OF PLASTIC AND RUBBER PRODUCTS

ANNEX A

PROCESSES AND WASTES DESCRIPTION

Contents :

A.1 OVERVIEW

The plastics processing and rubber industry are related because both process polymeric material based on hydrocarbons. The processing machinery for both sectors is similar. For the use of this report, the processes have been regrouped in three overall sectors :

- Plastic processing;
- Fibre-reinforced and composite plastics (FRC/P) processing;
- Rubber processing.

A.2 PLASTIC PROCESSING

* Process description

The sector's business is to convert plastic compounds into products. Thermal processes are used to manufacture *thermoplastics* (such as PVC, PP, LDPE, HDPE, PS). In the case of *thermosets* (such as PUR and polyester), polymerisation takes place in a chemical process.

The monomer is in general provided in pellet or in powder form in the case of thermoplastics, in liquid form for thermosets. The main plastic materials processed for the different plastic markets were in 1994 :

• polyvinyl chloride (PVC)	5.0 million tonnes
• polypropylene (PP)	4.8 million tonnes
• low density polyethylene (LDPE)	4.6 million tonnes
• high density polyethylene (HDPE)	3.0 million tonnes
• polystyrene (PS)	1.7 million tonnes
• polyurethane (PUR)	1.4 million tonnes

Plastic converters may produce finished articles which are used by other industries like food packaging and building articles, or distributed to consumers. They may also be custom processors who produce components on a subcontract basis for other manufacturers, or in-house operations integrated into the manufacturing process.

The production process is composed of three steps, a compounding step, a processing step and a finishing step.

The *compounding* step consists of the mixing of additives with a raw monomer / polymer before, during or after polymer production to make the plastic suitable for its intended use. The principal techniques for this step are dry solids mixing, liquid and paste mixing and motionless mixing. Examples of additives are fillers, colorants, lubricants, synergetic agents and flame retardants.

In the *processing* step, a large number of techniques can be used, depending upon the plastic material to be processed and the form of the product. Techniques commonly used are :

- *Extrusion* : the process of forcing a molten polymer under pressure through a shaping dye resulting in products of uniform shape - most commonly pellets;

- *Moulding* : forming molten polymer into a desired shape in a mould;

- *Calendering* : forming polymer film and sheet by squeezing pliable plastics between rolls (calenders);

- *Thermoforming* : the heating of thermoplastic sheet or film followed by forcing it around the fixed shape of a mould;

- *Coating* : the application of a surface coating of plastics onto a material to impart specific properties;

- *Casting* : the process of allowing plastics to set or cure (often catalysed).

The *finishing* step is the final processing of consumer products through machining (e.g. hot stamping), decorating (e.g. silk printing, painting) and assembly.

* **Waste description**

The following major waste streams arise in plastic processing industry :

- *Compounding scrap*
  Powder losses arising during compounding are reported to be minor (0,01% of the mixture). Higher losses are reported if additives in powder-form are added (0,1% per additive)[1].

- *Plastic particles*
  Plastics particles waste is produced in several process steps of plastics processing industry, primarily during mixing, handling and grinding operations and by the trimming of parts. This waste must be considered as rejected and/or excess raw material.

  In plastics processing industry in Germany, 71 000 t of PVC plastics wastes and 120 000 t of not-PVC de-gassed plastics wastes arise yearly[2]. For the Netherlands, mention is made of 34 000 t/a of plastics processing wastes (PVC and not-PVC). An average waste arising of 3.5% of the quantity processed material is reported[3].

- *Solvent wastes*
  Solvents (e.g. toluene, phenols, acetone, methyl ethyl ketone, methanol, styrene) are used in equipment cleaning, during coating, in painting and printing and in adhesives. Solvent wastes arise when solvents are contaminated. Solvent wastes are hazardous wastes according to the European list of dangerous wastes.

Other waste streams arising in the plastic processing, but not as significant as the above mentioned wastes, are oily wastes (from the processing machines), paint and ink wastes[4], office wastes, laboratory wastes and packaging waste.

1 Eijssen, 1993
2 Eureka, 1992
3 Eijssen, 1993
4 Literature reports that *printing* is a major finishing technique (Eijssen 1993). Wastes from printing consist of waste ink, dried ink and ink sludges (EWC group 080300) and are considered as hazardous if they contain solvents (according to the European list of hazardous wastes). *Painting* of plastic products is less commonly applied. If applied, paint wastes and in particular paint sludges (EWC codes 080106 / 080107) arise. These sludges are mainly generated from overspray painting. Overspray is captured in spray boots by a water curtain, some coagulates being added to water. The coagulate is the paint sludge. Paint sludges are hazardous according to the European list of hazardous wastes.

A.3 FIBRE-REINFORCED AND COMPOSITE PLASTICS (FRC/P) PROCESSING

* Process description

In the FRC/P industry, the most typical processing activity involves the combination of polymerising resin and reinforcing material, resulting in a product with an excellent strength-to-weight ratio. The reinforcing material is commonly fibreglass. The resin and reinforcing material are either sprayed onto a mould or the reinforcing material is coated with the resin.

During its early years in the fifties, the only technologies known for FRC/P were manual hand lay-up and spray lay-up. The first mechanisation appeared only in the sixties, while pultrusion (which can be thought of as extrusion by pulling) and winding were only introduced in the seventies. The breakdown of EU production of a specific thermoset (GRP) by manufacturing technique shows that manual techniques still account for about 35% of production, followed by automated techniques like Sheet Moulding Compound (SMC) and Bulk Moulding Compound (BMC). Semi-finished products in SMC/BMC and finished parts are at the centre of new technological developments, mainly linked to requirements of the automotive industry and transport sector, in general[1].

FRC/P industry makes use of specific raw materials as resins (polyesters, epoxies, polyamides, phenolics, etc.), fibreglass or other fibre substrates (e.g. in strand mat or fabric forms), solvents, hardeners or catalysts (e.g. amines, anhydrides, aldehyde condensation products, Lewis acid catalysts) and other speciality chemical additives (fillers, plasticisers, reinforcements, colorants)[2].

* Waste description

Major waste streams of the FRC/P sector are resin residues and solvent wastes. An average waste arising of 7% of the quantity processed material is reported[3].

- *Resin residues and resin / solvent mixtures*
  Gelcoat and resin overspray wastes are residues that arise during fabrication. This is material that lands on the floor instead of on the mould. The gelcoat overspray accumulates as a paint-like coating wherever it settles and dries. Approximately 85% of the resin spray goes on the mould and 15% ends up as waste. Thickened gelcoat and no longer usable resin are solidified by mixing with catalyst. Similar waste is obtained when the resin tank is cleaned (often an annual occurrence). US EPA indicates that app. 50 ECU are lost if 50 kg of resin is lost as described above. Gelcoat and resin overspray wastes consist of resins, pigments, catalyst and chemical additives[4].

  Other residues that arise are scrap solvated resin and partially-cured waste resins. Scrap solvated resin comes from the piping and treater pan at the end of a run, and from any residual resin mix that cannot be stored for later use. The partially-cured resin generally results from a small-quantity product run that requires only a partial drumload of a resin, leaving the rest as waste. They both contain resins and resin contaminated solvents.

  Resin residues also arise at the unloading of materials. Empty bags and drums usually contain residues if they contained liquid materials (resins). Resin / solvent mixture are further generated by laboratory analysis. These wastes occur during formulating and can contain all product stadia of the applied processes. They contain spent resins, solvents and finished and semi-finished products.

---

1 European Commission, 1995
2 US EPA, 1991
3 Eijssen, 1993
4 US EPA, 1991

According to the European list of hazardous waste, resin residues are hazardous if they contain solvents.

- *Scrap material.*
  Scrap fabric and cured resins (waste forms: grinder, grid, whole pieces) arise in FRC/P processing industry. These wastes are not hazardous.

- *Solvent wastes*
  Halogenated solvents (e.g. methylene chloride and 1,1,1-trichloroethane) are used for cleaning cured resin. Halogen-free solvents (e.g. acetone, methyl ethyl ketone, methanol, styrene) are used for equipment cleaning. Halogen-free solvents are further used to dissolve the resins supplied in liquid form; polyester is for example typically dissolved in styrene monomer.

  Solvent wastes arise when solvents are contaminated, e.g. with resin residues. Solvent wastes are considered as hazardous wastes (according to the European list of hazardous wastes). Disposal of contaminated solvents represents a major hazardous waste management expense[1].

Minor waste streams arising are oily wastes (from the processing machines), office wastes and packaging waste.

A.4 RUBBER PROCESSING

* Process description

The rubber industry comprises two main subsectors. The *tyre and inner tube rubber* industry manufactures tyres and tubes for passenger cars, trucks and buses, agricultural vehicles, earth moving and mining machinery, bicycles and motorbikes, and other applications. The *industrial rubber products* industry manufactures pipes, hoses, sealings, belts, profiles, foam, soles, adhesives, etc. which are produced for such end-markets as vehicles, machinery, electrical engineering, construction, the chemical industry, the food and drink industry, the medical sector and sporting goods. The production of tyres accounts for about 60% and industrial rubber products for about 40% of the total rubber products output of the EU.

The industry processes natural and synthetic rubber. Natural rubber is especially used in truck and bus tyres because of its low heat build-up. For technical rubber products a much higher fraction of synthetic rubber is used, depending on the specifications of the product. Other raw materials are carbon black, and textile and metal components.

The process of rubber processing is very similar to that of plastic processing and distinguishes also the steps of compounding, processing and fabricating/finishing. Processing consists principally of calendering and extrusion, laminating with textile and metal layers (for tyres) and vulcanisation. During vulcanisation the material is polymerised with heat, pressure and vulcanisation agents like sulphur, metal oxides or organic peroxides. The fabricating and finishing step consists of trimming, washing, and, in some cases, surface treatment with chlorinated water. Rubber processing is to a large extent automated in order to reduce production costs.

1 US EPA, 1991

* **Waste description**

The following waste streams arise in rubber processing industry :

- *Compounding scrap*
  As in plastic processing, powder losses occur during compounding. This concerns in particular additives in powder-form.

- *Rejected or excess rubber material*
  In Germany, 47 000 t/a of waste tyres that arise in rubber manufacture (in 1992). Waste rubber (no tyres) arises in a quantity of 103 000 t/a[1]. The arising of 5 500 t/a of waste rubber in rubber processing industry in the Netherlands in 1979 is reported, 11,6% of the processed quantity (47 500 t/a). Rubber waste arising of between 5 and 10% were estimated for 1989[2].

- *Scrap material.*
  Scrap fabric and scrap metal[3] arise in rubber processing industry. These wastes are not hazardous and can be recycled.

- *Solvent wastes*
  Halogenated solvents (methylene chloride and 1,1,1-trichloroethane) are used for degreasing the surfaces of metal before this metal is included in tyres. *Halogen-free* solvents (aliphatic solvents) are mainly used for surface treatment of rubber intermediate products, before vulcanisation. They are also applied in adhesives.

  Solvent wastes arise when the applied solvent is contaminated.

Minor waste streams arising are oily wastes (from the processing machines), washing water[4], office wastes, laboratory wastes and packaging waste.

1 Eureka, 1992
2 Huizinga, 1993
3 For more information on scrap material, the reader is directed to sector report 13 on manufacture of metal products.
4 During the finishing of rubber products, washing is a source of waste water. This waste water can contain hazardous substances as nitrite, zinc and amino-compounds. The effluents contain small quantities of chloride if surface treatment with chloride is applied. Discharge of salt can furthermore be significant (Huizinga 1993). The arising of oily waste water sludge is reported in other sources (Provincie Overijssel 1996).

SECTION 10

MANUFACTURE OF PLASTIC AND RUBBER PRODUCTS

ANNEX B

PREVENTION OPTIONS

Contents :

Sector	Manufacture of plastic and rubber products (NACE 25)
Process	Plastic processing - rubber processing
Waste stream	Compounding scrap

Prevention option	**Use of powder-free concentrates**
Option No	10-1
Type	IMC/TC
Group	1
Description	In the compounding step of both plastic and rubber processing, a part of the powder-form ingredients is lost (mainly specific additives). Literature reports that the use of concentrated, powder-free ingredients is applied progressively, in some cases in combination with closed systems[1].
Remarks	--
Economics	There are no cost details on these measures available. The measures are presented as being cost-effective. Reduced costs are mainly related to the reduced loss of (expensive) additives and, in some cases, to savings due to the fact that end-of-pipe treatment or internal air systems are not required.
Potential	The techniques applied are proven and can be applied easily. Because compounding scrap is not a significant waste stream in comparison with other waste streams in the plastic and rubber sector, the waste prevention potential is considered to be *moderate*.

1 Eijssen 1993 and Huizinga 1993.

Sector	Manufacture of plastic and rubber products (NACE 25)
Process	Plastic processing
Waste stream	Rejected and excess plastic material

Prevention option	**Re-use of thermoplastic process wastes**
Option No	10-2
Type	GOP/IMC/RU
Group	1
Description	Wastes arising during the production of thermoplastics can in most cases be reprocessed directly after its arising. Several measures can be envisaged to increase re-use[1]: • apply as much as possible the same input material for different products. This increases the possibilities of re-use; • rinse with raw material without additives and pigments, in order not to waste these materials • collect the residues of the master batch for re-use afterwards; • install mills and inlets on extruders so that excess rejected material can immediately be reprocessed; • use of 'hot runner moulds' in large productions. This reduces excess material; • take account of the waste arising difference between aluminium or steel moulds when choosing the mould (aluminium moulds are cheaper but cause in general more production break-down - and thus more waste); These measures should optimally be accompanied by management options as preventive maintenance, instruction of operators, minimisation and optimal planning[2] of colour changes in production, registration of product and waste quantities, and installation of a systematic stock of rejected projects.
Remarks	There is a trend that products will be increasingly designed using compatible materials with the aim to remove or reduce the need for dismantling products into individual component parts at the end of their life. This trend will also facilitate internal re-use.
Economics	The measures described are all low cost measures, that do not require significant extra costs.
Potential	Re-use of thermoplastic process wastes receives traditionally much attention in plastic processing industry. The recent rationalisation of production capacity, due to increased competition, resulted in new emphasis for loss prevention. Although much has been done, it is anticipated that there are still many good housekeeping measures possible in companies, particularly in SMEs. The waste prevention potential is considered to be *high*.

1 NMC 1995

2 Colour change from light to dark gives 20% less rejected product than change from dark to light (NMC, 1995).

Sector	Manufacture of plastic and rubber products (NACE 25)
Process	Plastic processing - FRC/P processing - rubber processing
Waste stream	Solvent wastes

Prevention option	**Solvent recovery**
Option No	10-3
Type	RU
Group	1
Description	*Distillation* is a proven technique for solvent recovery. *Batch-type distillation* units have proven to be successful in meeting the needs of firms producing small-to-moderate quantities of contaminated solvents (such as acetone in FRC/P industry). Commercial available sizes range from 20- to 200-litre units. Space required is generally less than that required for storage of virgin solvents and contaminated waste. Commercial *continuous-feed distillation* equipment is available for large volume generators of contaminated solvents[1]. *Adsorption of solvents on activated carbon in combination with recovery* afterwards, is another state-of-the-art technique. *Condensation* and re-use is an alternative method under research for styrene[2]. Adsorption on activated carbon cannot be applied for styrene as it can polymerise on the carbon and deactivate the adsorber. Solvent recovery can be facilitated by *good housekeeping measures* : • segregation of solvent wastes by separating : - chlorinated from non chlorinated solvent wastes - aliphatic from aromatic solvent wastes - chlorofluorocarbons from methylene chloride - (waste) water from flammables • minimisation of solids (solid concentration should be kept to a minimum to allow for efficient solvent reclamation) • control of solvent concentration (to be maintained above 40%) • labelling of waste and specification of its origin (keeping a chemical identification label on each waste container and recording the exact composition and method by which the solvent waste was generated). Commonly applied end-of-pipe treatments, that aim to combat air pollution only, not to recover solvents, are incineration and adsorption on activated carbon (without recovery).
Remarks	Off-site solvent recycling is well suited to small quantity generators.
Economics	Initial investment ranges from 2000 ECU for a 20-litre batch-distillation unit to more than 20000 ECU for a 200-litre unit[3]. Reduced costs are related to lower solvent purchase costs and reduced hazardous waste management expenses. Adsorption on activated carbon with solvent recovery is reported to economically feasible in concentrations above 70 ppm.
Potential	The waste prevention potential of solvent recovery is evaluated as *high*, because solvent recovery is an economically attractive option to reduce the major waste stream of solvent waste. It is recommended in several waste minimisation reports.

1 US EPA 1991.
2 Eijssen 1993.
3 US EPA 1991.

Sector	Manufacture of plastic and rubber products (NACE 25)
Process	FRC/P processing
Waste stream	Resin residues and resin / solvent mixtures

Prevention option	**Modify resin pan geometry**
Option No	10-4
Type	TC
Group	1
Description	Pan widths should be no more than 0,25 m wider than the fabric in FRC/P industry. If a narrow width fabric is run in an unnecessarily wide pan, additional solvent resin is wasted, since the wide pan holds a larger quantity at the end of the treater run[1]. To alleviate this problem, simple adjusting devices made to fit into the treater pan to reduce its volume may be installed. This could consist of a plastic, wooden or metal part moulded to fit into the end of the treater pan.
Remarks	--
Economics	A practical example in industry showed that pan widths were in average 0,75 m wider than the fabric (0,50 m more than necessary). In this industry, the pay-back period of the investment to modify the treater pans was evaluated in the order of a couple of days.
Potential	Such simple measures can yield important effects for waste prevention in FRC/P processing. They should not be evaluated on their own, but in the context of the whole of a management programme for reinforced attention on waste prevention. Because of the low pay back time and the significant reduction of hazardous wastes, the waste prevention potential is considered to be *high*.

1 US EPA 1991.

Sector	Manufacture of plastic and rubber products (NACE 25)
Process	FRC/P processing
Waste stream	Resin residues and resin / solvent mixtures

Prevention option	**Reduce transfer pipe size**
Option No	10-5
Type	TC
Group	1
Description	Typically, a long pipe connects the mix tank to the treater tank in FRC/P industry. Each time a run ends the solvated resin in the treater pan is discarded, along with the resin in the interconnecting pipe[1]. Significant resin savings can be realised by installing a smaller diameter pipe. However, this requires detailed hydraulic analysis and possibly pump modifications to ensure that an acceptable flow rate is maintained.
Remarks	--
Economics	A pay-back period of app. two years has been calculated in a practical case in industry.
Potential	Such measures can yield important effects for waste prevention in FRC/P processing and should be considered within a long-term waste prevention programme. The waste prevention potential is considered to be *moderate*.

1 US EPA 1991.

Sector	Manufacture of plastic and rubber products (NACE 25)
Process	FRC/P processing
Waste stream	Resin residues and resin / solvent mixtures

Prevention option	**Change material application process**
Option No	10-6
Type	TC
Group	1/2
Description	Significant waste reduction can be achieved by optimising material application processes in FRC/P industry. • *Spray application methods* are used by most open-mould fabricators of fibreglass products for transferring and applying coatings, resins and fibres to the mould. Delivery systems used by FRP fabricators include *high-pressure air*, *medium-pressure airless* and *low-pressure air-assisted airless spray guns*. In the order listed, the automation and spray patterns become more efficient, reducing excessive fogging, overspray, and bounce back. • *Non-spray resin application methods* exist, but are only taken into consideration in specific circumstances. These methods include *prespray fibre reinforcing, in-house resin impregnation, resin roller dispensers; vacuum bag moulding processes* and *closed mould systems.* For detailed discussion of advantages and disadvantages is referred to literature[1].
Remarks	--
Economics	No information
Potential	This measure can yield important effects for waste prevention in FRC/P processing and should be considered within a long-term waste prevention programme. The waste prevention potential is considered to be *moderate*.

1 US EPA 1991.

Sector	Manufacture of plastic and rubber products (NACE 25)
Process	FRC/P processing
Waste stream	Solvent wastes

Prevention option	**Good housekeeping measures**
Option No	10-7
Type	GOP
Group	1
Description	Several good housekeeping measures can be reported to reduce the arising of solvent waste. Major measures are[1]: • *Maximise production runs*: production runs should be scheduled together to reduce the need for equipment cleaning between batches. Consideration should also be given to the potential for scheduling families of products in sequence. • *Cleaning before hardening of resins*: methylene chloride is used because it is an effective solvent for cured resins. Many other solvents have been tried, including multicomponent mixtures, but had only mixed results. Cleaning equipment before the resin dries is the best way to minimise the need for methylene chloride. • *Reduce solvent rinse usage:* substantial quantities of solvent are used for cleanout of epoxy pretreaters, mix tanks and treater pans. Using small lab-type wash bottles for treater pan cleanouts can reduce solvent usage. Squeegee tools can also be used for the treater and vessel cleanouts, so that a smaller amount of solvent can be applied to the vessel to dissolve the remaining solvated resin. A two-stage cleaning process may also reduce solvent rinsing. Dirty equipment or a tool is first cleaned in dirty solvent, followed by a clean rinse with a smaller volume of fresh solvent, which is collected separately. • *Store and re-use cleaning solvents.* Some FRP/C fabricators collect spent solvents for re-use in cleaning operations. The solvents cannot be re-used until contaminants build up to levels that do not permit effective cleaning. • *Cover resin and solvent containers.* If the containers are left uncovered, solvent will evaporate and be wasted. These measures should optimally be accompanied by management options as instruction of operators, registration of solvent purchase and solvent waste quantities, etc. etc.
Remarks	--
Economics	These mentioned good housekeeping measures generate savings without significant extra costs. A pay-back period of 3 weeks was e.g. calculated for the measures to reduce solvent rinse usage in a FRC/P processing plant in the US, with savings of 25% of overall solvent usage.
Potential	The waste prevention potential for good housekeeping options is *high* as the measures reduce significantly the hazardous waste stream of solvent wastes, with economically attractive measures.

1 US EPA 1991, NMC 1995

Sector	Manufacture of plastic and rubber products (NACE 25)
Process	FRC/P processing
Waste stream	Solvent wastes

Prevention option	**Replace solvents with emulsifiers**
Option No	10-8
Type	IMC
Group	3
Description	Some fabricators use emulsifiers instead of organic solvents. The emulsifier is an alkaline mixture of surfactants, wetting agents and various proprietary ingredients which can be disposed of in the sewer. Advantages include: virtually no air emissions, biodegradability, and non-flammability. Some suppliers claim emulsifiers last twice as long as solvents[1]. However, some emulsifier concentrates may contain solvents, dissolved metals, silicates and phosphates that make them unacceptable in some sewage systems. Different cleaning techniques must be employed when using emulsifiers, so adequate instruction of both management and workers is essential. Changing over from solvents to emulsifiers is easiest for hand and tool cleaning, which usually represents the largest consumption of acetone. Emulsions are reported to be inadequate for cleanup of gelcoat or cured resins.
Remarks	--
Economics	No information available.
Potential	The utilisation of emulsifiers instead of solvents will prevent the arising of solvent waste. Information about economic, organisational and technological barriers to replace solvents with emulsifiers is however not available. The waste prevention potential is therefore evaluated as *moderate*.

1 US EPA 1991.

Sector	Manufacture of plastic and rubber products (NACE 25)
Process	FRC/P processing
Waste stream	Solvent wastes

Prevention option	**Changing resin formulation**
Option No	10-9
Type	IMC
Group	1
Description	A proven technique is to modify resin formulation in order to reduce VOC emissions[1]. In general, a resin with lower monomer content should produce lower emissions. Evaluation tests with low styrene emissions laminating resins having a 36% styrene content found a 60 to 70% decrease in emission levels, compared to conventional resin (42% styrene), with no sacrifice in the physical properties of the laminate. Vapour suppressing agents are sometimes added to resins to reduce VOC emissions. Limited laboratory and field data indicate that vapour suppressing agents reduce styrene losses by 30 to 70%.
Remarks	Agreement has been reached with the Dutch plastic processing industry on the implementation of this measure in the period of 1992-2000 within the programme on VOC emissions (KWS 2000)[2].
Economics	Not requiring excessive costs.
Potential	The waste prevention potential is evaluated as *low* because the option leads to reduced air emissions, not reduced waste arising.

1 US EPA 1991.
2 Eijssen 1993.

Sector	Manufacture of plastic and rubber products (NACE 25)
Process	FRC/P processing
Waste stream	Solvent wastes

Prevention option	**Alternative solvents**
Option No	10-10
Type	IMC
Group	3
Description	Relatively less toxic and less volatile solvents that are biodegradable, water-soluble, resin bed compatible and recoverable are commercially available as substitutes for the conventional solvents used in FRC/P industry[1]. These substitutes can be used in the curing process and/or for cleaning, depending on the type of the solvent. For example, dibasic ester (DBE) based organic solvents do not evaporate as rapidly as acetone. When it spills during operation, it will remain until it is cleaned up, collected and recovered by distillation, thus reducing the VOC emissions and increasing the potential for reuse.
Remarks	--
Economics	Reference is made of 60% savings by using DBE instead of acetone.
Potential	Substitution by less toxic solvents is can reduce the hazard potential of wastes and so reduce significantly the quantity of hazardous wastes. As it is until now restricted to specific solvents in specific applications, the waste prevention potential is evaluated as *moderate*.

1 US EPA 1991.

Sector	Manufacture of plastic and rubber products (NACE 25)
Process	FRC/P processing - rubber processing
Waste stream	Scrap material

Prevention option	**Re-use of scrap materials**
Option No	10-11
Type	RU
Group	1
Description	Scrap materials can in some cases be re-used in other parts of the process. The following examples are reported[1]: • re-use of scrap fabric, e.g. in assembly or in the process where parts are glued (in FRC/P and rubber processing); • re-use of grinned cured resin or grit from cured resin, e.g. to thicken adhesives (FRC/P processing).
Remarks	--
Economics	These measures described are low cost measures, that do not require significant extra costs.
Potential	The waste prevention potential is considered to be *low;* scrap fabric is a minor waste stream and there are only few applications possible for grinned resin or grit.

1 NMC 1995.

Sector	Manufacture of plastic and rubber products (NACE 25)
Process	Rubber processing
Waste stream	Rejected or excess rubber material

Prevention option	**Good-housekeeping in tyre manufacturing**
Option No	10-12
Type	GOP/RU
Group	I
Description	When uncured rubber is placed into a mould, an excess of rubber is used to ensure that there are no cavities in the finished tyre. This excess, which flows from the mould, is known as spew. Within a waste minimisation programme in UK tyre manufacturing industry[1], measurements of the amount of spew produced by each tyre generated ideas for minimising waste, i.e.: • *Spew reduction*: investigations revealed the amount of excess rubber could be reduced without compromising product quality. The specifications for the amount of uncured rubber to be placed into the mould, were rewritten to allow this change to be implemented. This new protocol reduced spew levels by 50%. • *Uncured spew recycling:* it was further found that, if the spew was removed before a pre-determined time, its quality was not impaired and it was suitable for reuse. A system to reclaim uncured spew rubber for re-use was consequently developed. The operators of the steam-presses are now instructed to remove the spew formed during the early stages of the curing process. This material is placed in a plastic bin, from where it is collected and sent for recycling. A similar example of re-use of unvulcanised rubber is reported for a major Dutch tyre manufacturing company[2]: • *Uncured rubber tyre recycling*: Rejected unvulcanised tyres were traditionally sent to landfill. The company reports to have started recently to split rejected unvulcanised tyres into components and to re-use the unvulcanised rubber.
Remarks	--
Economics	In the given example in UK manufacturing industry, the amount of wasted spew has been reduced by 50% leading to a saving of 2200 £/year (2700 ECU/year) at not extra cost. The procedural changes necessary to reclaim the spew's rubber content did not require any capital expenditure.
Potential	The waste minimisation options identified here are examples of good operating practices applied in industry that is at the centre of new developments. It is therefore anticipated that there is a potential for similar good practice measures in the tyre and rubber sector. The waste prevention potential has been considered to be *high*.

1 DTI/DOE 1996
2 Huizinga 1993.

Sector	Manufacture of plastic and rubber products (NACE 25)
Process	Rubber processing
Waste stream	Rejected or excess rubber material

Prevention option	**Good-housekeeping in extrusion**
Option No	10-13
Type	GOP/RU
Group	1
Description	Successful good housekeeping measures are reported for the manufacturing of extruded rubber products such as door and window seals and hosing for gas appliances, in UK technical rubber products manufacturing industry[1]: • *Rescheduling production*: set-up and shutdown losses were minimised by rescheduling production to dovetail runs using the same type of rubber. Wastage was reduced from 15% to as low as 5%. • *Pre-softening rubber for specific extrusion dies.* A extrusion dies with a particularly complex profile was found to produce more wastage due to off-specification product than any of the other dies. Discussion with equipment manufacturers produced the idea of pre-softening the rubber by installing a gauze prior to the die. Wastage from this particular dies has now fallen from 18% to as low as 4%. • *Avoid drag-out of salt.* Investigations highlighted the significant loss of salt from the molten salt bath due to drag-out from the salt bath. This phenomenon led to white streaks appearing on the rubber. Introduction of a small 9 kW air-knife (blower) to blow any dray-out salt back into the salt bath has eliminated problem of streaked rubber.
Remarks	The given industry started its waste minimisation programme with analysis of the amount of waste produced. This analysis revealed that the amount of waste produced by the extrusion department was traditionally measured in kilograms, although production was measured in linear metres (all products are sold by length). This mixture of units made it difficult to calculate yields accurately. The introduction of a standardised system for measuring waste, coupled with identification of the key areas of waste production, has enabled to identify waste prevention options.
Economics	The waste minimisation measures produced valuable savings without requiring significant time or expenditure. Pay back time was less than two years in all cases. The pay back time of the option to reduce the loss of salt was even less than six months; installation of an air-knife to blow drag-out salt back into the salt bath has produced salt savings worth 7500 £/year (9000 ECU/year).
Potential	The waste minimisation options identified here are examples of good operating practices applied in industry that is at the centre of new developments. It is therefore anticipated that there is a potential for similar good practice measures in other companies of rubber processing industry. The waste prevention potential has been considered to be *high.*

1 DTI/DOE 1996

Sector	Manufacture of plastic and rubber products (NACE 25)
Process	Rubber processing
Waste stream	Rejected or excess rubber material

Prevention option	**Substitution of vulcanised rubber through rubber thermoplastics**
Option No	10-14
Type	IMC
Group	3
Description	Thermoplastic rubbers have been developed for specific applications. Vulcanised rubbers were substituted by thermoplastic rubbers in product fields as shoes, insulation and adhesives. The developed thermoplastic rubbers are still too little resistant to solvents and have a too low utilisation temperature for application in tyres and in many technical products[1].
Remarks	--
Economics	No information available.
Potential	Use of thermoplastic rubbers will - in contrast to use of vulcanised rubbers - largely facilitate on-site recovery of rejected rubber waste and recycling of used rubber products. The technology is applicable for specific products. The prevention potential for the whole of the rubber sector is considered to be *low* because of the restricted possibilities of application until now.

1 Morgon 1989 (in Huizinga 1993)

Sector	Manufacture of plastic and rubber products (NACE 25)
Process	Rubber processing
Waste stream	Rejected or excess rubber material

Prevention option	**Re-use of vulcanised waste rubber**
Option No	10-15
Type	RU
Group	3
Description	Little success has until now been obtained with the reuse of vulcanised rubber. Research is undertaken to the re-use of granulated vulcanised rubber. Re-use up to 90% is reported to be possible for the manufacture of rubber products that will not or almost not be subject to varying mechanical traction (as carpets and shoes)[1].
Remarks	--
Economics	No information available.
Potential	Because the technology is restricted to specific applications, the waste prevention potential is considered *low.*

1 TNO 1985 (in Huizinga 1993)

Sector	Manufacture of plastic and rubber products (NACE 25)
Process	Rubber processing
Waste stream	Solvent wastes

Prevention option	**Alternative adhesives and paint**
Option No	10-16
Type	IMC
Group	3
Description	Specific IMC measures to reduce solvent wastes are reported for rubber industry[1]: • *water based adhesives:* the possibility of using water-based or two-components adhesives instead of adhesives with halogenated solvents, has been reported in rubber industry. Doubt has however been expressed on the feasibility of this substitution. • *water based paints:* rubber industry has in some cases successfully converted aliphatic solvents into water-based paints for the surface treatment of tyres before vulcanisation. Advantages as a better product quality, lower costs, better worker protection and lower fire hazard are mentioned.
Remarks	--
Economics	No information.
Potential	Water based adhesives and paints can reduce the hazard potential of wastes occuring during application. The prevention potential is considered as *low* because application was until now only possible in some specific cases.

1 Huizinga 1993

SECTION 11

MANUFACTURE OF OTHER NON-METALLIC MINERAL PRODUCTS

SECTOR REPORT

Contents :

NACE sectors involved in the present sector report:

Retained for analysis:	26.1	Manufacture of glass and glass products
	26.2	Manufacture of non-refractory ceramic goods other than for construction purposes; manufacture of refractory ceramic products
	26.3	Manufacture of ceramic tiles and flags
	26.4	Manufacture of bricks, tiles and construction products, in baked clay
	26.6	Manufacture of articles of concrete, plaster and cement
Excluded from analysis:	26.5	Manufacture of cement, lime and plaster
	26.7	Cutting, shaping and finishing of stone
	26.8	Manufacture of other non-metallic mineral products

11.1 SECTOR CHARACTERISATION [1]

This sector is covered bij code 26 of NACE, Rev.1 (1991), and includes the manufacture of the non-metallic mineral products like glass, ceramic goods, clay products, cement, concrete, lime and plaster, the shaping of stone and manufacture of other non-metallic mineral products. A detailed list of products, manufactured in this sector is given in annex A.

The EU is the world's leading producer of non-metallic mineral products. The production was valued at over 90 billion ECU in 1994 and involved materials measured in hundreds of millions of tonnes. Most of the products of this group (with the exception of flat glass, tiles and tableware) are major bulk items of relatively low value that are based on local raw materials and sold primarily to local markets. The non-metallic mineral products are strongly linked to construction. The demand for non-metallic mineral products is expected tot grow steadily in the latter half of the 1990s in response to the more favourable outlook for the construction industry.

The companies involved range from major international construction groups with turnovers measured in billions of ECU to small, family-owned businesses with a regional sphere of interest. The total employment is about 835 900. The number of enterprises with less than 20 employees is about 75 000, the number with 20-100 employees is about 7 900 and the number with 100 or more employees is about 1 700.

Concentration is high in some segments such as cement and glass, but low in others, i.e. concrete products, bricks and ceramics. Similarly, concentration is high in some countries (e.g. the UK and France), but low in others (e.g. Italy, Spain and Germany). The top six companies account for about 25% of total production, which is low compared to other industries.

11.2 PROCESSES AND WASTES

Within the wide variety of products and processes of NACE 26, and regarding the excluded sectors[2], basically the following groups of processes can be distinguished. More information on processes are provided in Annex A.

- Manufacture of glass (NACE 26.1); main technological operations are batch preparation, glass melting, glass forming and annealing and finishing.
- Manufacture of ceramic products (NACE 26.2, 26.3, 26.4); main technological operations are pre-treatment and mixing base materials, moulding, drying and bakening.
- Manufacture of articles of concrete, plaster and cement (NACE 26.6); main technological operations are storage and mixing of base materials, shuttering and/or moulding, drying and/or hardening (not for plaster) en aftertreatment (sawing).

In table 11.2.1. the different wastes are listed, together with their process origin. The table includes a tentative priority ranking, based on the amount and the hazardous character of the waste. Further details on wastes are provided in Annex A.

1 Main source: European Commission, 1995

2 The manufacture of cement, lime and plaster (**NACE 26.5**) is characterized by its large-scale production and therefore excluded from further analysis (the production of articles of cement (NACE 26.6) is not characterized by large-scale production). Cutting, shaping and finishing of stone (**NACE 26.7**) is exluded from analysis because the waste is of low significance; the waste is generally not hazardous and the amount is relatively low. The type of waste is similar to the other sectors. Manufacture of other non-metallic mineral products (**NACE 26.8**) is exluded from analysis because no relevant information on waste-prevention has been found in literature.

Table 11.2.1: Wastes of glass, ceramic and concrete processing

Process origin	Waste streams	Priority rank	Description and code according to EWC [1]	
Glass and glass products	Preparation mixture residues and sludges	o	Waste preparation mixture before thermal processing	10 11 01
	Glass residues, particles and sludges	o	Waste glass, other particles and dust	10 11 02 10 11 05
	Furnace demolition waste	-/o	Spent linings and refractories	10 11 08
Ceramic products	Preparation mixture residues and sludges	o	Waste preparation mixture before thermal processing	10 12 01
	Product residues, glaze, particles and sludges	o	Other particles and dust	10 12 03
Articles of concrete, plaster and cement	Preparation mixture residues and sludges	o	Waste preparation mixture before thermal processing	10 13 01
	Product residues, particles and sludges	o	Other particles and dust	10 13 06
	Shuttering residues	-/o	Wastes not otherwise specified	10 13 99

Priority rank: + : high significance, o : medium significance, - : low significance EurEco/Witteveen+Bos 1997

Waste streams of minor significance only, not included in the table, are:

- spent linings and refractories from manufacture of ceramics and articles of concrete, plaster, cement[2];
- moulds from the ceramic industry;
- asbestos residues.

The main waste streams in this sector are preparation mixture and product residues. These wastes have in general good recycling possibilities. On site, much waste of this kind arises in cleaning operations when floors or equipment are washed with water. The waste ends up as sludge.

External recycling options are generally available for the glass wastes. In many countries structures exist to collect used glass to be reused for new glass products. Sometimes the residues and refractories of concrete, glass and ceramics can be used in other industries.

Beside waste, environmental issues concerning the glass and ceramic industry are the high energy consumption for furnaces and moulding; and air pollution, consisting mainly of fluorine emissions in glass and ceramic production and waste gases from the use of fossil fuels. Water pollution seems not a major problem in the minerals industry; waste water, containing mixture and product residues, can be treated effectively[3].

1 Manufacture of mineral products does not generate major waste streams that are hazardous according to the European Hazardous Waste List. The only wastes that are retained in the Hazardous Waste List are wastes from asbestos-cement manufacture (EWC 10 13 02); as asbestos is not widely used anymore, it is considered a minor significance waste stream.

2 These spent linings are in general not hazardous and therefore considered of minor significance; spent linings and refractories from the glass industry (furnace demolition wastes) can be hazardous because of heavy metals (Kannah, 1984). Therefore spent linings and refractories from the glass industry stream are *not* considered of minor significance.

3 Huizinga, 1992

11.3 WASTE PREVENTION

This section discusses waste prevention methods identified in literature. The major waste streams along with prevention options are summarized in the next table, following the division into processes as made in the preceding chapter. The options are described in detail in Annex B.

Table 11.3.1: Overview of waste prevention options for glass, ceramic and concrete processing

Waste streams	Priority rank	Waste prevention method	Group	Potential
Glass and glass products				
Preparation mixture residues and sludges	o	11-1 Good housekeeping (GOP)	1	-/o
Glass residues, particles and sludges	o	11-2 Good housekeeping (GOP) 11-3 Recycling (RU)	1 3	-/o -/o
Furnace demolition waste	-/o	11-4 Alternative refractories (IMC)	3	-
Ceramic products				
Preparation mixture residues and sludges	o	11-1 Good housekeeping (GOP) 11-5 Recycling (RU)	1 1	-/o -
Product residues, glaze, particles and sludges	o	11-2 Good housekeeping (GOP) 11-6 Glaze sludge recycling (RU)	1 3	-/o ...
Articles of concrete, plaster, cement				
Preparation mixture residues and sludges	o	11-1 Good housekeeping (GOP) 11-7 Recycling (RU)	1 1	-/o -/o
Product residues, particles and sludges	o	11-2 Good housekeeping (GOP) 11-8 Bypass of chemicals (TC) 11-9 Rubbling concrete and reuse as gravel (RU)	1 1 1	-/o o o
Shuttering residues	-/o	11-10 Using shorter stacks (GOP) 11-11 Calculate elasticity of steel reinforcements (GOP)	1 1/2	-/o -/o

Priority rank: + : high, o : medium, - : low, ... = insufficient data — EurEco/Witteveen+Bos 1997

Descriptions of waste prevention options for the different processes found in literature are generally not extensive. The identified options are mainly directed to good operational practice, recovery methods and reuse of materials.

By improving internal recycling methods waste can be reduced significantly. Recycling is often a relatively simple method. In many cases recycling methods are applied to some extent already. The potential of the different prevention options ranges from low to moderate.

11.4 EVALUATION

The processes and waste streams in the manufacture of glass, ceramics, concrete/plaster/cement and other minerals, show large similarities.

Compared to other environmental problems in this sector (large energy consumption and significant air emissions), mineral waste streams pose relatively little problems. The main waste streams are mineral solid residues, sludges and particles from preparation operations and final products. In general, these wastes are rather harmless and can be used for various external purposes. Furthermore, good internal recycling possibilities are available.

In literature identified within this study, prevention options appear not to be widely available. Most options are related to good operational practices and recycling.

Summarizing it is concluded that mineral waste streams do not pose very significant environmental problems. A further continuation of internal recycling and external re-use opportunities is to be expected, rather than major technological changes.

11.5 BIBLIOGRAPHIC REFERENCES

Bijen, J.M.J.M. (1995), "Handboek cellenbeton", Nederlandse Cellenbeton Vereniging.

European Commission (1995), "Panorama of EC Industry 95/96, Bruxelles-Luxembourg.

Glass industry, editions october and february 1992.

Heidemij Advies (1995), "Preventie van bedrijfsafvalstoffen en emissies in de betonindustrie", in opdracht van de provincies Groningen, Friesland, Drenthe, Overijssel en Gelderland.

Hlavác, J. (1983), "The technology of glass and ceramics. An introduction", Glass science and technology 4.

Huizinga K., et al. (1992), "Grofkeramische industrie", Samenwerkingsproject Procesbeschrijvingen industrie", RIVM, Bilthoven.

Huizinga K., et al. (1992), "Fijnkeramische industrie", Samenwerkingsproject Procesbeschrijvingen industrie", RIVM, Bilthoven.

Kannah, K. (1984), "Special waste disposal and duty of care during furnace demolition", Glass Technology Vol. 36 No. 1 February 1995.

Marvin, C.G. (1993), "Government regulation increases for chrome-bearing hazardous waste", Glass industry, october 1993.

Tooley, F.V. (1984), "The handbook of glass manufacture", 3rd edition, Vol. VII.

UNEP IE Database (1992): "Saint-Gobain Emballage", France.

SECTION 11

MANUFACTURE OF OTHER NON-METALLIC MINERAL PRODUCTS

ANNEX A

PROCESSES AND WASTES DESCRIPTION

Contents :

A.1 OVERVIEW

In this report, the following sub-sectors from NACE 26 are analyzed[1]:

- Manufacture of glass (NACE 26.1):
  - flat glass
  - hollow glass
  - glass fibres[2]
  - other glass including technical glassware.

- Manufacture of ceramic products (NACE 26.2, 26.3, 26.4):
  - ceramic goods (other than for construction purpose):
    - household and ornamental articles
    - sanitary fixtures
    - insulators and insulating fittings and other technical ceramic products
    - refractory ceramic products
  - ceramic tiles and flags
  - bricks, tiles and construction products, in baked clay[3].

- Manufacture of articles of concrete, plaster and cement (NACE 26.6):
  - concrete products for construction purposes
  - plaster products for construction purposes
  - ready-mixed concrete
  - mortars
  - fibre cement.

A.2 MANUFACTURE OF GLASS AND GLASS PRODUCTS

* Process description

The main raw materials for glass are silica (quartz), metal oxides, soda ash, boric and substances with specific effects such as opacifiers (fluorides and phosphates), colourants and refining agents.

Main technological operations in producing glass are:
- batch preparation and its charging into the melting furnace
- glass melting
- glass forming
- annealing and finishing.

The minimum temperature for melting glass is 1400-1500 °C. In the next production stage, glass is viscously deformated. The glass industry is a major consumer of fossil fuels and is therefore subject to air emission regulations.

1 The manufacture of cement, lime and plaster (**NACE 26.5**) is characterized by its large-scale production and therefore excluded from further analysis (the production of articles of cement (NACE 26.6) is not characterized by large-scale production). Cutting, shaping and finishing of stone (**NACE 26.7**) is exluded from analysis because the waste is of low significance; the waste is generally not hazardous and the amount is relatively low. The type of waste is similar to the other sectors. Manufacture of other non-metallic mineral products (**NACE 26.8**) is exluded from analysis because no relevant information on waste-prevention has been found in literature.

2 The production of glass fibres is characterized by its large-scale production and therefore excluded from further analysis.

3 Defined by NACE 26.4, in this report worked out together with NACE 26.2 and 26.3.

* **Waste description**

- *Preparation mixture residues and sludges*
  Raw materials remain as residues in the mixing and melting processes. The amount of waste can be limited in case of good operational practices. On site, much waste arises in cleaning operations when floors or equipment are washed with water. The waste ends up as sludge. The sludge can be contaminated. To prevent contamination of the sludge, hazardous waste water has to be treated separately.

- *Glass residues, particles and sludges*
  This waste includes deformed glass, broken glass products, particles and sludges from waste water.

- *Furnace demolition waste*
  From time to time the lining, checkerwork, flues and other parts of the furnaces have to be renovated. These parts have been exposed to waste gases of combustion over the years. Spent linings and refractories from the glass industry are not considered as hazardous according to the EWC, but research shows that this waste can be hazardous due to the heavy metals it contains[1].

A.3 MANUFACTURE OF CERAMIC PRODUCTS

* **Process description**

The main raw materials in ceramic industry are industrial mineral raw materials, like clay and other silicates, mineral oxides derived from materials as magnesite, dolomite and bauxite.
Ceramic products are used in building and construction (tiles, pipes, sanitary ware), domestic and leisure industries (tableware, ornamental ware), electrical and electronic engineering (insulators) and metallurgy (refractories). Usually, ceramic products are classified in raw and fine ceramics.

Processes in this sector include:
- pre-treatment and mixing base materials
- moulding
- drying and bakening (including glazening and painting in fine ceramics).

Temperatures in bakening range from 900-1400 °C. Due to the consumption of fossil fuels air emissions are an important environmental aspect.

* **Waste description[2]**

- *Preparation mixture residues and sludges*
  This waste consist mainly of clay residues and broken clay-products. In the Netherlands most part of these are reused in the production process as a base material. Otherwise, this waste can be reused externally for pavement. On site, much waste arises in cleaning operations when floors or equipment are washed with water. The waste ends up as sludge. The sludge can be contaminated. To prevent contamination of the sludge, hazardous waste water has to be treated separately.

1 Kannah, 1984
2 Main source: Huizinga, 1992

- *Product residues, glaze, particles and sludges*
  This waste consists of lime, glaze and sand (only in raw ceramics). Glaze contains heavy metals like lead and is therefore to be considered hazardous. About 50% of the companies in the fine-ceramic industry in the Netherlands reuse the glaze. The surplus of glaze is disposed of as chemical waste. The glaze accounts for circa 25% of the total waste in the fine-ceramic industry. Both glaze and particles can end up as waste water sludge.

A.4 MANUFACTURE OF ARTICLES OF CONCRETE, PLASTER, CEMENT

* Process description

The main raw materials for articles of concrete, plaster and cement are sand, water, cement, gravel (for concrete), lime, steel and fibres. The industry covers a wide range of products like products for road construction, elements for building construction and elements for civil engineering works.

The production of these articles includes:
- storage and mixing of base materials
- shuttering and/or moulding
- drying and/or hardening (not for plaster)
- aftertreatment (sawing).

For the construction of reinforced concrete, steel is used in the shuttering stage.

* Waste description[1]

- *Preparation mixture residues and sludges*
  This waste consists mainly of gravel, cement and other raw materials. In the concrete industry sand and gravel account for 6-7% of the total waste. On site, much waste arises in cleaning operations when floors or equipment are washed with water. The waste ends up as sludge. The sludge can be contaminated. To prevent contamination of the sludge, hazardous waste water has to be treated separately.

- *Products residues, particles and sludges*
  This waste consists mainly of deformed products, rejects, dust and sludges. It accounts for 28 to 90% of the total waste in the concrete industry. Asbestos residues is no longer a major waste stream; asbestos is not widely used anymore, because of its hazardous character.

- *Shuttering residues*
  Shuttering residues consist mainly of wood, plastic and steel (reinforced concrete).

1 Main source: Heidemij Advies, 1995

SECTION 11

MANUFACTURE OF OTHER NON-METALLIC MINERAL PRODUCTS

ANNEX B

PREVENTION OPTIONS

Contents :

Sector	Manufacture of other non-metallic mineral products (NACE 26)
Process	Glass and glass products, ceramic products, articles of concrete, plaster, cement
Waste stream	Preparation mixture residues and sludges

Prevention option	**Good housekeeping**
Option No	11-1
Type	GOP
Group	1
Description	Reduction of preparation mixture residues can be achieved by good operational practices, such as[1]: • keeping raw materials wet to prevent wind losses; • use of shovel instead of transport belt; • not overloading grab; • (automatic) slides under stock/mixing machinery. Reduction of sludge waste can be achieved by[2]: • taking care that wastes are treated separately, so the main waste water stream can be treated and reused (internally or externally); sludge, not suitable for re-use, can be disposed of to landfill; • addition of agents, reducing the hardening-speed of plaster[3]; waste water can be reused the next day or week.
Remarks	
Economics	No economic data have been found in literature. In general, these options do not involve high investment costs and will pay back in reasonable time.
Potential	It is expected that the options mentioned will be applied already in most companies. However, low costs are involved and significant reduction can be achieved, so the prevention potential has been estimated as *low to moderate*.

1 Heidemij advies. 1995
2 Heidemij advies. 1995
3 Research on this topic is carried out by: Stichting CUR, Mailbox 420, 2800 AK Gouda, The Netherlands (onderzoekscommissie B54).

Sector	Manufacture of other non-metallic mineral products (NACE 26)
Process	Glass and glass products, ceramic products, articles of concrete, plaster, cement
Waste stream	Product residues, particles and sludges

Prevention option	**Good housekeeping**
Option No	11-2
Type	GOP
Group	1
Description	Reduction glass residues and particles can be achieved by good operational practices, such as[1]: • in time replacement of wore out moulds • installing quality-control sensors • training of fork-lift drivers • instruction to fork-lift drivers to clean up caused damage
Remarks	
Economics	No economic data have been found in literature. In general, these options do not involve high investment costs and will pay back in reasonable time.
Potential	It is expected that the options mentioned will be applied already in most companies. However, low costs are involved and significant reduction can be achieved, so the prevention potential has been estimated as *low to moderate.*

1 Heidemij advies, 1995

Sector	Manufacture of other non-metallic mineral products (NACE 26)
Process	Glass and glass products
Waste stream	Glass residues, particles and sludges

Prevention option	**Recycling**
Option No	11-3
Type	RU
Group	3
Description	Reduction of glass particles can be achieved by holding back particles out of the waste water stream in order to reuse the glass Kilns are cooled by a closed water circuit. On the cooling machines a gutter drains off the glass particles during cutoffs. Glass and water are thus discharged into a granulator where scraping chains remove the glass to the recycling plant. In the recycling plant the water is separated from the glass particles. The glass particles are remelted with the ground glass.
Remarks	The data are from a case study carried out in 1992 in France[1]. Other methods for separation, by physico-chemical treatment, are considered to be more expensive.
Economics	Costs of direct investment: ECU 700 000 (1992), annual operation and maintenance costs: about ECU 8 000.
Potential	No data on the achievable waste reduction are available. Only one application of this method is known. The prevention option has been estimated as *low to moderate.*

1 UNEP IE Database: "Saint-Gobain Emballage", France, 1992

Sector	Manufacture of other non-metallic mineral products (NACE 26)
Process	Glass and glass products
Waste stream	Furnace demolition waste

Prevention option	**Alternative refractories**
Option No	11-4
Type	IMC
Group	3
Description	Refractory materials consist of a variety of chemical species combined to develop properties for high temperature applications. When these refractory materials are exposed to process conditions like high temperature, high pressure and a multitude of chemical reactants, toxic by-products may be produced. Chromium is such a toxic substance. By using chrome-free regenerator systems the toxicity of the waste will be reduced[1]. Research on this issue is proceeding.
Remarks	
Economics	
Potential	No data have been found concerning practical experience with chrome-free regenerator systems. Therefore the potential option will be considered as *low*.

1 Glass industry, oktober and february 1992

Sector	Manufacture of other non-metallic mineral products (NACE 26)
Process	Ceramic products
Waste stream	Preparation mixture residues and sludges

Prevention option	**Recycling**
Option No	11-5
Type	GOP / RU
Group	1
Description	Recycling possibilities for residues are: • instant collecting of unhardened concrete and reuse in the batch preparation • collecting of sand and gravel spills • clay and broken product waste, produced in moulding and bakening, can be reused as a base material after grinding[1]. Sludges of waste water treatment installations in ceramic industry usually can be reused in the preparation process.
Remarks	
Economics	Costs are not defined in literature available.
Potential	Reuse of this waste is state of the art, so the prevention potential has been estimated as *low*.

1 Huizinga, 1992

Sector	Manufacture of other non-metallic mineral products (NACE 26)
Process	Ceramic products
Waste stream	Product residues, glaze, particles and sludges

Prevention option	**Glaze sludge recycling**
Option No	11-6
Type	RU
Group	3
Description	Glaze in waste water from glazing processes can be separated by flocculation and be reused for glazing[1].
Remarks	Recycling of glaze sludge is more fit for larger companies.
Economics	
Potential	Results of the flocculation of glaze and the practising are not found in literature. The reduction potential is therefore unsure.

1 Huizinga, 1992

Sector	Manufacture of other non-metallic mineral products (NACE 26)
Process	Articles of concrete, plaster, cement
Waste stream	Preparation mixture residues and sludges

Prevention option	**Recycling**
Option No	11-7
Type	RU
Group	1
Description	Recycling possibilities are: • in mortar manufacture, sand and gravel can be recovered from the concrete residues by the use of a recycling machine; a reduction of about 90% of the waste stream can be achieved[1]; • in manufacture of concrete products, unhardened concrete residues in the production of aerated concrete can be mixed with the base materials lime, cement and sand. In this way the residues are reused[2].
Remarks	In a modern plant for the production of aerated concrete, waste production can be avoided: unhardened residues can be internally recycled (as described above); hardened residues can be used as raw materials in other industries.
Economics	The achievable annual savings are estimated to be high. Costs for recycling machines are not defined in literature available.
Potential	Recycling of mortars is seen as a good option to minimise waste. The level of experience with recycling machines is not identified. The prevention potential has been estimated as *low to moderate*.

1 Heidemij advies, 1995
2 Bijen, 1995

Sector	Manufacture of other non-metallic mineral products (NACE 26)
Process	Articles of concrete, plaster, cement
Waste stream	Product residues, particles and sludges

Prevention option	**Bypass of chemicals**
Option No	11-8
Type	TC
Group	1
Description	In manufacture of mortars, the concrete mill does not have to be cleaned if certain chemicals, like chemicals to form bubbles and control the process, are added to the process not earlier than in the mixing stage. To achieve this, bypasses have to be made[1].
Remarks	
Economics	The possible reduction of the annual costs are estimated to be high, especially as a result of the extra production capacity from the extra production time (no cleaning).
Potential	A reduction of about 10% of the waste stream can be achieved. The method is seen in literature mentioned as a good option to minimise waste. The level of experience with this method is not identified. The prevention potential has been estimated as *moderate*.

1 Heidemij advies, 1995

Sector	Manufacture of other non-metallic mineral products (NACE 26)
Process	Articles of concrete, plaster, cement
Waste stream	Product residues, particles and sludges

Prevention option	**Rubbling concrete and reuse for gravel**
Option No	11-9
Type	RU
Group	1
Description	Concrete residues can be rubbled[1]. The small parts can then be reused as gravel in the production process. A reduction of 90-100% of the waste stream can be achieved.
Remarks	
Economics	The achievable annual savings due to less waste and/or reuse are estimated to be high.
Potential	The level of experience with this method is not identified. The prevention potential has been estimated as *moderate*.

1 Heidemij advies. 1995

Sector	Manufacture of other non-metallic mineral products (NACE 26)
Process	Articles of concrete, plaster, cement
Waste stream	Shuttering residues

Prevention option	**Using shorter stacks**
Option No	11-10
Type	GOP
Group	1
Description	In many cases it is not necessary to place wooden stacks over the whole length of the product. Shorter stacks can often be used[1].
Remarks	
Economics	The annual savings due to less waste and/or reuse are estimated to be high.
Potential	The level of experience with this method is not identified, but the principles are very simple and will often be practised. The prevention potential has been estimated as *low to moderate.*

1 Heidemij advies, 1995

Sector	Manufacture of other non-metallic mineral products (NACE 26)
Process	Articles of concrete, plaster, cement
Waste stream	Shuttering residues

Prevention option	**Calculate elasticity of steel reinforcements**
Option No	11-11
Type	GOP
Group	1/2
Description	Steel is used for reinforcement in concrete products for construction purposes. To prevent steel waste, the elasticity of the steel can be calculated before the steel is being drawn out. In this way the exact required lenght can be used[1].
Remarks	
Economics	The achievable annual savings due to less waste and/or reuse are estimated to be high.
Potential	According to this literature source, the method is seen as a good option to minimize waste. The level of experience with this method is not identified. The prevention potential is estimated as *low to moderate.*

1 Heidemij advies, 1995

SECTION 12

MANUFACTURE OF BASIC METALS :

CASTING OF METALS

SECTOR REPORT

Contents :

NACE sectors involved in the present sector report:

Retained for analysis: 27.5 Casting of metals

Excluded from analysis: 27.1 Manufacture of basic iron and steel and of ferro-alloys (ECSC)
27.2 Manufacture of tubes
27.3 Other first processing of iron and steel and production of non-ECSC ferro-alloys
27.4 Manufacture of basic precious and non-ferrous metals

12.1 SECTOR CHARACTERISATION [1]

This sector is covered by code 27 of NACE, Rev.1 (1991) that includes the manufacture of basic metals and basic metal products. The information presented afterwards in this sector report is related largely towards casting of metals (foundries) NACE 27.5. Other sub-sectors are excluded as they involve large industries or involve wastes already concerned in this report[2].

Foundries produce castings, i.e. articles made from melted metal and cast in a mould. NACE makes the following distinction:

- iron and steel foundries (NACE 27.51 and 27.52): production of mainly grey cast iron, ductile cast iron, steel casting and stainless steel casting;
- non-ferrous foundries (NACE 27.53 and 27.54): mainly aluminium, copper and zinc.

Castings from foundries are normally used as intermediate products. Major customer of foundries is the automobile industry; next, the mechanical engineering. The most important end products are pressure pipes, pipes and castings. The main competitors of foundries are enterprises that use other processes to mould metals, e.g. forging. Besides, competition has emerged from new materials - in particular certain plastics.

In 1993, total EU production was estimated at 9 664 kton, of which non-ferrous metals account for 17%. In 1990, the share of non-ferrous metals was only 13%. The increase of non-ferrous metals reflects the trend towards higher-quality castings. Besides, castings have become increasingly thin-walled, lighter and more complex to manufacture. During the recession period of 1990 till 1993, employment dropped with 60 000 jobs to approximately 230 000 in 1993. Since 1994 production has been rising again and this trend continued in 1995; employment remained more or less stable. The five largest manufacturing countries (Germany, France, UK, Italy and Spain) account for 93% of total EU production.

The sector counts approximately 3 000 companies and is mainly composed of small and medium sized enterprises. More than half of all foundries still have fewer than 50 employees, and many are still family-owned. Often foundries make part of a larger enterprise in order to produce castings to meet its own needs[3]. Independent foundries mostly act as sub-contractor.

---

1 Main source: European Commission, 1995

2 Manufacture of basic iron and steel and of ferro-alloys (**NACE 27.1**) is comprised largely of a small number of large integrated enterprises. However, in certain Member States (Italy and Spain), so-called 'mini-mills' account for a substantial share of steel production.

Manufacture of tubes (**NACE 27.2**) accounts for 285 plants in 1993, including concentrated large enterprises as well as small and medium sized enterprises operating in niches of the market. Waste materials (iron and steel) are immediately and completely recycled in-plant.

The number of companies in 1994 of other first processing (**NACE 27.3**) was 910. Waste streams may involve *metal wastes, metal working fluids, pickling wastes* and *blasting grit*. These waste streams are also typical for NACE sectors 28 and 29 that concern industry which manufactures fabricated metal products and machinery and equipment. These sectors are extensively dealt with in section 13 of this report.

The non-ferrous industry (**NACE 27.4**) covers primary and secondary production and processing. This industry comprises about 3 000 companies, most of which are active in the processing sector. Similar waste streams as with NACE 27.3 arise. The sectors of primary and secondary smelting and refining metallurgy, are more concentrated, counting much smaller numbers of companies. It is noted that these sectors account for several waste streams that are considered to be particularly hazardous and/or landfill-consuming. The Euroenviron Working Group on Industrial Wastes selected the following waste streams and provided information on available waste prevention methods and on-going R&D (source: Euroenviron, 1993):

- *aluminium salt slags* from secondary smelting and casting of aluminium within rotary kilns;
- *red mud* from the Bayer aluminium production process;
- *jarosite sludges* from zinc winning (the international zinc industry has installed a "Jarosite R&D group" that deals, among others, with jarosite waste problems);
- *dusts and sludges* from the steel and non-ferrous metal industries (ore agglomeration, blast furnaces, electric smelters and converters);
- *furnace brick lining* from primary and secondary steel production, primary aluminium production and anode production.

Other literature on these sectors is to be found in chapter 12.5 of this sector report.

3 As foundries are often part of a larger metal company, this sector is closely related to NACE sectors 28 and 29 that concern metal products industry. These sectors are dealt with in section 13.

12.2 PROCESSES AND WASTES

The processes for the manufacture of ferrous and non-ferrous products in foundries are almost similar. The basis steps involved for both products are:

- mould and core making
- metal melting in furnaces
- casting (pouring of liquid metal in moulds)
- separation of castings and moulds
- finishing of the cast products.

Generation of waste is directly related to the (furnace) technology employed and the type of moulds and cores used. In table 12.2.1 the different wastes are listed, together with their process origin; the table includes a tentative priority ranking, based on the amount and the hazardous character of the waste.

Further details on processes and wastes are provided in Annex A.

Table 12.2.1: Foundry wastes

Process origin	Waste streams	Priority rank	Description and code according to EWC [4]	
Mould and core making Casting Separation of casting and mould	Foundry sand	+	Casting cores and moulds containing organic binders	10 09 01 10 10 01 10 09 02 10 10 02
	Foundry dust	o		
Melting	Furnace slag and drosses	o	Furnace slag	10 09 03 10 10 03
	Furnace dust	o	Furnace dust	10 09 04 10 10 04
	Furnace lining	-	Wastes not otherwise specified	10 09 99 10 10 99
Finishing	Blasting grit	-	Wastes not otherwise specified	10 09 99 10 10 99

Priority rank: + : high significance, o : medium significance, - : low significance EurEco/Witteveen+Bos 1997

Waste streams of minor significance, not included in the table, are:
- metal wastes (metal wastes are completely reused)
- waste water treatment sludges (from treatment of scrubber waste water)
- polishing sludges from grinding, honing and lapping
- oils and chemicals.

The major waste problem is caused by foundry sands. Although approximately 95% of used foundry sands can be recycled into new moulds, the disposal of the 5% waste sand still involves very large quantities and environmental problems, because of the landfill-consuming consequences and sometimes hazardous character (leaching). In Germany, for example, total disposal of foundry sands amounted to more than 2 000 kt in 1986 [5].

4 EWC codes "10 09 xx" refer to ferrous pieces, while codes "10 10 xx" refer to non-ferrous pieces. Another distinction is made by EWC between casting cores and moulds which have not undergone pouring (unburnt sands) and those which do have undergone pouring (burnt sands).
Foundries do not generate major waste streams that are hazardous according to the European Hazardous Waste List.

5 Euroenviron, 1993

Various opportunities for external recycling, e.g. as a raw material for building material, and inertization are developed or under investigation[6].

Other main environmental issues associated with foundries are air pollution and energy consumption. The main pollutant emissions are combustion gases (CO, NO_x and SO_2), dust, metal oxides and volatile hydrocarbons (VOC). Metal oxide fumes are produced especially when processing metals and alloy having a relatively low melting point (e.g. zinc and tin). The VOC emissions result from burning of a part of the mould sand binders. Dust emissions are generally treated by cyclones and dry-bag (cloth) filters. Sometimes, wet-scrubbers are applied for dust-removal, causing water pollution and sludge production.

12.3 WASTE PREVENTION

This section discusses waste prevention methods identified in literature. The major waste streams along with prevention options are summarized in the next table. The options are described in detail in Annex B.

Table 12.3.1: Overview waste prevention options for foundries

Waste streams	Priority rank	Waste prevention method	Group	Potential
Foundry sand	+	12-1 Good operation practices (GOP)	1	o
		12-2 Alternative binder systems (IMC)	3	..
		12-3 Alternative moulding techniques (TC)	2	-
		12-4 Regeneration (RC/RU), including:	1/2	o/+
		12-4a Small-scale mechanical regeneration	1/3	o
		12-4b Central regeneration units	2/3	o
		12-4c Low-cost additional thermal reclamation	1	+
Foundry dust	o	12-5 Recycling of dust (GOP)	1	..
Furnace slag	o	12-6 Change-over from cupola furnaces (TC)	2/3	-
Furnace dust	o	12-7 Recycling of dust (GOP/RU)	1	o
Furnace linings	o	12-8 Extending useful operation time (GOP)	1	-
Blasting grit	o	12-9 Alternative methods and technologies (TC)	2/3	-

+ = high, o : medium, - : low, .. = insufficient data EurEco/Witteveen+Bos 1997

As the major waste problem is caused by *foundry sands*, most waste prevention options in literature are related to this waste stream. Major opportunities are found in regeneration methods. Many good operating practices and alternative binders and moulding techniques also have impact on the regeneration possibilities. For small foundries, regeneration methods are often not economically feasible. However, new opportunities are developing, including small-scale units, central regeneration as well as additional regeneration units. The over-all prevention potential for regeneration is considered to be moderate to high.

For *furnace wastes*, not many prevention options are available. Most options involve a change of furnace system. However, switch-over to other systems for waste reducing motives only, is not likely. Besides, furnace wastes constitute a medium foundry waste. For these reasons, the prevention potential is ranked as low to moderate. The moderate options involve re-use opportunities in modified cupola furnaces, especially for continuous ferrous production.

6 Euroenviron, 1993, and for example: Umweltbundesamt, Siempelkamp 1993 - 1996.

12.4 EVALUATION

According to various sources of literature, fundamental changes in mould manufacturing techniques are not to be expected in the short term. There are, however, gradual improvements of the existing techniques. This includes as well the techniques for sand regeneration.

In the past decades, major attention has been paid to improvement of moulding and casting techniques and quality, for reasons of competitiveness. Nowadays, environmental issues, especially waste problems, receive increased notice.
As many good operating practices for waste prevention are available already, significant prevention can be reached.
Another opportunity is the development of lower priced efficient regeneration methods for small and medium sized enterprises. At large foundries, used foundry sands are already recycled to a high degree into new moulds.
Finally, the environmental attention in the casting industry stimulated suppliers of chemicals to start considering the environmental consequences of their products, in order to stay competitive.

Foundry waste sands are mostly disposed of to landfill sites. Opportunities for external reclamation are not sufficiently utilized yet. One of the reasons is lack of contact between individual foundries and waste reclamation companies.

Summarizing, it can be concluded that outlooks for clean technologies for waste prevention in the casting industry are good. This applies in particular to small and medium sized enterprises. A significant reduction of foundry wastes, that now are disposed of to landfill sites, is possible.

12.5 BIBLIOGRAPHIC REFERENCES

Elzenga H.E., et al. (1994), "Preventie van industrieel lafval; een verkenning van het potentieel aan kwantitatieve preventie van industrieel afval", RIVM, Bilthoven, 181 p.

Euroenviron Working Group on Industrial Wastes (1993), "Industrial Waste Management, R&D Needs and Market Opportunities", Eureka, Euroenviron Umbrella Project

European Commission (1995), "Panorama of EC Industry 95/96", Bruxelles-Luxembourg

Eijssen P.H.M. et al. (1993), "Process Descriptions in Dutch Industry: Iron Foundries", RIVM, Bilthoven, 15 p.

Huizinga K. et al (1993) "Process Descriptions in Dutch Industry: Non-Ferrous Foundries", RIVM, Bilthoven, 16 p.

KHD Humbold Wedag (1987); Case study in Canadian publication: "Catalogue of Successful Hazardous Waste Reduction/Recycling Projects"; UNEP IE abstract, edited for the ICPIC diskette in July 1995; document No. UNEP 05 450-003-A-369.

Lehmann, H.H. et al. (1993), "Reststoffströme in der Metallindustrie - Technologien und Kernziffern", Universität Hannover, Institut für Wasserwirtschaft, Hydrologie und Landwirtschaftlichen Wasserbau", Hannover, Germany.

Österreichischen Giessereiinstitut (1994), "Branchenkonzept Giessereiindustrie", Bundesministerium für Umwelt, Wirtschaftskammer Österreich, Fachverband der Giessereiindustrie Österreichs, Wien (republished 1995).

Summer, D. (1989); Case study in: "Clean Technology, Environmental Protection Technology Scheme", Department of the Environment, London, UK, 6 p.; UNEP IE abstract, edited for the ICPIC diskette in August 1995; document No. UNEP 16 453-001-A-000B.

Triplex Alloy Ltd (1994), "Sand costs reduced by thermal reclamation", GC3 final results of a good practice case study at Triplex Alloys Ltd.; Environmental Technology Best Practice Programme, UK, published June 1995.

Umweltbundesamt, Projektträgerschaft Abfallwirtschaft und Altlastensanierung, Vorhaben 1988-1994, Bundesministerium für Bildung, Wissenschaft, Forschung und Technologie; Projektträger: Umweltbundesamt, Deutschland:
- SLR Giesserei St. Leon-Rot GmbH (1989 - 1992); Förderkennzeichen: 1450562
- Siempelkamp Giesserei GmbH & Co (1993 - 1996); Förderkennzeichen: 1490835 I

US EPA (1992), "Guides to pollution prevention: Metal casting and heat treating industry", Office of Research and Development, Washington DC.

The Association Européenne des Métaux (Eurometaux), the European Aluminum Association (EAA) and the Committee of European Foundry Associations (CAEF) have been asked to comment the draft version of the sector report. We are very grateful for the reaction of Eurometaux and EAA, in which they informed us that they had no comments to make. We did not receive a reaction from CAEF within the period made available for comments (mid November 1996 - mid January 1997).'

SECTION 12

MANUFACTURE OF BASIC METALS :

CASTING OF METALS

ANNEX A

PROCESSES AND WASTES DESCRIPTION

Contents :

A.1 OVERVIEW

According to NACE 27.5, foundries includes (i) ferrous and (ii) non-ferrous products and semi-manufactured articles. Products turned out by both types of foundries are often categorized as (i) cast iron, ductile cast iron, malleable cast iron and cast steel, and (ii) copper cast, aluminium cast and zinc cast.

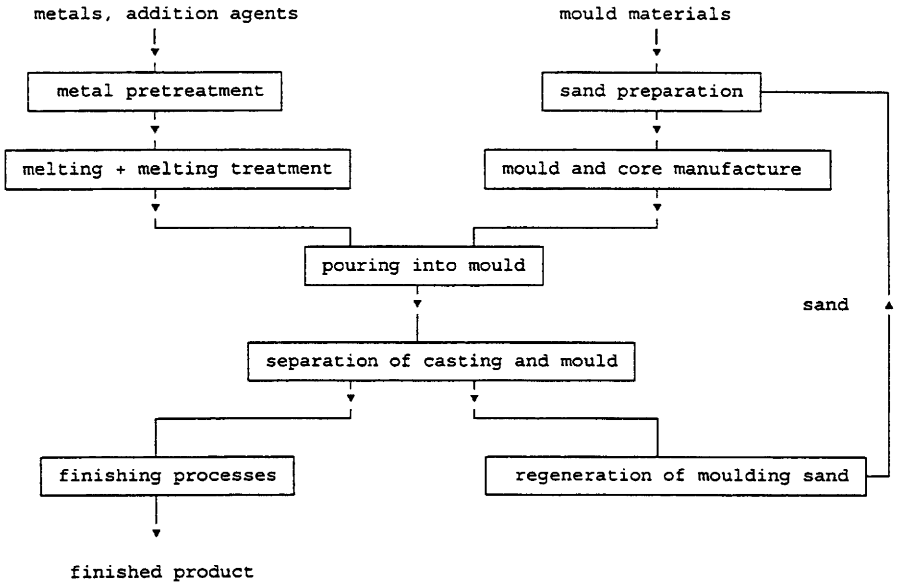
Typical raw materials are:
- primary and secondary metals
- quartz sand
- additives for the moulding:
  - mineral binder: bentonite, waterglass, gypsum or cement
  - organic binder, for chemically bonded sands: e.g. furane, phenolic or alkydic resins
  - lining material: suspensions of powdered coal, thickened graphite, talcum, silicate and others.

The processes for the manufacture of ferrous and non-ferrous products in foundries are almost similar. Therefore only one process description is incorporated. The basis steps involved for both products are:
- mould and core making
- metal melting in furnaces
- casting, separation of castings and moulds and sand regeneration
- finishing of the cast products

A diagram of the operations carried out in a metal foundry is shown in figure 12.1.

The main waste streams from foundries are moulding sand, filter dust, drosses and slags, linings and refractories and blasting grit. For the major part, drosses, filter dusts and metal wastes can be reused in the secondary metal industry. Used foundry sands may be recycled to a high degree into new moulds.

Figure 12.1. Block flow diagram of the operations at a foundry



A.2 MOULD AND CORE MAKING

* **Process description**

According to mould type, the main groups are temporary moulds ("lost-mould" process), and permanent moulds.

In permanent-mould casting, the same moulds are used a great many times. These moulds are usually made of iron and steel.

In temporary-mould casting, the moulds and cores (i.e. the inner moulds) are used only once or a few times. The most widely used material for this process is sand. Temporary-mould casting processes may be divided into:
- clay-bonded sand moulds, for the serial production of lighter castings (casting by machine); this most common type of process is also called "green sand process"; the sand consists of quartz sand and bentonite (clay) together with powdered coal or a substitute, to give the casting a smooth surface; approximately 4 to 10 percent of the mixture is clay; water activates the clay binder and is added in small percentages (2 to 5%); carbonaceous materials may make up 2 to 10 percent of the green sand mixture;
- chemically-bonded (self-hardening) sand moulds, for the production of heavier castings by hand; self-hardening sand is made by adding a small amount of hardening binder (for example furan resin) and a catalyst (for example phosphoric acid); chemical binders provide increased productivity and control and better casting surface quality.

The amount of sand used for making cast products varies between type of products and is in average ranging from 7 to 10 ton sand/ton cast product[1]. The sand is recycled many times; however, new sand (5 - 15 %) has to be added to compensate losses and to overcome problems with reduced quality of recycled sand.
Core moulds generally use chemically-bonded sand, while outer moulds can be made often of clay-bonded sand. Cores must be strong, hard and collapsible.

* **Waste description**

Foundry sands
Sand dust (unburnt sand) can be released during mould and core making. To control dust in work areas, an exhaust system is often installed. The collected dust can sometimes be fed back into the process. The total amount can be 2 - 10% of the weight of the casting in the case of clay-bonded sand.

A.3 MELTING

* **Process description**

The principal furnaces employed in foundries for the melting of metals are the cupola furnace, the electric furnace and the rotary furnace. If the feed for the furnace is purchased from the base metal industry, hardly any pretreatment is necessary. If scrap is the feed, it will have to be pretreated, including size reduction and removal of undesirable materials.

1 Euroenviron, 1993 and Lehmann, 1993

The **cupola furnace** is a continuous furnace[1]. Coke and iron are loaded alternately into the shaft through an opening in the side. As a result of the heat generated by burning coke, the metal melts and falls to the bottom.

The **electric furnace** is a batch furnace. An electrical (induction) furnace consists of a refractory-lined chamber surrounded by an induction heating coil. This type of furnace is used chiefly in small- and medium-sized foundries.

The **rotary furnace** is also a batch furnace. It consists of a slowly rotating refractory-lined cylinder, where an oil or gas burner has been mounted on the shaft.

* **Waste description**

Furnace slag and drosses
Approximately 90% of furnace slag and drosses is produced in cupola furnaces. In these furnaces burnt coke (slag) is continuously removed. Slag may be conditioned by fluxes to facilitate removal from the furnace.
Based on data in the Netherlands, it is estimated that roughly 100 kg slag/ton product is produced[2]. Other data give a range of 40 to 100 kg slag/ton product[3]. Electric furnaces produce considerably less slag and drosses wastes, ranging from 10 to 20 kg slag/ton product[4].

Furnace dust
In a cupola furnace, air is blown through the cylindrical furnace from the bottom upwards. Because of the high air speed in the furnace, considerable amounts of dust are emitted. The principal sources of dust are coke, limestone, refractory furnace lining and metallic charge. Cupola furnace dust consists mainly of silica (SiO_2, 20 - 40%) and metal oxide (12 - 16%). Dust is largely recovered form the air stream by cyclones and filter systems as cloth filters, electrostatic precipators and multi-cyclones.

Dust from ferrous foundries generally contain varying amounts of zinc, lead, nickel, cadmium and chromium. Dust associated with non-ferrous metal production may contain copper, aluminium, lead, tin and zinc.

Cupola dust production data give a range of 8 to 15 kg dust/ton product; electric induction furnaces are reported to produce 0.06 to 1 kg dust/ton product[5]. Other sources give ranges for cupola furnaces of 2 to 50 kg dust/ton product[6].

Furnace lining
Linings have to be replaced or repaired periodically due to damage or contamination. Generally, the linings are not toxic for the environment. In Austria, of the total furnace linings arising of 4.0 kt/y, 10% was officially classified as hazardous. However, leachate measurements of the hazardous fraction proved that levels were actually below the criteria for hazardous waste[7].

---

1 The cupola furnace is the oldest known, lowest priced and formerly most widely used furnace. In the last decades, many furnaces have been replaced by induction furnaces for technological (process control and casting quality) and environmental reasons. For instance, in 1953 Austria counted about 100 cupola furnaces of which nowadays only about 10 are left (source: Österreichischen Giessereiinstitut).
2 Huizinga 1993 and Eijssen 1993.
3 Österreichischen Giessereiinstitut, 1994
4 Österreichischen Giessereiinstitut, 1994
5 Österreichischen Giessereiinstitut, 1994
6 Lehmann, 1993
7 Österreichischen Giessereiinstitut, 1994

A.4 CASTING, SEPARATION AND SAND REGENERATION

* **Process description**

The melted metal is transfered from the furnace to the pouring area. Slag is removed from the surface of the metals and the metal is poured into the moulds. The casting is followed by cooling to a temperature at which the casting can be separated from the mould. This cooling period varies from about 30 minutes to a few weeks, depending on the size of the casting. Fumes or smoke from the metal pouring area are exhausted to a dust collection device.

In sand casting (temporary mould), the workpiece is placed in a so called shake-out grate and the sand is removed by jolting and vibrating. After screening, crushing and metal-removing, the removed sand is largely reused in the mould preparation process. Part of the sand (approx. 5%) is lost with sieving and exhaust systems and must be replaced with new sand. Besides, after various recycling loops, sand becomes contaminated and to maintain quality, new sand must be added as well. Used core sands are usually recycled into outer moulds without major problems regarding outer mould stability. In general, for cores, virgin sand is used to some extent, while moulds are typically made up from a mixture of virgin (30%) and used (70%) sands[1].

The possibilities for regeneration of moulding and core sand depend on the origin of the used sand and the binders applied. During the casting process, clay-bonded sand becomes loaded with scales of burnt clay, while organic binders in chemically-bonded sand will be partly diminished upon burning. This is accompanied by the uncontrolled formation of e.g. phenolic and polyaromatic hydrocarbons. These contaminations pose problems for internal or external recycling and for landfilling (toxic leachates). To overcome the problems with deteriorating of recycled sand quality, elaborate regeneration systems (e.g. three-phase), in particular by large foundries, are installed in the last decades. This has resulted in over-all 85 to 95% recovery of sand for internal use.

Mechanical separation of impurities on waste sand is a basic standard technology[2], i.e.:
- crushing and sieving
- cleaning and de-dusting:
  - mutual friction
  - impacting on a wall
  - wind-sighting[3]
  - washing with high-pressure jets.

Thermal treatment is useful for reclamation of organic- and clay-bonded sands. Both horizontal and vertical rotary kiln and fluidized bed systems are available[4].

Recovered sand quality of compact mechanical regeneration (one-phase system) is not completely comparable to that of three-phase systems. However, the quality is generally sufficient for re-use in most foundries, especially when 30 to 50% new sand is added[5].

1 Euroenviron, 1993
2 Euroenviron, 1993
3 The dust containing unburnt bentonite and carbon smoothing agent may be recycled into forming outer moulds.
4 US EPA 1992. For thermal reclamation case studies, US EPA 1992 refers to "Proceedings: 2nd Annual Environmental Affairs Conference." *American Foundrymen's Society, Inc.*, Illinois.
5 Österreichischen Giessereiinstitut, 1994

* **Waste description**

Foundry sands
Sand is lost as dust and spills during shake-out of metals and moulds. To control dust in work areas, an exhaust system and filters are often installed. Waste sand can also be in the form of large clumps that are screened out of the moulding sand recycle system or in the form of sand that has been cleaned from the castings. If wet scrubbers are applied, sand, metals and binding chemicals end up as sludge in waste water (5 - 50 kg (solid)/ton cast product[1])

Foundry sands account for 65 to 90% of the total waste generated by foundries. In the Netherlands, the average waste factor for foundry sand is estimated to be 0.3 ton sand/ton product[2]. Many other data are available, giving an over-all range of 200 to 3 000 kg waste sand/ton cast product.

The regeneration process of moulding sand produces a waste stream, consisting of the residues of bentonite and glance coal-forming agents (in case of clay-bonded sand). Exhaust air is filtered in dust-bags and cyclones (approx. 15 kg sand/ton sand regenerated[3]).

A.5 FINISHING

* **Process description**

After casting, cooling and shake-out, risers and runners are removed from the casting and mechanical cleaning is applied, using bandsaws, abrasive cut-off wheels, chipping hammers and grinders. Next, the surface is cleaned and adhering sand particles are removed from the casting. Further cleaning is generally done with metal shot and - especially in the case of larger objects - with a high pressure water-jet. In permanent-mould casting, the casting is generally removed from the mould with special equipment.

Depending on the final products and the facilities of the foundry, additional metal operations are performed (cutting and machining operations, and surface treatment).

* **Waste description**

Blasting grit
About 95% of the dust from finishing operations are metallic oxide particles resulting from the burning of the metal. The remainder is grindstone material and quartz originating from adhering sand particles. In the Netherlands and Germany, roughly 0.05 ton blasting grit/ton product is disposed of[4].

---

1 Lehmann. 1993
2 Huizinga 1993 and Eijssen 1993.
3 Lehmann. 1993
4 Lehmann 1993, Huizinga 1993 and Eijssen 1993.

SECTION 12

MANUFACTURE OF BASIC METALS :

CASTING OF METALS

ANNEX B

PREVENTION OPTIONS

Contents :

Sector	Manufacture of basic metals: Casting of metals (NACE 27.5)
Process	Mould and core making
Waste stream	Foundry sand

Prevention option	**Good operation practices**
Option No	12-1
Type	GOP
Group	1
Description	Good operation practices that can be applied, are[1]: • optimization of the moulding sand/product-ratio; this can be achieved by using the smallest moulding form as possible, by analysing the planning of required forms over longer periods and by placing as many products in one form as possible • replacement of massive cores by partly hollow cores; if necessary, the cavity can be filled with unbonded sand instead of (chemically) bonded sand; • whenever possible, addition of solid bodies in the cores to replace bonded sand; • in cold-box processes, new sand is only necessary around the model, while for backing recycled sand can be used; • minimization of binder addition (high binder content gives higer deteriorating rates of recycled sand); the minimum required dosage amounts should be determined and instructed to personnel; careful weight control during (hand) dosing of additives is of particular importance, however, the best method would involve an automatic dosing system; • optimization of mixing temperature: too high temperatures cause unnecessary emissions at the mixer, too low temperatures require additional catalysts and hardening agents; • disclosure of the bentonite *before* moulding sand preparation; • only *weak* activation of calcium-bentonite; • only regeneration of used sand that has been close to the casting workpiece; outer located sand can be re-used after normal recovery treatment (screening etc.); • separation of different types of waste sands as well as other wastes (dust, blast dust etc.); including, for example, installation of separate exhaust filter systems, changing of core sand shake-out procedure to keep this sand from being mixed, etc.
Remarks	As generally the amount of waste sand produced is a percentage of the amount of sand that is circulating, waste sand volumes are reduced when the volume of sand use is reduced.
Economics	Generally, these meausures involve low costs with short pay-back times.
Potential	Good operation practices are largely implemented for reasons of competitiveness. However, it is expected that especially in small and medium sized enterprises, still these options can be checked[2]. The prevention potential has been assessed as *moderate*.

1 Österreichischen Giessereiinstitut 1994 and US EPA 1992.
2 Österreichischen Giessereiinstitut, 1994

Sector	Manufacture of basic metals: Casting of metals (NACE 27.5)
Process	Mould and core making
Waste stream	Foundry sand

Prevention option	**Alternative binder systems**
Option No	12-2
Type	IMC
Group	3
Description	In the last years, suppliers of chemical binder systems have started to pay more attention towards developing and offering more environmental sound binder systems. Use of high-quality binders[1]; for example, silaniced furan resins require considerable less organic substances: e.g. lower levels of formaldehyde (providing less air-polluting problems); in the Croning-process, liquid resins can be replaced by solid resins that contain less free phenol (0.5 instead of 2%). On-going promising research is reported directed towards possible use of clay-bonded sands for big, heavy and highly structured products also[2].
Remarks	
Economics	Alternative binders may involve higher prices than traditional chemicals; however, this is compensated by often lower dosing rates, less problems in air pollution and - most importantly- higher degree of re-use of regenerated sand.
Potential	Attention towards binder chemicals in relation to improved recycling opportunities is a relatively new development. The quantitative effects, however, can not be predicted at this stage. The prevention potential is therefore *unknown*.

1 Österreichischen Giessereiinstitut, 1994

2 In Österreichischen Giessereiinstitut 1994, reference is made of the german research project "01 H 399" (Brühwiller G. and Schuricht D.; "Kernherstellung aus tongebundenem Formstoff für eine automatische Form- und Giessanlage"; Giesserei Nr. 16, Düsseldorf, 1993).

Sector	Manufacture of basic metals: Casting of metals (NACE 27.5)
Process	Mould and core making
Waste stream	Foundry sand

Prevention option	**Alternative moulding techniques**
Option No	12-3
Type	TC
Group	2
Description	Prevention can be achieved by using less bonded sand per mould, e.g. by the following techniques: • Lost-Foamprocess (also: Evaporative Pattern Casting): certain products may be produced with moulds made of expanded polystyrene in a sandbed[1]; this largely avoids the need to bind the surrounding sand; only the places where the hot metal is let in, need core sands. During the casting process the polystyrene is gasified. Disadvantages of this process are the high price of the plastic mould and a new emission problem (provisions have to be taken for treatment of flue gases containing styrene, toluene and benzene). • Croning-process (also shell-pack-system): to cast large series, the Croning mask mould process may be applied, using very thin-walled moulds that are supported by binder-free quartz sand or clay-bonded sand. • Vacuum moulding: vacuum is used to keep the mould in shape; it is applied only in special cases with small tolerances and high precision requirements, due to rather small throughput[2]. • Improved spraying systems for application of liquid separation-chemicals to the moulds, that reduces losses and over-dosing of separation-chemicals[3].
Remarks	According to various sources of literature, fundamental changes in mould manufacturing techniques are not to be expected in the short term.
Economics	No specific cost data and/or cost/benefit analyses are provided in literature mentioned in this report.
Potential	Although no information on EU wide implementation of these methods has been obtained, literature indicates that the applications of these methods are restricted to only certain products. For these products, these techniques are well known and will often be implemented. The prevention potential has therefore been assessed as *low*.

1 In Euroenviron, 1993: Safam and Peugeot, France.

2 Euroenviron, 1993

3 It is often assumed that automatic spray-systems result in less consumption of agents than hand spraying; however, this need not be the case, as the multiple spray-nozzles often interfere and become less efficient than hand pressure spray; in: Österreichischen Giessereiinstitut, 1994.

Sector	Manufacture of basic metals: Casting of metals (NACE 27.5)
Process	Mould and core making
Waste stream	Foundry sand

Prevention option	**Regeneration**
Option No	12-4
Type	RU/RC
Group	1 - 2
Description	Used foundry sands may be recycled to a high degree into new moulds by application of regeneration units. In these units the sand is cooled, reduced in size (crushing and sieving), cleaned by mechanical friction[1], wind-sighting[2], washing with high-pressure jets and/or cleaned by incinerating the organic binder. Elaborate three-phase systems[3] include a mechanical, thermical and mechanical treatment; more simple schemes involve only mechanical cleaning. For medium and large size foundries, these methods are considered standard technology[4].
Remarks	New approaches and equipment designed for sand regeneration are continuing to evolve; therefore, it is adviced that foundries evaluate carefully different systems and suppliers with regard to the best suitability for a particular foundry operation[5]. In the next options, some methods to increase the degree of regeneration are discussed, including: • development of economically attractive small scale units (option 12-4a) • central recycling units for small and medium sized enterprises (option 12-4b) • low cost additional thermal reclamation (option 12-4c).
Economics	Sand reprocessing units require high capital investments and for this reason, mostly in large companies units have been installed. Cost indications are[6]: • a three-phase unit with 25 000 t/y (5 t/h) throughput is estimated to cost about 2.5 million ECU; operating costs (energy, maintenance and personnel) were estimated at 18 ECU/t sand (of which personnel and maintenance account for about 50%); • an one-phase (mechanical) unit with 3 600 t/y (0.75 t/h) throughput is estimated to cost about 310 000 ECU; operating costs (energy, maintenance and personnel) were estimated at 22 ECU/t sand (of which personnel and maintenance account for more than 70%).
Potential	Regeneration is often applied in large foundries. Literature reports overall reuse in Germany and Austria of about 85 to 95%[7]. Mechanical regeneration (attrition) is common use in many UK foundries to reclaim spent chemically bonded sand[8]. However, as costs for modern systems are high and some plants still operate relatively old units, it is expected that implementation of regeneration units can still be improved, while existing systems can be optimized. Together with the potentials of the options to be discussed next (12-4a to 12-4c), the over-all conclusion towards the prevention potential of regeneration is *moderate to high*.

1 To improve sand quality and re-use opportunities, grinding is preferred rather than impacting methods.
2 The dust containing unburnt bentonite and carbon smoothing agent may be recycled into forming outer moulds.
3 For example in: Umweltbundesamt, SLR Giesserei 1989 - 1992.
4 Euroenviron, 1993
5 US EPA, 1992
6 Österreichischen Giessereiinstitut, 1994
7 Österreichischen Giessereiinstitut, 1994; Lehmann, 1993 and Euroenviron, 1993.
8 Triplex Alloys, 1994.

Sector	Manufacture of basic metals: Casting of metals (NACE 27.5)
Process	Mould and core making
Waste stream	Foundry sand

Prevention option	**Small-scale mechanical regeneration**
Option No	12-4a
Type	RU/RC
Group	1 / 3
Description	At large foundries, elaborate regeneration schemes generally can often be applied. However, for small-sized foundries (e.g. with waste sand production of less than 5 000 t/y), economically and technically attractive small-scale regeneration units were not available[1]. Some recent developments towards (mechanical) small-scale units are[2]: • A german pilot plant[3] ("Öko-Sandregenerierungssystem", Germany) for small and medium sized foundries is designed for 1 - 5 t/h throughput of mixed sands (e.g. 75% core sand and 25% clay-bonded sand). The technique is based on mechanical removal of the impurities by mutual friction using pneumatic forces. The system can be operated during foundry down-time in order to make use of existing power facilities. • A second example[4] (GEMCO, the Netherlands) is mechanical removal of the impurities using grinding discs. This high-performance system for clay-bonded sand, produces newly rounded sand that can be used for core-moulding as well. Furthermore, by separating the large part of sand that has not been in direct contact with the hot metal product, the still active components (bentonite and carbon) can be recovered for re-use in the moulding process as well. Though also higher recovery rates are claimed, at least 85% is considered possible.
Remarks	The grinding of sand not only increases the fine particle content of the sand, it also produces round-shaped sand particles that improve the quality and performance of the casting process.
Economics	Investment costs in 1993 of the GEMCO plant were about 290 000 ECU; with operation costs of about 33 ECU/t sand, the pay-back time is 5 to 8 years.
Potential	Most small and medium sized foundries do not operate waste sand regeneration[5]. The implementation potential therefore is high; on the other hand, the larger foundries account for the major quantity of waste sand. For these reasons, the prevention potential has been assessed as *moderate*.

1 Österreichischen Giessereiinstitut, 1994.
The number of foundries in Austria in 1993 was 73 of which 18 employed regeneration (1 thermical, 5 thermical/mechanical and 12 mechanical). Is is on the SME level that regeneration is absent.

2 Besides these mechanical treatment schemes, investigations on small-scale three phase systems are reported, including mechanical treatment (a.o. grinding), thermal treatment at 600 - 800 °C and mechanical after-treatment of reusable sand and inert dust (reference in Österreichischen Giessereiinstitut, 1994: H. Tillmans, W. Tilch; Vortragsband Internationaler GIFA-Kongress Giessereitechnik '94, Düsseldorf 1994).
Furthermore, Euroenviron 1993 reports on-going and planned R&D at Halberger Hütte (Germany) towards recycling techniques in the range of 1 t/h waste sand.

3 Österreichischen Giessereiinstitut, 1994.
Pilot plant and practical testing were assisted by the "Giesserei-Institute" (Foundry Institute) of the Rheinisch-Westfälischen Technische Hochschule Aachen (Germany).

4 Österreichischen Giessereiinstitut, 1994

5 Österreichischen Giessereiinstitut, 1994; Huizinga, 1993.

Sector	Manufacture of basic metals: Casting of metals (NACE 27.5)
Process	Mould and core making
Waste stream	Foundry sand

Prevention option	**Central regeneration units**
Option No	12-4b
Type	RU/RC
Group	2 - 3
Description	For medium and small size enterprises, regeneration opportunities can be found in joined operation of a regeneration unit in one centrally located foundry[1]. In Germany, also commercial waste management companies provide regeneration services; however, in some cases, prices appear still to be much higher than disposal costs[2,3]. In Finland, technical (thermal/mechanical recovery) and economical feasibility is studied of centralized reclamation of used foundry sands[4].
Remarks	
Economics	No specific information of costs are available. As indicated above, prices might still be high for the small and medium sized enterprise level.
Potential	Central regeneration certainly offers an alternative for many small and medium sized foundries. However, techniques and methods should operate on prices that are economically feasible. For this reason, the prevention potential has been assessed as *moderate*.

1 Österreichischen Giessereiinstitut, 1994: mention is made of the foundry Halberger-Hütte, in Lage, Germany.

2 Österreichischen Giessereiinstitut, 1994: mention is made of the B.U.S. company (Berzelius Umwelt Service).

3 Euroenviron 1993: the Klöckner-Humboldt-Deutz and B.U.S. consortium built a plant to treat the waste sands of approximately 20 regional foundries. About 85% of the waste sands are said to be recyclable.

4 Euroenviron, 1993

Sector	Manufacture of basic metals: Casting of metals (NACE 27.5)
Process	Mould and core making
Waste stream	Foundry sand

Prevention option	**Low cost additional thermal reclamation**
Option No	12-4c
Type	RU/RC
Group	1
Description	This low-cost installation[1] (designed for 0.5 t/h throughput) removes chemical binder residues left on sand grains after particulation[2]. The unit comprises two fluidised bed chambers. In the first chamber the sand settles like a bed around a gas-fired burner and is heated to 720 °C. Compressed air fluidises the bed. In the second fluidised chamber the sand is cooled to 35 °C by a bank of water tubes immersed in the bed. Emissions from the unit are ducted to a dry-bag filter for removal of particulates.
Remarks	It is essential that emissions are monitored, particularly after installation, to ensure that combustion conditions are adequate to destroy the binder residues. Tests proved that particulate and VOC emissions from the thermal reclamation unit are at acceptable low levels[3]. Good process control is essential for maintaining low emission levels. Besides regular maintenance, critical parameters are: • adequate bed and above-bed temperature; • control of air supply to the fluidised beds; • control of the sand feed-rate to within 20% of the rated capacity. Other thermal reclamation systems named in literature[4] are Centrozap, TNEE, FMI and GDF (France) and Lurgi and Klöckner-Humboldt-Deutz AG and B.U.S.[5] (Germany).
Economics	Thermally reclaimed sand is technically acceptable for moulding and coremaking and can be used instead of new sand. Costs for new sand and disposal of used sand are reduced or eliminated. Installation costs for a 0.5 t/h troughput installation costed about 62 000 ECU in 1994. Operation costs (electricity, gas and maintenance) are 5.2 ECU/t sand, of which gas accounted for 57%. Savings on purchase and disposal resulted in a payback of 9 months.
Potential	This low-cost method claims a high re-use rate of chemically bonded waste sands. Its waste prevention potential is therefore considered to be *high.*

1 All information presented here on thermal reclamation (description and costs) is derived from: Triplex Alloys, 1994.

2 Particulation (mechanical attrition) is common use in many UK foundries to reclaim spent chemically bonded sand. However, binder residues remaining on the particulated sand grains affect the re-use possibilities: new sand must be mixed (e.g. 30% new sand and 70% mechanically recovered sand) to ensure adequate mould strength and casting quality (source: Triplex Alloys, 1994).
Prior to thermal reclamation, extraneous material must be removed from the particulated sand by using screens or separators.

3 Concentrations (mg/m^3) reported in <Triplex Alloys, 1994> show: particulates < 5; VOC < 10; CO < 20; NOx < 10; formaldehyde < 0.05 and isocyanates < 0.0002.

4 Euroenviron, 1993

5 Euroenviron 1993, reports for this case:
The consortium built a plant to treat the waste sands of approximately 20 regional foundries (see also prevention option 18-2b). The plant contains as well a fluidized-bed furnace to incinerate organic binders and dead-burn clay binder. It subsequently separates valuable quartz sand from contaminants by impact crushing and sifting. About 85% of the waste sands are said to be recyclable.
KHD Humboldt Wedag 1987:
In this UNEP IE abstract, the multi-stage process (capacity 5 t/h) is shortly described. Investment costs were 2.9 million ECU, while operation/maintenance was 275 000 ECU/y (operation costs are reduced to 150 000 ECU/y when energy is recovered).

Sector	Manufacture of basic metals: Casting of metals (NACE 27.5)
Process	Mould and core making, casting and separation of castings and mould
Waste stream	Foundry dust

Prevention option	**Recycling of dust**
Option No	12-5
Type	GOP/RU
Group	1
Description	Fugitive foundry dust emissions (from ventilation from mould and core making, casting and separation of castings and mould and from crushing for re-use) can be treated with wet scrubbers. The dust collected as a sludge by the scrubber can be recovered by returning it to the mould making process instead of dumping[1]. In this case study, a special sludge pumping system, using a centrifugal pump with a natural rubber impeller, was used to overcome problems associated with the abrasive properties of the sludge. For re-use in the moulding process, the slurry had to be added carefully. An electronic control and display system was developed for the 5 process variables (water quantity, weight of sand, sand temperature, ambient temperature and the weight of the various additives).
Remarks	The re-use of foundry dust into moulds increased the casting quality as the surface characteristics of the moulds are improved by incorporating the fine dust particles.
Economics	In this case study, the system for recycling of foundry dust sludge in the moulding process, involved a capital investment of 19 000 English Pounds (price level 1989). The system recovers 1 600 t/y of sludge. Material savings and reduced disposal charges result in a payback time of 3 months.
Potential	No information on EU wide implementation of these methods has been obtained. The prevention potential is therefore *unknown*.

1 Summer, 1989

Sector	Manufacture of basic metals: Casting of metals (NACE 27.5)
Process	Melting
Waste stream	Furnace slag

Prevention option	**Change-over from cupola furnace**
Option No	12-6
Type	TC
Group	2 - 3
Description	Cupola furnace slag is produced from the necessary limestone and from cokes ashes, furnace lining, rust etc. The main destination of these slags is landfill. It can, however, be externally used as road grit, building material, road construction material, etc., or for cement and abrasives manufacture. A change-over from cupola furnace to electric or rotary furnace, can give a reduction of the formation of slags and refractories with 90%. Induction furnaces offer also other advantages over cupola furnaces, e.g. by emitting about 75% less dust and fumes[1].
Remarks	Planning of a switch of cupola to other types of furnaces will off course require careful analyses of technological and economical aspects. US literature[2] reports extensively on prevention options for hazardous desulfurizing slag. This waste stream is not identified as a major waste stream in European literature evaluated.
Economics	If continuous melting of large quantities is required without cupola furnace, advanced electric furnaces are necessary, but generally, this is economically not attractive.
Potential	Switch-over to other furnace techniques for waste reducing motives only, is not likely. Technological, economical and product quality are main considerations. In the last decades, the number of cupola furnaces has been reduced substantially in some countries[3]. For these reasons, the prevention potential has been assessd as *low*.

1 US EPA 1992.

2 US EPA 1992.

3 The cupola furnace is the oldest known, lowest priced and formerly most widely used furnace. In the last decades, many furnaces have been replaced by induction furnaces for technological (process control and casting quality) and environmental reasons. For instance, in 1953 Austria counted about 100 cupola furnaces of which nowadays only about 10 are left (source: Österreichischen Giessereiinstitut).

Sector	Manufacture of basic metals: Casting of metals (NACE 27.5)
Process	Melting
Waste stream	Furnace dust

Prevention option	**Recycling of dust**
Option No	12-7
Type	GOP/RU
Group	1
Description	Disposal of collected furnace dust can be prevented by on-site recycling: • Furnace dust recovered from cupola furnaces can be fed back (blowing or suction) into the furnace, reducing the amount of this waste with 90 %[1]. • Recovery of stainless steel or alloy steel dust from electric arc furnaces is possible by returning the dust to the furnace for recovery of base metals (iron, chromium or nickel); dust from steel products based on galvanised scrap, however, are often high in zinc, which causes problems; recovery methods for zinc containing dusts have been proposed.[2]
Remarks	A change-over from cupola furnace to electric or rotary furnace (see discussion at the previous option) also results in reduction of furnace slag produced.
Economics	Furnace dust re-use in cupola furnaces involves costs for modification of the furnace inlet nozzles; operation costs may increase due to maintenance of nozzles and transport systems and for mixing operations of dust with other furnace feed material. No specific cost data are obtained.
Potential	The opportunity to recycle dust can be considered as an advantage of cupola furnaces. However, for technical reasons it is expected that this recycling option is not yet extensively implemented. The prevention potential has been assessed as *moderate*.

1 Österreichischen Giessereiinstitut 1994 and Eijssen 1993. In the first reference, results are discussed of a study of the Düsseldorf Insitute for Foundry Technique at seven foundries investigating four dust inlet-systems (Forschungsbericht E-214; Institut für Giessereitechnik GmbH, Düsseldorf).

2 US EPA 1992.

Sector	Manufacture of basic metals: Casting of metals (NACE 27.5)
Process	Melting
Waste stream	Furnace lining

Prevention option	**Extending useful operation time**
Option No	12-8
Type	GOP
Group	1
Description	Linings have to be replaced or repaired periodically due to damage or contamination. By using well-controlled high quality raw materials and by careful application[1], the useful operation time of the furnaces can be increased. *On-going investigations* are reported towards cupola furnaces contructions without lining and ring-cooling[2].
Remarks	Sometimes, waste linings can constitute major waste problems when the linings are heavily contaminated. This is the case for instance with aluminium-electrolysis furnaces[3].
Economics	No significant costs are involved.
Potential	The waste reduction that can be achieved by good operating practices is estimated at 5%[4]. As furnace linings constitute only a small part of total foudry wastes (approximately 5%), the waste prevention potential has been assessed as *low*.

1 Österreichischen Giessereiinstitut, 1994

2 Lehmann, 1993

3 Lehmann, 1993: besides salts from the electrolytic melt (kryolith, aluminiumfluoride, potassiumfluoride and sodiumfluoride) the furnace linings accumulate as well cyanides and nitrites that are easily leached out when disposed of to landfill; R&D considers pyrohydrolyse, pyrosulfolyse and washing with caustic soda.

4 Österreichischen Giessereiinstitut, 1994

Sector	Manufacture of basic metals: Casting of metals (NACE 27.5)
Process	Finishing
Waste stream	Blasting grit

Prevention option	12-9
Option No	**Alternative methods and technologies**[1]
Type	TC
Group	1/2/3
Description	*Alternative methods and technologies* mentioned in literature[2], are: • Basically, the old method of manual de-rusting and paint removal by scrubbing yields only the material removed as waste. • Mechanical paint removal, using plastic grit ("plastic media blasting": PMB). *On-going and planned R&D*, shortly mentioned in literature, are directed to alternative technology; however, most alternatives have limited applications: • hydrojetting; the use of hydrojet blasting, when applicable, will replace the problem of grit pollution by the easier-to-handle problem of water pollution. Small quantities of grit added to the hydrojet will improve cleaning efficiency and the range of applicability. • cryogenic paint removal; this system is not suitable for large scale operations • dry-ice (solid CO_2) blasting; questions are still concerned about costs, possible damage of surfaces and effectiveness • laser or flash-lamp paint stripping; still in experimental stage and considered to be very expensive • salt-bath stripping • pyrolytic paint removal • fluidised sand bed • sustainable coating systems • use of wet, vacuum or mobile cast-blasting.
Remarks	
Economics	The methods mentioned above may involve higher costs than traditional grit blasting, and have only limited applications.
Potential	Considering the economical and technical constraints, the prevention potential has been estimated as *low*.

1 This option is obtained from section 13 on manufacture of metal products; literature references are to be found in section 13.

2 The options mentioned here are equally shortly presented in: Euroenviron, 1993. The general references named by Euroenviron are Lufthansa, Germany; Sliperi Mekaniske Verksted, Norway and Schlick, Germany.

SECTION 13

MANUFACTURE OF METAL PRODUCTS

SECTOR REPORT

Contents :

NACE sectors involved in the present sector report:

28 Manufacture of fabricated metal products, except machinery and equipment
29 Manufacture of machinery and equipment N.E.C.
33 Manufacture of medical, precision and optical instruments, watches and clocks
34 Manufacture of motor vehicles, trailers and semi-trailers
35 Manufacture of other transport equipment

13.1 SECTOR CHARACTERISATION [1]

The various sectors of manufacture of metal products comprise companies which manufacture a wide variety of products. The main economic features of these sectors are summarized below.

The European fabricated metal products sector (NACE 28) is mainly made up by a large number of small and medium-sized companies, employing approximately 2 million people. The total number of companies in the EU in 1990 was about 230 000, of which 88% employed less than 20 employees and 1,8% more than 100. In 1992 the most important sectors are tools and finished products; other important sectors are structural metal products, boilermaking and forging. The industry is concentrated in Germany (41%); other major producing countries are France (17%), the United Kingdom (12%) and Italy (11%).

The machinery and equipment sector (NACE 29) supplies almost exclusively capital goods and their components. Like production of metal products, this sector is characterised by small and medium-sized companies as well. The total number of companies in the EU in 1990 was almost 120 000, employing 2.4 million people. Of this number of firms almost 100 000 had fewer than 20 employees. They were primarily involved in repairs or the production of parts. Between 1990 and 1993 employment dropped with about 320 000 jobs. Forecasts for 1997 show a further drop of employment of about 100 000. The machinery and equipment sector accounts for 8% of the European industrial production output. The industry is concentrated in Germany (49% of net product); other important producers are the United Kingdom (15%), Italy (13%) and France (10%).

The manufacture of precision instruments (NACE 33) employed about 330 000 people in 1990 within approximately 35 000 enterprises. The great majority of firms had fewer than 20 employees. However, major employment and turnover of the sector is found within less than 1 000 enterprises.

The European transport equipment industry (NACE 34 and 35) included a total number of enterprises in 1990 of about 15 300, of which 79% employed less than 20 employees and 7.4% more than 100. The enterprises employing over 100 employees, however, account for approximately 95% of the total number of employees within the EU (approximately 2.5 million people). The industry is concentrated in Germany, France, the United Kingdom, Italy and Spain. Especially the manufacture of coach-work, (semi-)trailers and boat-building and the second- and third-tier parts suppliers are represented by a large number of small and medium-sized companies.

13.2 PROCESSES AND WASTES

Within the wide variety of products and sectors of NACE 28 and 29, basically four different groups of processes can be distinguished. Each group itself is comprised of a great number of different sub-processes. The four main processes are:

- machining operations
- cleaning and stripping
- metal surface treatment and plating
- paint application

Minor waste generating activities are unpacking, assembling, packing, cleaning and maintenance.

1 Main source: European Commission, 1995

An enterprise can employ a mix of (sub)processes or can be dedicated to one process only[2].

In table 13.2.1 the different wastes are listed, together with their process origin and composition. The table includes a tentative priority ranking, based on the amount and the hazardous character of the waste.

Further details on processes and wastes are provided in Annex A.

Table 13.2.1: Metal products wastes

Process origin	Waste streams	Priority rank	Description and code according to EWC [3]	
Machining operations	Metal working fluids Metal scrap	+ +	Wastes from shaping	12 01 00
Cleaning and stripping	Halogenated solvent waste Halogen-free solvent waste	+ o	Wastes from metal degreasing and machinery maintenance	14 01 00
	Contaminated water	-	Wastes from water and steam degreasing processes	12 03 00
	Blasting grit	o	Wastes from mechanical surface treatment processes	12 02 00
Metal surface treatment and plating	Spent process bath solutions Filter sludges Wastewater treatment sludges	+ o +	Liquid wastes and sludges from metal treatment and coating of metals	11 01 00
	Spent salt bathes Spent quenchants	o o	Sludges and solids from tempering processes	11 03 00
Paint application	Waste paint and sludges containing halogenated solvents Waste paint and sludges free of halogenated solvent Aqueous waste paint and sludges	+ o -	Wastes from the MFSU of paint and varnish	08 01 00

Priority rank: + : high significance, o : medium significance, - : low significance EurEco/Witteveen+Bos 1997

Waste streams of minor significance, not included in the table, are:
- welding waste
- abrasives and polishing sludges
- powder paint.

With the exception of metal scrap waste and blasting grit, all wastes with high or medium significance are related to the use of chemicals. These wastes are comprised of liquids, waste water or sludges and are generally hazardous due to the chemicals and/or metals that they contain.

Metal scrap wastes can be recycled almost entirely. However, still significant quantities are lost to disposal instead of being re-used, due to lack of attention in enterprises or inadequate infrastructure. Despite the good recycling possibilities, reducing the amount of metal scrap waste is desirable for environmental reasons as reprocessing scrap costs energy and produces slag wastes and air emissions.

---

2 For example: metal surface treatment and plating is often an independent, i.e. not vertically integrated activity; specialised plants for electro-plating constitute about 50% of total electro-plating production in the EU (source: European Commission, 1995).

3 With the exception of metal scrap, all waste streams included in this table are hazardous according to the European List of Hazardous Wastes. Spent blasting grit (EWC 12 02 01), however, has been retained as a possible hazardous waste, depending on case to case evaluation.

Environmental issues relevant to these sectors are related mostly to the use of chemicals and coatings in metal surface treatment, plating and finishing. This results in water pollution by discharge of (treated or untreated) waste waters; outside air emissions by volatile organic carbons; possible contamination of soil and groundwater; and the disposal of (hazardous) wastes. Other important issues, relevant for the sectors as a whole, are workplace safety and noise production.

13.3 WASTE PREVENTION

This section discusses waste prevention methods identified in literature. The major waste streams along with prevention options are summarized in table 13.3.1, following the division into four independent processes as made in the preceding chapter. The options are described in detail in Annex B.

Table 13.3.1: Overview waste prevention options for metal products

Waste streams	Priority rank	Waste prevention method	Group	Poten-tial
Machining operations				
Metal working fluids	+	13-1-1 Working fluids management program (GOP) 13-1-2 Preventive measures (GOP) 13-1-3 Avoidance of working fluids (GOP/TC/IMC) 13-1-4 Selection and make-up of working fluids (IMC) 13-1-5 Recycling (RC/RC)	1 1 1/3 1 1	o o - - o / +
Metal scrap	+	13-1-6 Management/organisation (GOP/TC)	1/2	- / o
Cleaning and stripping				
Solvent wastes: halogenated and halogen-free solvents	+	13-2-1 Avoidance of cleaning (GOP) 13-2-2 Minimising vapour losses (GOP) 13-2-3 Maintaining solvent quality (GOP) 13-2-4 Alkalic degreasing (IMC/TC) 13-2-5 Alternative paint removal techniques (IMC/TC) 13-2-6 Recycling of solvents (RU/RC)	1 1 1 1/2 2/3 1/2	- - - + - +
Contaminated water	-	13-2-7 Optimised rinsing (GOP) 13-2-8 Biological degreasing (TC/IMC)	1 3	- / o ..
Blasting grit	o	13-2-9 Improved collection efficiency (GOP) 13-2-10 Alternative methods and technologies (TC)	1 1/2/3	- -
Metal surface treatment and plating				
Plating wastes: spent process baths, filter sludges and wastewater treatment sludges	+	13-3-1 Good housekeeping 13-3-2 Reduction of rinse water (GOP/TC) 13-3-3 Alter bath compositions (IMC) 13-3-4 Alternative technologies (TC) 13-3-5 Regeneration of baths (RU/RC)	1 1 1/2 2 1/2/3	- / o o o - / o -
Heat treating wastes: spent salt bathes spent quenchants	 o o	 13-3-6 Preventive measures (GOP/TC) 13-3-7 Alter bath composition (IMC) 13-3-8 Alternative technologies (TC) 13-3-9 Preventive measures (GOP/TC) 13-3-10 Internal recycling (RU/RC)	 1 1/2 1/2 1 1/2	 .. .. + / .. .. ..

Table 13.3.1: Overview waste prevention options for metal products				
Waste streams	**Priority rank**	**Waste prevention method**	**Group**	**Poten-tial**
Paint application				
Waste paint and sludges containing solvents	+	13-4-1 Alternative paints (IMC) 13-4-2 Alternative application methods (TC) 13-4-3 Catching of overspray (GOP/RU/RC)	1/2/3 1/2/3 1	o / + + -
Aqueous waste paint and sludges	-	13-4-4 Electrodepositing (TC) 13-4-5 Catching and re-use of overspray (TC/RU/RC)	2 2/3	- -

+ = high, o = medium, - = low, .. = insufficient data EurEco/Witteveen+Bos 1997

All options identified for *metal working fluids* can be regarded as proven methods and state-of-the-art (group 1). Significant waste reduction can be achieved by recycling of the fluids.
The prevention potential for *metal scrap waste* has been estimated as low to moderate, depending on the degree of automation, management and computer-aided design. Options vary from good-housekeeping (group 1) to change of technology (group 2).

Many options for waste and emission reduction of *solvents* for degreasing and cleaning activities are available[4]. Most prevention options identified (options 13-2-1 to 13-2-3) are considered to have low prevention potentials. The main reason is that these options often are related to good operation practices. Although these practices are not (yet) implemented extensively, the effects on waste reduction are not very significant. Nevertheless, as the costs for these options are generally very low, implementation should clearly not be neglected. Water-based degreasing is generally regarded to be the most desirable and effective alternative. Finally, the well-known method of recycling of solvents, e.g. by distillation, is considered an option that still has a high potential for waste prevention.

Options for the reduction of *blasting grit waste* involve mostly a change of technology. Their prevention potential are estimated as low because of technological and economical constraints.

For metal surface treatment, the prevention potential of *plating wastes* are assessed as low to moderate. Many options as well as specific literature were identified. Environmental issues have been traditionally addressed to water pollution control, which is closely related to measures for waste prevention.
Options 13-3-6 to 13-3-10 are related to *wastes from heat treatment processes* (case hardening). The prevention potential could not be estimated because no information was found yet on waste quantities, number of enterprises and level of implementation of the methods presented[5].

Paint application (solvent) wastes have become an issue since the world-wide attention to reduce the emission of volatile organic compounds (VOC). An increasing number of companies has since then switched to alternative paints and application methods[6]. The potential is

4 In the last decades, the halogenated solvents CFC-113 and 1,1,1-trichloroethane were widely used in metal industries for degreasing and cleaning activities. Due to their excellent properties and low MAC values, these solvents had often replaced other solvents like per- and trichloroethylene. However, due to their ozone layer depletion potential, the use of CFC-113 and 1,1,1-trichloroethane is now prohibited by the Montreal Protocol. To facilitate the change-over from these solvents to alternatives, a great many studies were performed world-wide.
Detailed information is to be found in, for example: CEC 1992, Chem Systems 1989, Ellis 1990, Glas 1989, Higgins 1989 and UNEP 1991.

5 Only literature sources so far: US EPA 1992a and UNEP IE 1995, Chartered Metal Industries.

6 A clear overview and discussion of these alternative types is to be found in: Giddings 1994. As possibilities are industry specific, discussions relating to which customers are using/likely to use these alternative coating types is included in this document.

considered to be moderate to high, as more alternative paints and techniques have become available in the last years. Because the use of water-based paints in metal industry is a relatively new item, only few specific prevention options for waste paints and sludges are found in literature.

In general, there are many prevention options reported for the manufacture of metal products. Sector-wide handbooks and reports (e.g. US EPA waste prevention guides: US EPA 1990, US EPA 1992a and US EPA 1992b; Higgins 1989: a handbook dedicated entirely to the metal industry) as well as case-studies (for example UNEP IE 1995, Berkel 1991 and Miller 1993) used for this study are given in chapter 13.5. This report provides a broad outline of options; the literature sources facilitate further research.

13.4 EVALUATION

The sectors of the manufacture of metal products and machinery and equipment can be divided basically into four groups of processes that have specific waste and prevention characteristics. The sector is characterised by a vary large number of enterprises (approx. 400 000), mainly on the small and medium-sized (SME) level. Prevention options were assessed tentatively in order to provide the reader with a (rough) idea of the prevention potential. Given that comparative statistics on the application of techniques were in most cases not available, the potentials are based on expert judgement.

The typical main processes for metal industry are machining operations. Waste minimisation of metal scrap is an issue that is directly related to the competitiveness of companies, as metals are the main raw material input. External recycling of scrap can be applied to a large extent; maximising this opportunity appears to be a point of interest, as well for individual metal companies as for public and private infrastructure for collection and recycling.

Cleaning and stripping activities are applied in metal industry as well as in other sectors. Waste minimisation is closely related to reduction of solvent emissions to air (for reasons of environment and workplace safety). Within the programmes on air emission reduction, an integral approach is necessary in order to reduce waste streams as well, e.g. by promoting recovery of solvents.

Chemicals are used for many processes: machining operations (metal working fluids), cleaning and stripping, metal surface treatment and plating and paint application. Specific chemical know-how is often absent in metal companies, especially on the SME level. Professional associations and suppliers of chemicals can in this context play an important role within programmes for waste minimisation.

Summarizing, it can be concluded that the outlook for further implementation of clean technologies in the metal products industry are favourable. Many waste prevention studies have been performed world-wide, resulting in a very large amount of information available. Moreover, suppliers of equipment and chemicals have developed many alternatives and services relevant for waste prevention. Waste strategies are now directed towards further continuation of the implementation process of available prevention methods.

13.5 BIBLIOGRAPHIC REFERENCES

Barendregt W., Loos B. (1993), "Ontvetten, Samenwerkingsproject Procesbeschrijvingen Industrie", RIVM, Bilthoven, 15 p.

Berkel C.W.M. van et al. (1991), "Prevention of waste and emissions at Stork Amsterdam", PRISMA, Report V, IDES University of Amsterdam.

Braber A. den (1994), "Biotechnology for cleaner production", Report nr. 94094, University of Utrecht, The Netherlands, October 1994.

CEC (1992), "Solvent Cleaning (Degreasing), an assessment of emission control options", Center for Emissions Control, Washington D.C.

Chem Systems (1989), "Metal degreasing technical options", Chem Systems International Ltd., London.

Elzenga H.E., et al. (1994), "Preventie van industrieel afval; een verkenning van het potentieel aan kwantitatieve preventie van industrieel afval", RIVM, Bilthoven, 181 p.

Euroenviron Working Group on Industrial Wastes (1993), "Industrial Waste Management, R&D Needs and Market Opportunities", Eureka, Euroenviron Umbrella Project

Ellis B.N. (1990), "Replacement of CFC-113 in industry", Swiss Fedral Office of Environment, Forest and Landscape, 3003 Berne (also available in Germand and French).

European Commission (1995), "Panorama of EC Industry 95/96", Bruxelles-Luxembourg

Giddings E.J., et al. (1994), "Reduction of volatile organic compound emissions from industrial coating of metallic surfaces using carbon based materials", European Commission, Bruxelles-Luxembourg

Glas L., et al. (1989), "Replacement options for 1,1,1-trichloroethane in degreasing/cleaning and electronics", Swedish Environmental Protection Agency, Information Department, Solna, Sweden.

Goldrite (1996), "Rinsing and chemical recovery system achieves large savings", NC11 final results of a new practice case study at Goldrite Metal Finishing Ltd; Environmental Technology Best Practice Programme, managed by AEA Technology PLC, through ETSU and the National Environmental Technology Centre, UK; first printed April 1996.

Higgins T. (1989), "Hazardous waste minimization handbook", Lewis Publishers, Inc., Chelsea, Michigan 48118, USA

Kohnen E.A.E.M., de Vlieger, G.J. (1992) "Fosfateren en chromateren, Samenwerkingsproject Procesbeschrijvingen Industrie", RIVM, Bilthoven, 14 p.

Koppert P.C. et al. (1991), "Bedrijfstakrapportage Chromolux", ESM, PRISMA, NOTA publicatie, Distributiecentrum DOP, PO Box 20014, The Hague, The Netherlands.

Loos B. (1992), "Metaalbewerking, Samenwerkingsproject Procesbeschrijvingen Industrie", RIVM, Bilthoven, 15 p.

Miller A., et al. (1993), "Case study: Effective waste minimization and wastewater pretreatment at an aluminum extrusion and anodizing facility", 48th Purdue Industrial Waste Conference Proceedings, Lewis Publishers, Inc., Chelsea, Michigan 48118, USA

Mortier J.W. du, Ros J.P.M. (1992), "Galvanische bewerkingen", RIVM, RIZA and DGM, Bilthoven, 11 p.

Obid G., (1995), "Oberflächenbehandlung von Metallen zur Reststoffvermeidung und -verwertung", Abfallwirtschaftsjournal 7 (1995), Nr. 12, EF-Verlag für Energie- und Umwelttechnik GmbH, Neuruppin, Deutschland.

Outokumpu (1995), "Regeneratie beitsbad", CopperBulletin 87/1995.

PRISMA (1992), "Handboek voor de preventie van afval en emissies in de metaalproduktenindustrie", Amsterdam, Ministry of Economic Affairs.

UNEP (1991), "Solvents, coatings and adhesives, Technical Report, Peer Review Draft, september 1991" United Nations Environmental Programme.

UNEP IE/PAC (1989), "Environmental Aspects of the Metal Finishing Industry: A Technical Guide", United Nations Publications, Paris, France.

UNEP IE Database, ICPIC diskette publication 1995:
- Chartered Metal Industries, Singapore
- Delot Process SA, France
- DOCNO: 10-01 (source material in, a.o.: "Clean technology" EPT Office, Department of environment, London, UK)
- DOCNO: 400-100-A-332 (source material in: Compendium on Low and Non-waste Technology, United Nations Economic and Social Council, Monograph "Copper-plating of Parts Followed by Electrodialysis: Recovery of Copper Contained in Rinsing Water")
- DOCNO: 400-125-A-332 (source material in: Compendium on Low and Non-waste Technology, United Nations Economic and Social Council, Monograph "A Low-waste Electroplating Process of Aluminium in Non-aqueous Solvent (Sigal Process)")
- DOCNO: 400-125-A-332 (source material in: Compendium on Low and Non-waste Technology, United Nations Economic and Social Council, Monograph "A No-Dump Bath Using Trivalent Chromium for the Blue Passivation Process in the Galvanic Industry")
- DOCNO: 450-003-A-348 (source material: Catalogue of Successful Hazardous Waste Reduction/Recycling Projects", Canada, March 1987)
- Electroless Hardcoat SA (source material: Centre for Cleaner Production Initiatives; Departamento de Medi Ambient, Generalitat de Catalunya, Barcelona, Spain).
- Egidius Jansen (source material: Manders, J. (1990) "Membrane electrolysis in practice", Tijdschrift voor oppervlaktebehandeling en corrosiebestrijding, Vol. 34, No. 1, January 1990, p.14-16)
- Elkhart Products Inc. USA (source material: Huisingh, D. et al. (1985) "Proven profit from Pollution Prevention", The Institute of Self-Reliance, Washington D.C.)
- Modine Manufacturing USA (source material: Huisingh, D. et al. (1985) "Proven profit from Pollution Prevention", The Institute of Self-Reliance, Washington D.C.)
- ENEA; submitted by ENEA CRE Casaccia (1994); Rome, Italy

US EPA (1990), "Guides to pollution prevention: The fabricated metal products industry", Office of Research and Development, Washington DC.

US EPA (1992a), "Guides to pollution prevention: Metal casting and heat treating industry", Office of Research and Development, Washington DC.

US EPA (1992b), "Guides to pollution prevention: The metal finishing industry", Office of Research and Development, Washington DC.

Umweltbundesamt, Projektträgerschaft Abfallwirtschaft und Altlastensanierung, Vorhaben 1988-1994, Bundesministerium für Bildung, Wissenschaft, Forschung und Technologie; Projektträger: Umweltbundesamt:
- Fritz Schäfer GmbH (1991 - 1993); Förderkennzeichen: 1460756 I.
- Lack-Recycling GmbH (1986 - 1989); Förderkennzeichen: 1460424.
- Mercedes Benz (1993 - 1996); Förderkennzeichen: 1470889.
- Preussag AG Metall (1990 - 1994); Förderkennzeichen: 1470662.

The Liaison Group of the European Mechanical, Electrical, Electronic and Metalworking Industries (Orgalime) and the European Secretariat of Manufacturers of Light Metal Packaging (Sefel) have provided general information for the study and have been asked to comment the draft sector report. We received a reaction from Sefel, for which we are very grateful. Sefel confirmed that the option on with paint application (with which metal packaging is involved) is an accurate summary of the current position.

SECTION 13

MANUFACTURE OF METAL PRODUCTS

ANNEX A

PROCESSES AND WASTES DESCRIPTION

Contents :

A.1 OVERVIEW

Within the wide variety of products and sectors of NACE 28 and 29, basically four different groups of processes can be distinguished. Each group itself is comprised of a great number of different sub-processes. The four main processes are:

- machining operations
- cleaning and stripping
- metal surface treatment and plating
- paint application

Raw materials used are, naturally, mainly iron and a wide range of steels and non-ferrous alloys; depending on the processes involved, other raw materials are metal working fluids and chemicals for metal surface treatment, plating and finishing.

A.2 MACHINING OPERATIONS

* Process description

Machining operations generally involve various **metal cutting processes**, like: turning, milling, drilling, reaming, broaching, scouring, grinding and polishing. For most cutting processes, metal working fluids are used for lubricating and cooling.

Shaping methods without cutting (thus not producing metal chips) are forging, extrusion and drawing. In the case of **forging**, a piece of steel (a so-called slug) is shaped between dies, which press together more or less rapidly. With **extrusion** tubes and profiles are made by pressing material through a narrow hole. For extrusion of steel, lubricants like grease and graphite are used. Wires and bars can be produced by **drawing** raw material through a matrix. Used lubricants are mineral oils, grease, graphite and molybdeniumsulfide.

A minor waste generating process considered here is welding. Welding is executed by heating metal parts until they get weak or liquid. Welding can be based on electrical currents, electrical bows, autogenic incineration and laser.

* Waste description

The major wastes from machining operations are spoiled or contaminated metal working fluids. Many fabricated metal industries generate cuttings and other metal scrap. Minor quantities of wastes are generated by welding.

- *Metal working fluids*
  During their service lifetime, metal working fluids degrade and become contaminated, reducing the cooling and lubricating properties. They have to be replaced in order to prevent damage to machines and working pieces. Contamination results mainly from "tramp" lubricating and hydraulic oils from the machines. Especially water-based fluids will suffer deterioration effects, due to bacterial growth and rancidity, difficult filterability and can contribute to oil smoke and mist in the working environment[1]. Generally, one or two times a year the working fluids are refreshed[2]. Metal working fluids are lost by evaporation (25 - 60%), spilling (20 - 25%) and drag-out with workpieces (15 - 20%) and metal waste chips (5 - 20%)[3] and lost as a wastestream (5 - 20%).

---

1 US EPA, 1990
2 Loos, 1992
3 This loss can be prevented by separating the oils from the scrap by chip wringers or centrifuges.

Waste metal working fluids are regarded as hazardous waste because of their oil content, as well as other additives that some contain; the wastes are also polluted with metal parts, rust and dust.

On- or off-site recycling of the spent fluids is often possible; however, most fluids based on water cannot be re-used. Oil separators are installed as some of the fluids will be lost into the sewerage.

- *Scrap metal*
  Many fabricated metal industries generate cuttings and other scrap metal. This waste also contains about 8% liquid waste consisting of water, oil, grease etc. Depending on the technique[1] applied, about 20 to 40% scrap is produced during forging. Extrusion (15%) and drawing (6%) produce less waste. The metal loss of the most current cutting treatment like turning and milling is 20 to 30%. The loss is higher for more complicated shapes (up to 90%). Metal loss with grinding is 1 to 10%.

  Off-site recycling of scrap in metal casting foundries is generally possible for almost 100%. This activity is dealt with in this report in section 18 on manufacture of basic metals.
  Fine metal cutting parts, for example from grinding, that are filtered out of the metal working fluids, can contain up to 40% oils. This metal is often burnt and oxidized and contaminated with dirt and abrasives. Methods for external recovery of metals out of these wastes are developed. Washing techniques for oil-removal are tested[2], making pyro-metallurgical reprocessing of this waste feasible.
  Prices paid for metal scrap are subject to strong fluctuations. To facilitate recycling, different types of scrap can be collected separately: e.g. ferrous and non-ferrous, steel and stainless steel, chips and sheetings etc..

- *Welding wastes*
  The dust that results from welding contains iron, fluoride, copper or chromium, depending on the welding method used. Most of the welding fumes are extracted; to reduce the emission to the air, it is partly filtered out. The collected dust has to be treated as hazardous waste. Other wastes produced by welding are slags and residues of used electrodes.

A.3 CLEANING AND STRIPPING

* Process description

Most fabricated metal products require some form of cleaning or stripping. Stripping is applied to remove coatings, oxides or old metal-plating layers, using abrasives, solvents or alkalies; cleaning (degreasing) is applied as pretreatment for further surface processing (e.g. plating or coating) or as final treatment to remove oils and particles.
Three types of cleaning or stripping media are utilized: solvents; aqueous cleaners; and abrasive materials.

Solvents (both halogenated and non-halogenated) are employed in cold cleaning (wiping or immersion baths - with or without ultrasonic support) or vapour cleaning operations. Vapour degreasing solvents are mostly halogenated hydrocarbons like per- and trichloroethylene. Dichloromethane is widely used for paint removal by immersion or spraying.

Alkalic cleaning is the most applied aqueous cleaning method, using immersion baths like in solvent cleaning. As a pre-treatment for plating processes, usually several water-based cleaning steps are applied, using acids, alkalies and detergents. Alkalic cleaning is now replacing solvent

---

1 Loos, 1992
2 Umweltbundesamt, Preussag AG Metall 1990 - 1994

degreasing in many occasions, avoiding air-emissions and health problems associated with the use of (halogenated) solvents. After water-based degreasing, drying is often required. Drying is mostly based on air, sometimes preceded by hot water rinsing.

Abrasive cleaners are designed for removing oxides, paints etc. and to produce a smooth surface. Typical abrasives applied to buffing wheels, are aluminium oxide or silicon carbide, mixed with water or oil.
Blasting processes apply grit that mostly consists of melting-slag from coal-fired power plants (the use of silica and metal slags generally being prohibited by laws).

* **Waste description**

The primary wastes associated with metal part cleaning and stripping are halogenated and non-halogenated solvents from metal degreasing and machinery maintenance, contaminated water from water and steam degreasing processes (rinse water, acids and alkalies) and blasting grit and abrasives from mechanical surface treatment processes.

- *Halogenated solvent waste*
  In most degreasing processes that use halogenated solvents, the major loss of solvent is caused by air emission. However, when solvents in degreasing baths have build up a certain level of contamination, the contaminated solvent needs to be replaced.
  These solvent wastes consist of solids, such as cuttings and grinding dust, organic components, such as drilling oils, lubricants and stabilizers, and water. Typical halogenated solvents used for metal-degreasing are per- and trichloroethylene and, to a lesser extent, dichloromethane. The widely use of CFC-113 and 1,1,1-trichloroethane will soon be reduced almost completely as their use is prohibited due to their ozone layer depletion potential.

  Dichloromethane is widely used for paint removal by immersion or spraying. Spent immersion baths and spray losses are disposed of as hazardous waste to incineration or to solvent recycling. After dissolving paints in the solvent, the objects are often sprayed clean with water, resulting in paint sludges from the filtration of the water/solvent mixtures.

  Due to stricter regulations for air emissions of solvents, sometimes abatement techniques are applied like activated carbon or synthetic resin absorption filters. Spent filter material constitutes a hazardous waste stream; however, regeneration of solvents and subsequent re-use of filter material can often be applied.

  As frequently mixtures of different halogenated solvents are involved, these wastes become generally difficult to regenerate. Halogenated solvent wastes are regarded as hazardous. In the EU 25 to 50% of halogenated solvent waste is recycled externally; in some countries more than 50% of the waste is incinerated[1].

- *Halogen-free solvent waste*
  Halogen-free solvents are used in paint removal and degreasing. Their wastes contain aliphatic and aromatic solvents, such as alcohols, esters, ketones, acetates and glycols. Most of the wastes are inflammable and irritating.
  A significant part of the solvents is emitted into the air during and after use. Smaller amounts of solvent wastes are regularly emitted into water bodies. In the EU 20 to 35% of halogen-free solvent waste is recycled externally; in some countries more than 65% of the waste is incinerated[2].

1 Euroenviron 1992
2 Euroenviron 1992

- *Contaminated water*
  Contaminated water results from spent alkalic or acids bathes or primary rinsing water. Alkalic baths can contain lyes, silicates, phosphates, borates, tensides, sulfonate and complexing agents (alcoholamines, gluconates, carbonacids and EDTA).
  Rinsing water, the largest volume, can often be discharged directly to the sewer. The major part of the waste alkalic bath is discharged to communal waste water treatment plants after neutralization and passing oil and sludge separators. Alkaline and acid cleaning solutions may be mixed together (neutralizing each other) and treated. Secondary rinse water (if employed) is usually used to replace discarded primary rinse water and/or used as a make-up for cleaning solutions.

- *Blasting grit*
  Blasting grit waste is generated during paint, dirt and rust removal from metal and other surfaces. Blasting grit generally is loaded with 5 to 10% of paint, dirt and rust particles. In a typically dry-blasting process with screening and non-vacuum collection systems, approximately one third of the waste grit will be diffusely lost to the air. The collected residue may be purified and subsequently re-used or stored[1].

  The average waste blasting grit will contain high concentrations of zinc, lead, copper, chromium, nickel and other heavy metals. It will be polluted from tarry substances with PAHs and oily matter.

  Most of blasting grit wastes are disposed of to landfill. External recycling is possible if the particles of the grit are not too small. In that case, organic material, such as paint, tar and oil, can be removed by flotation and gravitation techniques. The grit is then ready for re-use or other useful applications (e.g. drainage material at landfills). The problem that prevents re-use of the purified grit is the higher salt content, as compared to virgin grit.

A.4 METAL SURFACE TREATMENT AND PLATING

* Process description

Surface treatment included in this section are chemical and electrochemical conversion, metallic coating, galvanic processes and heat treating. These are typically batch operations, in which metal objects are dipped into and then removed from baths containing various reagents for achieving the required surface condition. The objects are generally carried on racks or in barrels and moved through a series of baths. In most surface treatment processes rinsing takes place between various baths to avoid drag-in and thus contamination of the next bath. Most of the surface treatment processes start with a pre-treatment. Besides processes like cleaning, degreasing and stripping (as described earlier), typical pretreatment for surface treatment processes, however, are pickling and etching, using acid immersion baths.

Conversion processes include phosphatising, chromatising, anodising and passivation. These processes produce a coating on the metal surface and are performed for corrosion protection or as a preparation for painting by improving the adhesive properties of the surface. Chromatising baths include hexavalent chromium, acids and activating compounds. Anodizing employs electrochemical means to develop a protective oxide film on the object. Passivating takes place in an acid bath containing metals (often chromium, zinc or cadmium) that produce protective films.
Through **metallic coating** the object becomes a composite material of two or more metals. The most applied process is thermic zincking, which takes place by immersion of workpieces into fluid zinc at high temperature.

---

1 Euroenviron 1992

The main **galvanic process** is electroplating[1], in which metals or alloys are deposited on the objects by passing an electric current through a solution containing dissolved metal salts as well as the objects. Major coatings applied are zinc, nickel, copper and chromium; specific applications consist of for example tin, alloys and cadmium. Most electroplating enterprises can be covered by one of the next plating activities:
- only zincking
- nickel-, copper- and chromium-plating
- zinc-, copper-, nickel- and chromium-plating
- various.

Heat treating refers to the heating and cooling of metal objects to change their properties. Discussed below are case hardening and quenching; other heat treating processes, like stress-relief, annealing, austenitizing and tempering do not generate (hazardous) wastes. In these processes, heating is performed in conventional furnaces, salt baths or fluidised-bed furnaces.
Case hardening means introducing carbon or nitrogen into steel by diffusion or absorption. These processes are carried out in gas-phase furnaces or in salt-bath furnaces - the latter being the major source of waste. Salt-baths are used in liquid cyaniding, nitriding and carburizing. After absorbing a sufficient quantity of carbon or nitrogen from the hot molten salt bath, the metal parts are often quenched in oil, water or brine to develop a hard surface layer.

A number of ancillary operations may produce wastes and loss of chemicals as well. These include:
- storage of chemicals
- transfer and handling of chemicals
- discharges from process control laboratories
- disposal of residues and empty chemical containers.

* **Waste description**

Conversion and plating processes produce waste streams like spent process solutions, filter sludges and wastewater treatment sludges. Depending on the kind of surface treatment applied, waste streams can contain chromium, other heavy metals and cyanide. Especially chromium (VI) and cyanide are regarded highly toxic and require additional treatment.

Heat treating processes like stress-relief, annealing, austenitizing and tempering do not generate (hazardous) wastes. Refractory materials (furnace lining) and drag-out loss of the fluidized-bed particles are the only wastes generated. Drag-out loss can be minimised by water spraying. Recovered particles can then be reused after being dried and sieved. Case hardening in liquid media (and subsequent quenching) is the major source of waste, consisting of spent salt (cyanide) baths and spent quenchants.

- *Spent bath solutions*
  A great variety of spent bath solutions from plating and conversion processes are generated. Spent galvanic solutions, like chromium or cadmium cyanide baths, contain high concentrations of metals. Spent conversion solutions contain phosphates and additives, together with the used conversion metals, like zinc, iron or chromate. Spent cleaning solutions may be acidic or alkalic, and may contain organics; heavy metals are usually not present. Some or all of these waste streams may be combined and discharged to a waste water treatment system.

- *Filter sludges*
  Waste removed from plating and chemical conversion baths by the filtering of the solutions, results in filter sludges. The sludges can contain silica, silicides, ash and bath constituents.

---

1 Electro-less plating uses similar steps, but without external electrical energy.

- *Waste water treatment sludges*
  Treatment of plating waste water streams and filter sludges produces hazardous sludge wastes. Heavy polluted waste water sources are the mentioned spent cleaning and plating bath solutions. The largest volume of waste (water) streams arises from rinsing water, due to overflow and to contamination of drag-out that adheres to the objects after they are removed from a bath. Waste water is also produced from spills and leaks and from the wet scrubbing of ventilation exhaust air. The mixed waste water produced may contain a variety of heavy metals and cyanide.

  The typical treatment of these streams is a so-called D.N.D. installation (**D**etoxification - Neutralization - **D**ewatering). Detoxification is applied first if cyanides are present (de-cyanidation by oxidation of cyanide) or chromium (de-chromatation, i.e. reduction of chrome-VI into less toxic chrome-III). Neutralization is required for acids and alkalies, followed by removal of heavy metals by transforming dissolved metal ions in insoluble compounds (mostly hydroxides, formed by adding alkalies) and precipitation of the metalhydroxides as a dilute sludge. This metalhydroxide sludge can be thickened and dewatered in filter or belt presses to around 30% dry solids content. Final water purification may involve ion exchangers to remove heavy metals left in the effluent.

  Surface treatment sludges are regarded as highly hazardous and even acutely toxic, depending on their composition. The sludges can contain up to 30% of metals, such as chromium, cadmium, copper, nickel and zinc and further cyanide, acids, lyes, fluoride. The average value of heavy metal content reported in the Netherlands is 5%, whilst the average production of electroplating sludge is about 40 tonnes per enterprise per annum[1]. In the EU 10 to 20% of this waste is externally recycled; landfilling of the sludges is generally restricted and storage therefore takes place in hazardous waste landfills or waste depositories[2].

- *Spent salt baths*
  The salt baths used in heat treating processes (liquid carburizing, liquid nitriding and liquid cyaniding) undergo an aging process resulting in a decreasing activity of the baths. The spent salt baths are considered hazardous. Oxidation products in cyanide-containing salt baths, that are continuously used in hardening processes described before, deplete the activity of the bath, which than becomes (hazardous) waste. Besides spent salt baths, up to every few years salt pots themselves have to disposed of, due to corrosion from contact with the salt media.
  Typical spent baths contain molten sodium, potassium cyanide, cyanate salts and barium chloride in various concentrations. In addition hazardous waste can be produced at specific hardening processes by source materials required to generate carbon and nitrogen.

- *Spent quenchants*
  Spent quenchants in the form of spent quenching baths and wastewater are being generated by washing the quenched workpieces to remove the remaining quenching media from the workpiece. The type of quenching media and therefore the type of spent quenchants depends on the required quenching rate and can for example contain oil, water and brine. It should be noted that the spent quenchants become hazardous waste when exposed to metal workpieces contaminated with hazardous bath residues. Some spent quenchant can be recycled.

---

1 Mortier 1992
2 Euroenviron 1992

A.5 PAINT APPLICATION

* Process description

The application of paint (coatings) is practised within most fabricated metal industries. Before coating, the surface must be cleaned - as described above. Additionally, conversion layers can be applied to improve adhesion properties.
Different forms of wet painting are spraying, immersion ("dip"), brushing and rolling. For spraying, use is made of spray guns that are manually operated or are automated. Spray guns can be pneumatic or airless (spray under pressure) or can be applied in electrostatic units; in general, airless and electrostatic spraying generate less wastes. Spraying usually takes place in contained workplaces, i.e. a ventilated room or a paint spray booth.
Powder coating forms an alternative to solvent- or waterbased coatings. The process is simple in operation and can be done manually or by highly automated equipment.

* Waste description

Besides waste streams of halogenated and halogen-free spent solvent (cleaning) solutions and paint sludges, wastes consist of empty paint containers and equipment cleaning wastes. Finally, waste from paint application includes leftover paint.

- *Paint sludge*
  Waste paint sludges are mainly generated from overspray during spray painting and by cleaning and paint removal operations. Overspray is captured as paint sludge in spray booths by a water curtain, some coagulants being added to water. Cleaning of paint tools is necessary whenever there is a change of colour.

  Typical spray losses for different painting techniques are:

- pneumatic	30 - 60 %
- airless	20 - 30 %
- hot	40 - 60 %
- electrostatic	5 - 8 %

  The powder coating spray process has the advantage that overspray material can be recycled efficiently so that product utilisation yields are achieved with minimal waste; recycling is difficult, however, when colour changing between workpieces is necessary[1].

  Paints consist of solids and solvents. Some of the pigments contain heavy metals such as lead, chromium, molybdenum, zinc, and cadmium. Water-based paints can be protected against microbial digestion using biocide, such as mercury compounds, chlorinated phenols and formaldehyde. Almost no recycling of paint sludges takes place in the EU.

A.6 VARIOUS

The manufacture of metal product often involves assembling of different parts. Forms of assembling and joining methods are screwing, gluing, shrinking, soldering, welding, and clinching. For soldering several materials are used, mostly consisting of lead, bismuth and tin. Also flux is used for prevention of oxidation and spreading of the solder materials. Except for welding (see discussion under machining operations), these processes produce almost no waste.

After assembling the products are packaged in shrink-wrapping, cardboard, plastic etc. Because of production faults and cutting loss some waste is produced.

---

1 Giddings 1994

Periodically the production sites will be cleaned by sweeping and spraying of water. Sweeping waste contains metal parts, oil, grease, wood chips, absorption grains etc. The spray water is drained off to the sewerage. Mostly oil and sludge is separated before the water is drained off. The collected oil and sludge must be treated as chemical waste.

For maintenance of machines lubricants and system oil has to be replaced. For cleaning polishing cloth is used. Sometimes accumulators, batteries, fuel filters have to be replaced. Most of the used lubricants, oil, polishing cloth etc. have to be treated as chemical waste.

SECTION 13

MANUFACTURE OF METAL PRODUCTS

ANNEX B

PREVENTION OPTIONS

Contents :

Sector	Manufacture of metal products (NACE 28, 29, 33, 34 and 35)
Process	Machining operations
Waste stream	Metal working fluids

Prevention option	**Working fluids management program**
Option No	13-1-1
Type	GOP
Group	1
Description	Service life time of working fluids depends to a certain extent on factors of management with regard to preventive measures and maintenance, like[1]: • training of metal workers and general awareness of the importance of fluids control (see below on the item of economics); • establishing criteria for replacement of fluids (e.g. refractive value, number of hours of operation), accompanied by keeping a registration of fluids use, changes and additions at each machine. The analysis and comparison of the registration provides basic information for improving fluid management; • establishing of procedures for replacement and cleaning; replacement of fluids should preferably be carried out by one person only, equipped with proper tools (e.g. a sump cleaning device to remove chips); before filling with new fluids, the reservoirs, filters and pipes must be cleaned thoroughly; • regular inspection and replacement of seals, gaskets, wipers and filters of the tooling machines; this will minimise contamination of working fluids caused by lubrication oil (tramp oil) of the tooling machines themselves; the recording of lubricating oil consumption will provide helpful information; • regularly fluid testing; a periodic schedule of testing can optimize the replacement frequency of the fluids; depending on the type of fluids and its requirements, tests may involve rather simple measurements of pH, conductivity, dissolved oxygen or solid matter, or may be more complex measurements of specific compounds like biocides or additives.
Remarks	Interesting opportunities are provided by some major suppliers of working fluids that now offer maintenance contracts for the fluids applied.
Economics	These practices include mainly organisational measures, involving low costs. Increasing the lifetime of metal working fluids results in a reduction of costs for waste disposal and for purchase of new fluids; additional savings from management of working fluids are found generally in less machine downtime losses.
Potential	Although these measures can be considered as good-operating practices, the waste prevention potential has been assessed not as low, but as *moderate*, because fluid management is often applied at only a limited level.

1 Main sources are: Higgings 1989, US EPA 1990 and Van Berkel 1991

Sector	Manufacture of metal products (NACE 28, 29, 33, 34 and 35)
Process	Machining operations
Waste stream	Metal working fluids

Prevention option	**Preventive measures**
Option No	13-1-2
Type	GOP
Group	1
Description	Preventive measures to increase service life time of working fluids include: • coverage of sumps to prevent trash contamination (cigarettes, papers, food etc.) of the fluids; • storage of working fluids at the correct temperature conditions; • mobile working fluids reservoir for tooling machines that are only used occassionaly, in order to prevent deterioration of the working fluids; • reduction of drag-out losses with metal scrap and workpieces; loss of oil with metal scrap waste can be prevented by separating the oils from the scrap by chip wringers or, if larger volumes are involved, by centrifuges[1]; • reduction of spilling and spraying losses by placing screens and drip-cups; • optimization of fluids dosage rate and spray direction and coverage on the metal workpieces; • aeration of working fluids to prevent biological deteriorating; e.g. by periodical pumping round of stagnant fluids.
Remarks	
Economics	These practices include low costs. Increasing the lifetime of metal working fluids results in a reduction of costs for waste disposal and for purchase of new fluids; additional savings from management of working fluids are found generally in less machine downtime losses.
Potential	Although these measures can be considered as good-operating practices, the waste prevention potential has been assessed not as low, but as *moderate*, because optimal attention is not often applied yet.

1 If simple drainage of working fluids is applied, the metals chips can contain 6 to 7% working fluids. Centrifuges can minimise the loss of working fluids, while the opportunities and prices paid for recycling of the separated and dried chips, are increased. Investment costs for centrifuges are about ECU 7 000 to 10 000.

Sector	Manufacture of metal products (NACE 28, 29, 33, 34 and 35)
Process	Machining operations
Waste stream	Metal working fluids

Prevention option	**Avoidance of working fluids**
Option No	13-1-3
Type	GOP/TC/IMC
Group	1/3
Description	In general, most effective waste prevention would be achieved if the use of fluids is avoided at all[1]. In some cases, working fluids can be avoided or usage reduced: • If cooling of workpieces and tools is the main objective of using fluids, sometimes air can be used to replace (part of) the fluids[2]. • For production of very small series or only a few workpieces, working fluids need not be necessary sometimes. • When surface quality of the workpieces permits the absence of working fluids. • If high temperature of metal chips has no influence on tooling machine and workpiece.
Remarks	
Economics	In general, no costs will be involved for the good operation practices mentioned.
Potential	The waste prevention potential has been assessed as *low*, as working fluids are in most cases indispensable. If feasible opportunities are possible, like air cooling, these will often be applied already.

1 For this purpose, TNO The Netherlands started research in 1995 on ceramic or coated tooling machines and alternative techniques that need no support of working fluids. Yet, results of this research show that in most cases working fluids are still indispensable.

2 US EPA 1990

Sector	Manufacture of metal products (NACE 28, 29, 33, 34 and 35)
Process	Machining operations
Waste stream	Metal working fluids

Prevention option	**Selection and make-up of working fluids**
Option No	13-1-4
Type	IMC/TC
Group	1
Description	Lifetime and performance of fluids depend on the quality and stability of the selected working fluid. Synthetic oils can sometimes increase significantly lifetime[1], as they offer greater thermal stability, resist oxidation better and are not easily contaminated by tramp oil. Synthetic fluids, however, often are made up of chemicals such as nitrites, phosphates and borates, that are environmentally harmful. A high mineral content of water has a negative effect on fluid performance by deteriorating of emulsions and increasing of corrosion and biological growth. Lifetime is increased if demineralized water is used before it is mixed with the fluids[2].
Remarks	The use of an environment friendly fluid reduces the harmfulness of the waste stream generated. The entire range of potential substances, however, is huge and for many substances little or no information is available. Generally speaking, undesirable groups of substances are considered[3]: nitrosamines (formed from nitrite and secondary/tertiary amines), polycyclic aromatic hydrocarbons (PAHs), chlorinated paraffins and biocides.
Economics	An environmental[4], technical and financial evaluation of different fluids must be established through on-site practical experiments and support of various suppliers, as the possibilities for alternative fluids depend on site-specific requirements. In general, there is little difference in the price of the various fluids. However, working fluid qualities may differ, resulting in generally higher prices for the so-called "long-life" fluids.
Potential	The waste prevention potential sector-wide has been assessed as *low*. This option is of major interest for large enterprises that consume high amounts of working fluids; extensive evaluation of fluids is often not concidered feasible for the large number of small enterprises that use quantities between 10 and 100 kg per year.

1 US EPA 1990
2 US EPA 1990
3 in: Van Berkel 1991
4 According to EU Guideline 91/155, suppliers must provide information on the composition of their products.

Sector	Manufacture of metal products (NACE 28, 29, 33, 34 and 35)
Process	Machining operations
Waste stream	Metal working fluids

Prevention option	**Recycling**
Option No	13-1-5
Type	RC/RU
Group	1
Description	*Proven recycling methods* for separation of tramp oils from water-based fluids are comprised of various physical treatment methods, such as skimming, flocculation, flotation, filtration, centrifugation and ultra-filtration. For removing water-miscible hydraulic oils or emulsified lubricating oils, chemical treatment has to be included, using inorganic or organic emulsion breaking agents. Besides from suppliers of (waste) water treatment systems, recycling systems are often available from (the major) suppliers of metal working fluids as well. On-site regeneration can also be performed by specialised other firms. Metal working fluid recycling can be implemented on a continuous basis in a by-pass system or periodically for each machine that needs an oil-change[1].
Remarks	Re-use and up-grading of oils will be facilitated by segregation of waste streams, including good housekeeping measures and schemes for the separate collection of used oils.
Economics	On-site regeneration is aimed at extending life-time of the fluids, reducing costs for waste disposal and for purchase of new fluids. Tentative investment cost for some methods[2] are: • a sump cleaning device; a relatively simple and practical mobile unit used for siphoning off and cleaning the machine fluid reservoir. The solid particles in the fluid are then filtered out. The fluid can than be re-used or transferred to further treatment. Tentative costs are approximately 3 000 ECU; • an oil wheel; that is a wheel assembled above the fluid reservoir on the tooling machine, separating the oil that floats on the top of the metal working fluid; tentative costs are approximately 500 ECU; • centrifuges remove suspended matter in the metal working fluid as well as oils; costs are 10 000 ECU and more; • ultrafiltration-units provide high removal efficiency for oils and suspended matter; costs are 10 000 ECU for small units (.. m^3/h) and upwards for larger sizes; • integrated systems are advanced systems including filtration, oil separation, sterilization and concentration adjustment; costs are from 50 000 ECU upwards. In this example, an investment in several oil wheels and a centrifuge (approximately 15 000 ECU in total) would have a pay-back time of four years if a reduction of the use of fluids of 50% could be achieved.
Potential	For large enterprises with high consumption rates of working fluids, recycling of fluids is a feasible option, significantly reducing this waste stream. It is estimated that most enterprises have not yet optimized the opportunities for recycling. Therefore, the waste prevention potential has been assessed as *moderate to high.*

1 Metal working fluids recovery can be integrated part of (automatic) metal chip transportation and processing systems. Metal chips together with the fluids are transported by piping systems, conveyers or manually to, for example, a shredder and centrifuge. Here, chips are separated, dried and stored for external recycling, while the fluids can be reclaimed as described.

2 Van Berkel 1991

Sector	Manufacture of metal products (NACE 28, 29, 33, 34 and 35)
Process	Machining operations
Waste stream	Metal scrap

Prevention option	**Management/organization**
Option No	13-1-6
Type	GOP/TC
Group	1/2
Description	Prevention of scrap by management and organization involves the following possibilities: • "design for recycling", i.e. designing products taking into account a minimization of scrap produced; • optimization of 'nesting' (the positioning of workpieces on sheet metal) by organization measures[1] and/or computer aided design (CAD); • automation and standardization of production; • planned purchasing of metal.
Remarks	The possibilities of automation and standardization depend largely on the diversity of workpieces handled. A large part of metal scrap wastes consists of chips. Chips can be shreddered and cleaned from adhering working fluids in order to improve opportunities for recycling (see also option 13-1-5). Separated storage of various types of metal scrap wastes further facilitates external recycling. Despite the good recycling possibilities, however, reducing the amount of metal scrap is desirable for environmental reasons as reprocessing scrap costs energy and produces slag wastes and air emissions.
Economics	Costs vary from low cost organizational measures to high cost investments in computer aided design and automation.
Potential	The waste prevention potential has been assessed as *low to moderate.* The possible prevention of scrap metal is estimated[2] in the Netherlands as 5 to 10%. For most sectors however, the prevention potential of iron scrap is relatively low, because a high degree of automation and management has been reached already. Examples are the production of bolts and screws. The prevention potential of non ferrous scrap is lower (0 to 5%) than ferrous, as minimising waste is applied sooner, considering the high costs of materials.

1 A successful example of metal scrap management concerned a re-organisation of nesting operations. Originally, nesting preparation was performed centrally at a planning office. When this nesting was transferred to the operators in the machining process itself. a better utilization of sheet metal was the result, as these workers had a good overview of the sheet metal remnants.
Detailed information is to be found in: Van Berkel 1991.

2 Loos. 1992

Sector	Manufacture of metal products (NACE 28, 29, 33, 34 and 35)
Process	Cleaning and stripping
Waste stream	Halogenated and halogen-free solvent wastes

Prevention option	**Avoidance of cleaning**[1]
Option No	13-2-1
Type	GOP
Group	1
Description	The first step in reduction of solvent use (and subsequent emissions and wastes) is analysing the necessity of cleaning and/or the required level of cleanliness. *Examples*: • If greasy raw material is degreased only prior to further processing, non-greasy raw materials sometimes are available. Other requirements put on raw metal materials may be the protective layers applied (often for corrosion protection). If different types of lubricants are available, those that are removed most easily should be selected. • Sometimes cleaning can be avoided between process steps. • Finally, the final cleaning step can be avoided as well, if cleaning has only cosmetic purposes or if the client self starts its process with a cleaning step.
Remarks	Although the question of the necessity of cleaning seems rather obvious, in various cases cleaning steps did prove to be unnecessary in the end.
Economics	Avoidance of cleaning generally involves no extra costs, while savings are obtained from less use of labor and degreasing chemicals and less waste streams produced.
Potential	Although in various cases cleaning can be avoided, sector-wide the waste prevention potential has been assessed as *low*.

1 Various detailed information on waste and emission reduction of solvents in metal-degreasing is to be found in, for example: CEC 1992, UNEP 1991, Ellis 1990, Chem Systems 1989, Glas 1989 and Higgins 1989.

Sector	Manufacture of metal products (NACE 28, 29, 33, 34 and 35)
Process	Cleaning and stripping
Waste stream	Halogenated and halogen-free solvent wastes

Prevention option	**Minimizing vapour losses**[1]
Option No	13-2-2
Type	GOP
Group	1
Description	Reducing evaporation loss (air emission) out of degreasing equipment (immersion baths or vapour degreasers), will indirectly prevent waste production by better maintaining the composition of the solvents, thus reducing the need of replacement and disposal of residues. *Proven good operation measures* to reduce vapour losses are[2]: • apply covers and lids on tanks; lids should be placed on tanks when not in use; they should preferably slide open and close horizontally in order to prevent disturbance of the vapour zone above the solvent; 'closed' equipment is available that can be operated covered; • increase freeboard space; the freeboard is the distance between the top of the vapor zone and the top of the tank; to prevent vapour loss, US EPA recommends heights of 75 to 100% of the width of the tank; • addition of a freeboard chiller; besides the condensor coils that are normally installed in vapour degreasers, extra chillers can be placed above the vapour zone, providing a second barrier for vapour loss; • drag-out reduction; the speed of withdrawal of an object should be slow in order to prevent turbulence of vapour and subsequent loss; in addition, the cross-sectional area of the object should not exceed approx. 50% of the tank's open area, in order to prevent suction of vapour ("piston effect"); • no solvent sprays above the vapour zone.
Remarks	
Economics	Some measures involve little or no costs; construction costs for increase of freeboard space or additional chillers are compensated by reduced costs for purchase of solvents.
Potential	The prevention potential regarding waste has been assessed as *low*, because waste reduction is an indirect consequence of these measures; direct effects are principally the reduction of emissions into air.

1 Various detailed information on waste and emission reduction of solvents in metal-degreasing is to be found in, for example: CEC 1992, UNEP 1991, Ellis 1990, Chem Systems 1989, Glas 1989 and Higgins 1989.

2 US EPA 1990

Sector	Manufacture of metal products (NACE 28, 29, 33, 34 and 35)
Process	Cleaning and stripping
Waste stream	Halogenated and halogen-free solvent wastes

Prevention option	**Maintaining solvent quality**
Option No	13-2-3
Type	GOP
Group	1
Description	Halogenated solvents contain chemical stabilizers to neutralize and prevent acid formation[1]. If a solvent is close to "going acid", new stabilizers might be added to increase the lifetime of the solvent bath. Water contamination, sludge formation and other solvents can lead to the mentioned acid formation and to a reduction of cleaning efficiency. To minimise water contamination, regular check and cleaning of the water/solvent separator that is installed on vapour degreasers is necessary, as well as checking of leakage of parts. Sludge that collects in the bottom in the tank should always be removed promptly.
Remarks	Regular solvent (pH) testing is required for monitoring the quality of the bath content.
Economics	Generally low costs measures.
Potential	These good-operation practices are effective for increasing bath lifetime and will therefore often be applied already. Therefore, the prevention potential has been estimated as *low*.

1 US EPA 1990

Sector	Manufacture of metal products (NACE 28, 29, 33, 34 and 35)
Process	Cleaning and stripping
Waste stream	Halogenated and halogen-free solvent wastes

Prevention option	**Alkalic degreasing**
Option No	13-2-4
Type	TC/IMC
Group	1/2
Description	Liquid halogenated and halogen-free solvent wastes (and emissions into air) from metal degreasing can be avoided by switching to water based alkalic systems[1]. An aqueous cleaning system generally consists of various immersion baths, of which the last ones are for rinsing. Cleaning and rinsing can be improved by increasing temperature, mixing, ultra-sonic support and/or by spraying. After final rinsing, objects have to be dried. In most of the cases drying can be performed simply by air; final rinsing with hot water, however, reduces drying time significantly - as does the use of air-knives and fans. If a brilliant clean metal surface is required, final rinsing should be performed with demineralized water. For special applications, various drying techniques are available, like absorption in rotating mais drums, immersion in water-immiscible solvents (like toluene), vapour-drying using iso-propanol, vacuum-ovens and centrifuges. Finally, for discharge into the sewer of the waste water stream, most water boards will require pH neutralization and removal of dirt and particles as well as bio-degradability of detergents used. Waste (water) prevention methods are discussed under options 13-2-7 and 13-2-8.
Remarks	In only few cases, water based degreasing may not be possible. Resistance from end customers and specifiers is a special problem for an affective switch to water-based systems. Many end customers require specific performance standards, for example in the aircraft industry. However, in most cases alkalic cleaning results in better cleaning performance than solvent-based cleaning.
Economics	For small and medium-sized enterprises a change-over from already existing vapour degreasing equipment to a new alkalic cleaning system is often difficult due to relatively high investment costs. Operational costs of water based systems are, however, generally lower than of solvent based systems due to the much lower purchasing costs of alkaline degreasers and the much lower waste disposal costs.
Potential	The prevention potential has been assessed as *high*.

1 Although only alkalic degreasing is mentioned, other water-based cleaning, like neutral or acidic, can constitute an efficient alternative as well. Alkalic cleaners are, however, generally employed to remove organic contaminants from surfaces (degreasing); acid cleaners are used to remove oxidation, scale and rust. Basically, a wide variety of chemicals are available and should be evaluated when a switch is considered. It is adviced to request various suppliers of chemicals as well as of equipment.

Sector	Manufacture of metal products (NACE 28, 29, 33, 34 and 35)
Process	Cleaning and stripping
Waste stream	Halogenated and halogen-free solvent wastes

Prevention option	**Alternative paint removal techniques**[1]
Option No	13-2-5
Type	TC/IMC
Group	2/3
Description	For paint removal, instead of using solvents, the following technique is considered most promising: • mechanical paint removal, using plastic grit ("plastic media blasting": PMB)[2] • water-based (hot) alkalic paint removal; this technique is commercially practiced and equipment is available; however, applications are limited to steel only, while many coatings, e.g. epoxies, are alkalic resistant. Alternatives that have limited applications, are[3]: • use of a coating softener and then blasting with high pressure water[4] • water jet blasting[5] • cryogenic paint removal by immersion in liquid nitrogen and subsequent milling; this system is not suitable for large scale operations (see also option 13-2-10) • dry-ice (solid CO_2) blasting; questions are still concerned about costs, possible damage of surfaces and effectiveness • laser or flash-lamp paint stripping; still in experimental stage and considered very expensive • salt-bath stripping • pyrolytic paints removal • fluidised sand bed.
Remarks	Most options have disadvantages like noise production, slow or less effective. Implementation requires new equipment and facilities. It is foreseen that the use of dichloromethane (methylenechloride) for paint removal might be restricted by emission limitations by European and/or national legislation.
Economics	With the exception of PMB stripping and alkalic paint removal, the options mentioned are generally more expensive than the use of solvents.
Potential	Taken into account the disadvantages of many options, the prevention potential has been estimated as *low*.

1 Option No. 19-2-10 on prevention of blasting grit is related to this issue as well.
2 Higgins 1989, provides extensive information of the application of PMB.
3 Euroenviron 1993, Giddings 1994, Elzenga 1994 and Higgins 1989.
4 Giddings 1994; according to this source, this method is used in Germany as legislation precludes the use of conventional coating strippers.
5 According to Euroenviron: Plastic grit: Schlick, Germany and LAB, France; sand or water-jet blasting: Lufthansa, Germany.

Sector	Manufacture of metal products (NACE 28, 29, 33, 34 and 35)
Process	Cleaning and stripping
Waste stream	Halogenated and halogen-free solvent wastes

Prevention option	**Recycling of solvents**
Option No	13-2-6
Type	RU/RC
Group	1/2
Description	Methods for recovering of solvents from wastes are distillation processes, such as vacuum distillation or thin-film evaporation. With such systems solvent bath life time of more than two years may be achieved without the need to replace the solvent. *Batch-type distillation units* are commercially available in ranges from 20 to 200 litre units. Commercial *continuous-feed distillation* equipment is available for large volumes of contaminated solvents waste production. Since distillation removes most stabilizers and other additives of solvents (if present), these chemicals need to be added again if the same usage of the solvent is required. Good housekeeping measures facilitate solvent recovery: • keep different solvents separated • mimimise solids for efficient solvent reclamation • control solvent concentration (to be maintain above 40%) • label waste and specify its origin.
Remarks	In-house recycling of halogenated solvents is often possible for larger units[1] For small quantities, off-site reclamation is well suited.
Economics	Initial investment ranges from 2 000 ECU for a 20-litre batch distillation unit to more than 20 000 ECU for a 200-litre unit[2]. Benefits are related to lower solvent purchase costs and reduced hazardous waste management expenses.
Potential	For large enterprises with high consumption rates of solvents, recycling is a feasible and economically attractive option, that reduces this waste stream significantly. It is estimated that most of these larger enterprises do not operate on-site distillation. Therefore, the waste prevention potential has been assessed as *high*.

1 In literature (US EPA 1990) is indicated that recycling is economical when at least 10 m^3 solvent is generated per year.
2 US EPA reference included in sector report 16, option 16-3.

Sector	Manufacture of metal products (NACE 28, 29, 33, 34 and 35)
Process	Cleaning and stripping
Waste stream	Contaminated water

Prevention option	**Optimised rinsing**
Option No	13-2-7
Type	GOP
Group	1
Description	Drag-out of cleaning solution from the cleaning bath into the rinsing baths, will increase the use rate of rinsing water. Reduction of drag-out losses can be achieved by: • reducing speed of withdrawal of the workpiece from the baths; • allowing ample drainage time for the workpieces withdrawn form the baths; • proper positioning of the workpieces on the plating rack, allowing maximum drainage. The volume of consumed rinse water can be further reduced by implementing various types of proven measures: • installation of flow meters, allowing to identify priorities for prevention at individual sources; • determination by trial of the minimum required rinse water quantities for each operation; • installation of flow restrictors to keep the flowrate constant and permitting only supervisors to make changes; • improvement of rinsing efficiency by supporting the rinse stage with: air agitation or agitation by mechanical, hydraulic or ultrasonic methods; agitation of the workpieces; raising the water temperature; water supplementation at the bottom of the rinse tank; application of spray rinsing; • using one or more intermediate static rinse baths in sequence before the final flow rinsing tank; the static rinse tanks can in addition be used to supplement the preceding cleaning bath; • multiple rinsing and/or replacing flow rinse tanks by a counter-current rinse water cascade, where the water flows in the opposite direction of the workpieces; • ensuring complete mixing of the rinse water within the rinse tank.
Remarks	These options are as well applicable for plating wastes.
Economics	Generally low costs measures.
Potential	It is estimated that these good-operation practices are not applied extensively in industry; therefore, the prevention potential has been estimated as *moderate.*

Sector	Manufacture of metal products (NACE 28, 29, 33, 34 and 35)
Process	Cleaning and stripping
Waste stream	Contaminated water

Prevention option	**Biological degreasing**
Option No	13-2-8
Type	TC/IMC
Group	3
Description	Biological degreasing in combination with a closed rinse water system can replace conventional alkalic degreasing processes[1]. In this case study, the biological system was to replace alkalic hot degreasing that was the first step of a pretreatment system in electroplating industry. The patented system consists of the following steps: • washing in an aqueous solution of tensides, in order to dissolve oil, grease and other contaminants • separation of the washing liquid from the metal objects • nutrient salts are added to the separated washing liquid to activate micro-organisms • organic matter is degraded by the micro-organisms • re-use of the tenside washing liquid. The second step in the pretreatment process involves pickling. In combination with biological degreasing, the consumption of acids in the pickling bath is reduced significantly. The method is called activated oxide scale dissolving, and is patented.
Remarks	The process is commercially available and around 25 facilities of biological degreasing have been installed at different Scandinavian hot dip galvanising companies[2]; literature reports, however, still some technical constraints observed by some companies and professionals.
Economics	For this case study, the total investment costs for new equipment and a changed piping system was USD 422 000 (1990). If new piping is not required, investment may be 50% lower. Savings in running costs are less water and chemical consumption and less handling. In this case, the payback time was about 5.5 years.
Potential	Waste hydroxide sludge reduction was about 50% (30 tons sludge before, 15 tons after), while water use was reduced with 90%. The prevention potential can not be estimated, as further information on implementation and possible constraints is not reported.

1 Braber, 1994 (case study also published in the UNEP IE document "Cleaner Production Worldwide", Volume II). Industry/program contact and adress: Lars Siljebratt, TEM University of Lund, Sjöbo, Sweden.

2 Braber 1994.

Sector	Manufacture of metal products (NACE 28, 29, 33, 34 and 35)
Process	Cleaning and stripping
Waste stream	Blasting grit

Prevention option	**Improved collection efficiency**
Option No	13-2-9
Type	GOP
Group	1
Description	To improve collection efficiency of rebound blasting grit, the addition of small amounts of water to the grit may prove useful.
Remarks	-
Economics	Low cost measure.
Potential	As this involves a simple measure that can be applied easily, implementation - when possible - can be expected at a high degree. The prevention potential has therefore been assessed as *low*.

Sector	Manufacture of metal products (NACE 28, 29, 33, 34 and 35)
Process	Cleaning and stripping
Waste stream	Blasting grit

Prevention option	**Alternative methods and technologies**[1]
Option No	13-2-10
Type	TC
Group	2/3
Description	*Alternative methods and technologies* are: • Basically, the old method of manual de-rusting and paint removal by scrubbing yields only the material removed as waste. • Mechanical paint removal, using plastic grit ("plastic media blasting": PMB)[2]. *On-going and planned R&D*, shortly mentioned in literature[3], are directed to alternative technology like: • hydrojetting; the use of hydrojet blasting, when applicable, will replace the problem of grit pollution by the easier-to-handle problem of water pollution. Small quantities of grit added to the hydrojet will improve cleaning efficiency and the range of applicability. • cryogenic paint removal[4]; this system is not suitable for large scale operations • dry-ice (solid CO_2) blasting; questions are still concerned about costs, possible damage of surfaces and effectiveness • laser or flash-lamp paint stripping; still in experimental stage and considered to be very expensive • salt-bath stripping • pyrolytic paint removal • fluidised sand bed • sustainable coating systems • use of wet, vacuum or mobile cast-blasting.
Remarks	
Economics	Manual de-rusting will generally be too expensive to be feasible, due to the high labour input. Plastic media blasting can give substantial savings, by near-elimination of pollution and toxic wastes.
Potential	Considering the economical and technical constraints of most alternatives, the prevention potential has been estimated as *low*.

1 Option No. 13-2-5 on prevention of solvents for paint stripping is related to this issue as well.

2 Higgins 1989, provides extensive information of the application of PMB.

3 Most options mentioned here are equally shortly presented in: Euroenviron, 1992. The general references named by Euroenviron are Lufthansa. Germany; Sliperi Mekaniske Verksted, Norway and Schlick, Germany.

4 UNEP IE 1995, ENEA: This case study reports on a cryogenic process for paint removal from steel structures, using liquid nitrogen instead of acids or pyrolithic ovens. Objects to be treated are placed in a tank containing liquid nitrogen (- 196 °C). Due to the different contraction of steel and paint coat, the paint cracks and can be removed by mechanical action. The solid waste that is produced can be recovered and utilized to produce plastic objects. The plant (capacity 2 500 kg/h of objects to be treated) has been fully implemented and in operation since 1990.

Sector	Manufacture of metal products (NACE 28, 29, 33, 34 and 35)
Process	Metal surface treatment and plating
Waste stream	Plating wastes

Prevention option	**Good housekeeping**[1]
Option No	13-3-1
Type	GOP
Group	1
Description	Examples of good operation practices are discussed below. The life time of baths can be prolonged by protecting the baths from contamination. The main source of external contamination is the drag-out from preceding operations. The amount of drag-out depends on various factors and can be reduced by: • reducing the speed of withdrawal of the workpiece from the baths; • allowing ample drainage time for the workpieces withdrawn form the baths; • the use of surfactants, reducing the surface tension of the plating solution that therefore adheres less on the workpieces; • lowering the concentrations of plating bath constituents, resulting in a reduced amount of hazardous substances dragged out as well as in a reduced volume due to the lower viscosity of the plating solution; • proper positioning of the workpieces on the plating rack, allowing maximum drainage. In addition to the contamination by drag-out losses, the lifetime of baths is limited by the accumulation of other impurities. These impurities can be caused by the racks, anodes, water make-up and the air. Hence, the lifetime can be prolonged by: • cleaning the racks prior to operation • using purer metal for anodes • periodic filtering of the bath solution • installing lids on the baths to protect them against depositions from the air. Recovery of electroplating valuables[2] is facilitated by the reduction of the amount of water used for washing and rinsing. Further, in-plant separation of waste water streams will facilitate the production of mono sludges (sludge containing only one metal compound). Finally, good housekeeping measures should be implemented to avoid accidants, spills and the generation of contaminated effluents.
Remarks	-
Economics	Low cost measures.
Potential	The prevention potential has been estimated as *low to moderate*.

1 Much information on plating waste reduction is available; main sources for this section are: Higgins 1989; UNEP 1989; US EPA 1990; US EPA 1992b; Euroenviron 1993; Mortier 1992 and a great number of UNEP IE case studies.

2 The internal recycling will reduce the value of the sludges that in some cases may be externally recycled. So the economy of internal recycling will be influenced by the degree to which valuables can be recovered.

Sector	Manufacture of metal products (NACE 28, 29, 33, 34 and 35)
Process	Metal surface treatment and plating
Waste stream	Plating wastes

Prevention option	**Reduction of rinse water consumption**[1]
Option No	13-3-2
Type	GOP/TC
Group	1
Description	The volume of consumed rinse water can be reduced by implementing various types of measures: • installation of flow meters, allowing to identify the priority for waste prevention at individual sources; • determination of the minimum required rinse water for a specific operation by a trial and error method; • installation of flow restrictors to keep the flowrate constant and permitting only supervisors to make changes; • improvement of rinsing efficiency by supporting the rinse stage with: air agitation or agitation by mechanical, hydraulic or ultrasonic methods; agitation of the workpieces; raising the water temperature; water supplementation at the bottom of the rinse tank; application of spray rinsing; • using one or more intermediate static rinse baths in sequence before the final flow rinsing tank; the static rinse tanks can in addition be used to supplement the bath from the preceding operation; • replacing flow rinse tanks by a counter-current rinse water cascade, where the water flows in the opposite direction of the workpieces; • ensuring complete mixing of the rinse water within the rinse tank; • application of reactive rinsing, where the rinsewater from one operation is used as the source for another (e.g. rinsewater following chloride zinc plating may be used for the hydrochloric acid rinse preceding the zinc plating).
Remarks	Decreasing rinse water consumption without reduction in drag-out losses may result in a smaller, but more toxic, volume of waste water.
Economics	Installing counter-current rinsing systems may amount to considerable costs; however, significant benefits are obtained from savings in water supply charges and effluent disposal charges[2]. Most other measures involve minor costs.
Potential	It is estimated that these good-operation practices are not applied extensively in industry; therefore, the prevention potential has been estimated as *moderate*.

1 Much information on plating waste reduction is available; main sources for this section are: Higgins 1989; UNEP 1989; US EPA 1990; US EPA 1992b; Euroenviron 1993; Mortier 1992 and a great number of UNEP IE case studies.

2 Goldrite, 1996. In this case study, countercurrent rinsing replaced conventional dip-tank rinsing. The water use decreased from 25.5 m^3/day to 7.3 m^3/day, an annual saving of 4 730 m^3 (payback time less than 5 years).

Sector	Manufacture of metal products (NACE 28, 29, 33, 34 and 35)
Process	Metal surface treatment and plating
Waste stream	Plating wastes

Prevention option	**Alter bath composition**[1]
Option No	13-3-3
Type	IMC
Group	1/2
Description	The hazardous chemicals in plating baths (especially cyanide, cadmium and chromium-VI) can sometimes be replaced by less toxic substances. Some of the *common replacements* are mentioned below: • replacement of cyanide plating solutions by cyanide-free or low-cyanide solutions; this replacement has especially been successful in zinc plating (cyanide-free, alkalic plating)[2]; • replacement of cadmium plating solutions[3]; the development of highly corrosion-resistant zinc plating has virtually eliminated the necessity to use cadmium, except for special applications; for some uses aluminium coatings can also be employed[4]; • replacement of hexavalent chromium by trivalent chromium[5]; trivalent chromium systems are considerably less toxic than hexavalent chromium systems and in addition require lower concentrations of chromium metal, rinses more freely and permits simpler waste treatment facilities; trivalent chromium systems can successfully replace hexavalent ones for decorative chrome applications but are unsuitable for hard chrome applications.
Remarks	As the selection of alternative chemicals for individual processes requires chemical knowledge and experience, this must be supported with information from the industry and professional associations.
Economics	The case study of alkalic zincking shows annual savings of about 85 000 ECU due to savings in chemicals for detoxification (no detoxification required anymore) and reduced hazardous waste management costs (less waste water sludge produced). In general, case studies report savings on operational costs, against low investment costs.
Potential	It is estimated that some alternatives are not applied extensively in industry; therefore, the prevention potential has been estimated as *moderate*.

1 Much information on plating waste reduction is available; main sources for this section are: Higgins 1989; UNEP 1989; US EPA 1990; US EPA 1992b; Euroenviron 1993; Mortier 1992 and a great number of UNEP IE case studies.

2 Koppert 1991. In this case study, a cyanide bath was replaced by an alkalic bath. Products are of high quality, while more types of steel can be processed and less process time is required. As zinc bath concentration can be much lower than with cyanide zincking (12 g/l instead of 30 g/l), drag-out losses of zinc are reduced consequently.

3 For example: UNEP IE, 1995 - case study at Elkhart Products, Inc. Elkhart fabricates pipe fittings and replaced its cyanide dip and chromic acid bright dip passivation with a process that utilizes sulfuric acid and stabilized hydrogen peroxide; the company also installed counter-current rinsing and copper-sulfate precipitating, followed by electrolysis for reclamation of copper scrap.

4 For example: UNEP IE 1995, DOCNO: 400-125-A-332; case-study for use of aluminium instead of cadmium as the plating metal; a thin layer of nickel is initially deposited on ferrous and aluminium die casting materials. The pieces are dried and aluminium layer is applied to the nickel coating in an electrolytic cell. Operating costs are reduced due to elimination of cadmium and cyanide sludge.

5 For example the following case studies:
UNEP IE 1995, DOCNO 10-01; case study 1985: replacement was accompanied by addition of specially developed organic compounds; special membranes were used to protect anodes from oxidizing to hexavalent chromium; product quality was improved due to better coverage and uniform plating.
UNEP IE 1995, DOCNO 400-126-A-333; case study: conventional blue passivating process for chromating of zinc coatings was performed using trivalent chromium and hydrogenperoxide, which dissolves little zinc; the bath can be replenished with concentrate and reused.

Sector	Manufacture of metal products (NACE 28, 29, 33, 34 and 35)
Process	Metal surface treatment and plating
Waste stream	Plating wastes

Prevention option	**Alternative technology**[1]
Option No	13-3-4
Type	TC
Group	2
Description	Certain processes can offer an alternative to electro- and electroless plating. Alternative processes are[2]: • hot dipping of tin and other metals in which the workpiece is immersed in a molten metal bath; • chemical vapour deposition, which is the gas-phase analog of electroless plating; vacuum coating, where the evaporated atoms impringing on the workpiece are condensed to a solid phase; • mechanical cladding and coating where mechanical techniques are used to force the coating material into contact with the workpiece under high pressure, resulting in thick coatings; • metal powder coatings, where ductile materials can be coated on the workpieces by cold welding techniques. A *proven method*[3] is the modification of traditional steel immersion in molten zinc baths: • In this case study, the original galvanising method involved chemical pretreatment of steel, followed by immersion in gas-fired baths of molten zinc at 450 °C. In the new system, steel is shot blasted and then heated by induction. The zinc is melted in an inert atmosphere by an electric furnace and flows into the galvanising unit. The liquid zinc is held in suspension by an electromagnetic field. This technoloy eliminates conventional plating waste, requires less zinc, improves product quality and reduces labour requirements. Alternative prevention technologies that are applied in some cases are[4]: • alternative pickling; spent pickling solutions from thermal zinc plating may be partially avoided by using other cleansing procedures, such as pickling with other acids than hydrochloric acid, lasting or continuous pickling. The life-time of pickling solutions may be further increased by separating of the de-zincking and pickling processes; • vacuum-plating, e.g. with aluminium instead of cadmium; • vacuum plasma-spraying with titanium nitride to replace chromium hardening.
Remarks	
Economics	Payback time of the alternative induction heating zinc process is three years when replacing an existing plant. No information on costs of other techniques mentioned has been compiled.
Potential	Most of these alternatives are only applied in very few cases; nevertheless, the prevention potential has been estimated as *low*, as information on the technical and economical feasibility is scarce, the potential of sector-wide introduction of these methods cannot be assessed properly.

1 Much information on plating waste reduction is available; main sources for this section are: Higgins 1989; UNEP 1989; US EPA 1990; US EPA 1992b; Euroenviron 1993; Mortier 1992 and a great number of UNEP IE case studies.

2 US EPA 1992

3 UNEP IE 1995, Delot Process SA.

4 Euroenviron 1993

Sector	Manufacture of metal products (NACE 28, 29, 33, 34 and 35)
Process	Metal surface treatment and plating
Waste stream	Plating wastes

Prevention option	**Regeneration of baths**[1]
Option No	13-3-5
Type	RU/RC
Group	1/2/3
Description	Spent bath solutions can be regenerated and recycled; available methods are, e.g.: • removing pollutants by the use of ion exchange resins and recycling the bath and rinsing waters[2]. Used ion exchangers may be regenerated within the enterprise itself; however, systems have been organized in some countries to supply fresh and collect loaded ion exchangers and treat them in central installations; • evaporation of plating baths and rinse waters; the remaining concentrated solution can sometimes be returned to the plating process, while evaporated water can be condensed and used as distilled water[3]; • electrodialysis, a technique combining electrolysis, ion exchanging membranes and osmosis to upgrade salt solutions, thus recovering silver, copper, nickel and zinc salts; this is applied only in some larger installations[4]; • electro-electrodialysis, i.e. an electrodialysis membrane between two electrodes, allowing regeneration of used acids and recovery of metal ions in separate compartments, is applied for the regeneration of chrome electrolytes[5]; • electrolysis is used to regenerate washing baths[6], to recover metals, and to destroy cyanide and complex-forming agents such as EDTA.
Remarks	
Economics	Recycling is economically attractive, especially for high-valued metals; lead and zinc are generally not recycled due to their low value.
Potential	As various techniques have evolved and have become economically more attractive, the prevention potential has been estimated as *moderate*.

1 Much information on plating waste reduction is available; main sources for this section are: Higgins 1989; UNEP 1989; US EPA 1990; US EPA 1992b; Euroenviron 1993; Mortier 1992 and a great number of UNEP IE case studies.

2 For example:
UNEP IE 1995, Modine Manufacturing. Case study on ion exchange and electrolysis for recovery of copper by continuously recirculating bright dip solution through the ion exchange column; the saturated column is regenerated and the copper solution is fed into an elctroplating cell where copper is recovered as scrap. The payback time of the system was 14 months.
UNEP IE 1995, DOCNO 450-003-A-348. Case study on two-step ion-exchange to recover chromic acid from rinse water. The cation and anion resins are regenerated with sulfuric acid and sodium hydroxide, respectively, to recover 2 300 kg/y concentrated chromic acid for reuse.

3 For example: Goldrite 1996 and Electroless Hard Coat SA 1993.
Goldrite applied an atmospheric pressure evaporator of simple and robust construction (investment approx. 20 000 ECU); recovery and re-use of plating chemicals has resulted in 60% saving on chemicals and a payback time of less than 2 years.
Electroless Hard Coat employed an evaporation process consisting of a pressurized electric heating pump; a cooling system condenses steam, resulting in distilled water for reuse; a 90% waste sludge reduction was achieved; the payback time was 2.4 years.

4 In Euroenviron 1993: this application needs special care (e.g. Legrand and Bohin, France); total in-process chrome recycling was shown to be technically and economically viable under certain conditions (Fichtel & Sachs, Germany).
UNEP IE 1995, Egidius Jansen: case study on membrane electrolysis for recovery of 5 000 kg/y nickel (value: 50 000 ECU/y), requiring investment of 335 000 ECU, with additional savings on reduction of waste sludge production.
ENEP IE 1995, DOCNO 400-100-A-323: case study on recovery of copper in rinse water with electrodialysis; volumes of waste sludge were reduced with 90%, combined with savings on energy and raw materials.

5 In Euroenviron 1993: further studies on membranes are performed (Snias, France).

6 For example: Outokumpu 1995. Zinc and copper are removed from a pickling bath used in the production of copper strips. The recovery unit consist of groups of two anodes with a rotating disc in between. Zinc and coppper are deposited on the rotating disc and scraped continuously away into containers for recycling. Disposal of 135 m^3/y pickling waste could be prevented at investment costs of about 105 000 ECU.

Sector	Manufacture of metal products (NACE 28, 29, 33, 34 and 35)
Process	Metal surface treatment and plating
Waste stream	Heat treating wastes: spent salt baths

Prevention option	**Preventive measures**
Option No	13-3-6
Type	GOP/TC
Group	1
Description	The life time of salt baths can be increased by avoiding contamination of the baths and prevention of spills; this can be achieved by changing operation practises like[1]: • cleaning the workpieces prior to the hardening process. The workpieces normally contain impurities like scale, oxide, entrapped sand etc., that adversely affect the life time of the baths; • closing lids and using covers to prevent the baths against deposition of contaminations from the atmosphere. In addition, covers of graphite should be used to protect baths containing cyanide against exposure to carbondioxide, resulting in a bath contamination with carbomate; • using dry workpieces will avoid spattering of the salt baths during the contact with the workpieces; • reduction of drag-out, referring to the excess media that adheres to the workpieces, by using racks instead of trays, reducing the speed of withdrawal and a proper position of the workpieces on the rack allowing maximum runoff; • periodic purification of the salt baths will prolong the life time of the baths; purification can be achieved by cooling the bath and allowing the precipitated salt to settle at the bottom of the salt pot, thus removing the main oxidation products (carbomate).
Remarks	In addition to a prolonged life time of the salt baths the prevention measures will also increase the life time of the pot, which undergoes corrosion by the salt media.
Economics	The literature available provides no details on costs and revenues of the preventive measures. Due to the type of preventive measures, however, the costs are considered to be low.
Potential	The waste prevention potential has been assessed as *low*.

1 US EPA 1992a

Sector	Manufacture of metal products (NACE 28, 29, 33, 34 and 35)
Process	Metal surface treatment and plating
Waste stream	Heat treating wastes: spent salt baths

Prevention option	**Alter bath composition**
Option No	13-3-7
Type	IMC
Group	2
Description	For liquid carburizing and nitriding processes, the typicial concentrations of sodium or potassium cyanides of 30% wt and higher in the baths can be reduced[1]. Reduction can be achieved by using non-cyanide baths containing a special grade of carbon instead of cyanide. Another low-cyanide alternative is using organic polymers for bath regeneration. When water quenching is employed, the low level of cyanide permits easier detoxification. Alternatively, quenching inta a caustic-nitrate salt bath may be used for cyanide/cyanate destruction.
Remarks	Parts that are slowly cooled following noncyanide carburization are more easily machined than parts slowly cooled following cyanide carburization.
Economics	The increased cost of detoxifying cyanide-containing effluents has led to the development of low-cyanide salt baths for nitrocarburizing treatments. No detailed information on costs and revenues is provided in the literature available.
Potential	The waste prevention potential has been assessed as *low*.

1 US EPA 1992a

Sector	Manufacture of metal products (NACE 28, 29, 33, 34 and 35)
Process	Metal surface treatment and plating
Waste stream	Heat treating wastes: spent salt baths

Prevention option	**Alternative technologies**
Option No	13-3-8
Type	TC
Group	2
Description	A number of alternative technologies can be utilized to minimize or totally eliminate the spent salt baths[1]. A *proven, commercially applied, process* is: • Ion nitriding and ion carburising, where an electrically charged gas of ions is used to alloy metal surfaces. Gas phase treatment can take place in fluidised beds; all formes of heat treatment are amenable to fluidised bed techniques, but austempering is the most cost effective (in spite of the nitrate bath method that is generally less troublesome than other traditional methods)[2]. A process that is still in the *development stage* is: • Induction heat treatment, relying on electrical currents that are induced internally in the workpiece material, dissipating energy and bringing about heating.
Remarks	Ion nitriding offers numerous advantages over conventional nitriding and carburizing processes, like: increased control and improved properties, more uniform cases, negligible thermal shock and distortion, broader treatment range, faster cycle times, lower energy consumption, easier masking and increased safety. Induction hardening produces case depths that are substantially greater than those obtained by traditional carburizing and nitriding.
Economics	Induction hardening as well as ion nitriding are attractive and economic alternatives for the conventional processes.
Potential	The waste prevention potential for the alternative technologies have been assessed as *moderate*, due to their technical and economic advantages.

1 US EPA 1992a

2 For example: UNEP IE 1995, Chartered Metals. In this case study, the hardening, carburising and nitrocarburising of steel in baths of molten salts was replaced by gas phase treatment using a fluidised bed of alumina particles. A mixture of air, ammonia, nitrogen, natural gas, lpg (liquified petroleum gas) and other gases are used as the fluidising gas to carry out the heat treatment. Hydrocarbon gases are used for carburising, ammonia for nitriding and nitrogen for neutral hardening. The bed is heated by electricity or gas and the hot exhaust gases are used for heat exchange. Quenching is also carried out in a fluidised bed. Payback time of the system consisting of four fluid beds, was approximately 2 years.

Sector	Manufacture of metal products (NACE 28, 29, 33, 34 and 35)
Process	Metal surface treatment and plating
Waste stream	Heat treating wastes: spent quenchants

Prevention option	**Preventive measures**[1]
Option No	13-3-9
Type	GOP/TC
Group	1
Description	The following good operation practices are identified: *Reduction of drag-in and drag-out.* The liquid salts, adhering to workpieces from the preceding salt baths, do not dissolve in mineral quenching oils and must therefore be removed as sludge. These liquid salts also have an adverse affects on the water and salt based quenching media and should be removed as well from these baths. Reduction of these spent quenchant wastes can be achieved by reducing the drag-in and drag-out. • The drag-out of the salt baths preceding the quenching, can be minimised by using racks instead of trays, reducing the speed of withdrawal and a proper position of the workpieces on the rack, allowing maximum runoff. A constant low speed of withdrawal can be achieved by applying automatic withdrawal. • For drag-out of quenchant, the same prevention measures apply as for drag-out of salts. When quenching oil is used, mechanical removal of surface oil by forced air can be applied. *Control of temperature* Oil quenchant systems undergo a degradation due to a transformation of the oil at high temperatures. The degradation can be limited by controlling the temperature and installing a cooling system, thus preventing the oil from being exposed to uncontrolled high temperatures. *Use of modified quenchants* To minimize the degradation of oil quenchants at high temperature (up to 180°C), the mineral oil can be fortified with nonsaponifiable additives that increase the quenching effectiveness and prolongs its lifetime. Additives are commercially available.
Remarks	Reduction of drag-in is being achieved by measures applied on the previous treatment. In addition, these measures positively affect the amount of spent materials at the preceding treatment. Contamination of the quenchants by drag-in increases the degradation. Temperature control and cooling should therefore be applied in combination with measures to minimise drag-in.
Economics	The costs of the measures for drag-in and drag-out reduction are not identified in the available literature, but are considered as being low. The costs of temperature control and cooling systems have not been specified in the literature available; neither the costs for the additives. Reburnishment of existing equipment will require additional investments.
Potential	The waste prevention level of the measures has been assessed as *low to moderate.*

1 US EPA 1992a

Sector	Manufacture of metal products (NACE 28, 29, 33, 34 and 35)
Process	Metal surface treatment and plating
Waste stream	Heat treating wastes: spent quenchants

Prevention option	**Internal recycling**
Option No	13-3-10
Type	RU/RC
Group	1
Description	The lifetime of quenchants can be prolonged by de-sludging the quenchant and recycling it to the original process[1]. The desludging can be achieved by filtering and should focus on removing carbonaceous materials, scale, sand and other insoluble solids. In addition, water should be removed from oil quenchants by evaporation or draining. The lifetime of quenching water can be prolonged by ultrafilters if a water soluble polymer is used to modify the rate of a water quench. The ultrafilter is used for a continuous salt removal, preventing the polymer from precipitation by salts.
Remarks	Sintered metal filters and clay filtering media can be reused.
Economics	No detailed information on costs is provided in the available literature. Although the investment costs are estimated as being high, the traditional filter techniques are considered to be economically feasible; the investment into ultra-filtration systems, however, will only be justified in few cases.
Potential	The waste prevention potential of the measure has been estimated as *low*, due to the required investments.

1 US EPA 1992a

Sector	Manufacture of metal products (NACE 28, 29, 33, 34 and 35)
Process	Paint application
Waste stream	Waste paint and sludges containing solvents

Prevention option	**Alternative paints**
Option No	13-4-1
Type	IMC
Group	1/2/3
Description	Major alternatives[1] are: • higher solids coatings • waterborne coatings • powder coatings[2] • solvent-free liquid coatings • low reactivity solvent based products. An extension of coating reformulation is to eliminate one coating stage completely, for example replace a primer+base coat system for biscuit tins with a single base coat[3].
Remarks	The world-wide attention to reduce the emission of volatile organic compounds (VOC) has increased attention for opportunities to reformulate paints. Most alternatives will consequently reduce solvent wastes as well. Barriers against widespread use of alternative formulations are: • performance characteristics are sometimes not as good as solvent-based paints; • reluctance towards experiments and time-consuming performance trials; • significant investment costs to change process equipment.
Economics	As mentioned, significant investment costs are often involved to change process equipment.
Potential	In spite of the barriers mentioned above, general tendencies show a slow but steady process of change-over to alternative paints (principally as a result of the environmental pressure to reduce VOC emissions), especially powder painting. Therefore, the prevention potential has been estimated as *moderate to high.*

1 A clear overview and discussion of these alternative types is to be found in: Giddings 1994. As possibilities are industry specific, discussions relating to which customers are using/likely to use these alternative coating types is included in this document.

2 Especially powder painting techniques have proved to be successful, providing a large reduction of VOC emissions, reduction of hazardous waste and improved work environment.

3 Giddings 1994; annex on coating of metal packaging.

Sector	Manufacture of metal products (NACE 28, 29, 33, 34 and 35)
Process	Paint application
Waste stream	Waste paint and sludges containing solvents

Prevention option	**Alternative application methods**
Option No	13-4-2
Type	TC
Group	1/2/3
Description	The following alternative painting techniques are in use[1]: • alternative painting technology using brushes and rollers; for example, when more coating of the material prior to assembling is applied, these efficient methods can be applied rather than spraying the finished product; • optimization of painting parameters, such as spray shape, spraying time and spraying device design; • alternative spray-painting technologies (airless, electrostatic, high-volume-low-pressure)[2]; • dry spray cabin, i.e. airstream capture of paint spray and waste air filtration; • plunge-bath painting with minor amounts of sludge remaining from workpiece rinsing; • plunge-bath painting using water based paints, positioning electrodes within the painting bath to make use of physical-chemical effects; • use of water-soluble spray paints that can be recovered from the catching of the overspray; • moving the workpiece through a paint curtain.
Remarks	Not all these techniques will provide the requested quality of paint, so the applicability is restricted.
Economics	Generally, these techniques are economically feasible as significant savings on purchase of paints are obtained.
Potential	It is estimated that these (partly good-operation) practices are not yet applied extensively sector-wide. Therefore, the prevention potential has been estimated as moderate to *high*.

1 Euroenviron 1993

2 Conventional manual air-atomised spray roughly produces the double amount of paint waste as compared to airless or high pressure spraying; electrostatic paint spraying produces about 20% of the waste compared to conventional spraying.

Sector	Manufacture of metal products (NACE 28, 29, 33, 34 and 35)
Process	Paint application
Waste stream	Waste paint and sludges containing solvents

Prevention option	**Catching of overspray**
Option No	13-4-3
Type	GOP/RU/RC
Group	1
Description	General good operating practices involve training of operators; right adjustment, pressure and positioning of the spray-nozzles; and good positioning of the metal objects. A fairly common recycling technique is to catch the overspray on rotating disks or moving belts from which the paint may be scraped and re-conditioned for re-use in the painting process. This is applicable only to certain paint types. Overspray and solvents in spray-booths are proved to be catched effectively with venturi-scrubbers, while with the use of coagulants like calcium-chloride, re-use of paints could be achieved[1].
Remarks	Paint sludge may be recycled for the production of lower-grade paint.
Economics	Generally, catching of overspray is economically feasible.
Potential	These good-operation practices are expected to be applied already in many occasions. Therefore, the prevention potential has been estimated as *low*.

1 Umweltbundesamt, Lack-Recycling GmbH 1986 - 1989.

Sector	Manufacture of metal products (NACE 28, 29, 33, 34 and 35)
Process	Paint application
Waste stream	Aqueous waste paint and sludges

Prevention option	**Electro-depositing for coil-coating**
Option No	13-4-4
Type	TC
Group	2
Description	For coil coating, electrodepositing of water-based coatings is possible for primers on aluminium or single coats for steel[1].
Remarks	-
Economics	No information available
Potential	*Low*

1 Giddings 1994

Sector	Manufacture of metal products (NACE 28, 29, 33, 34 and 35)
Process	Paint application
Waste stream	Aqueous waste paint and sludges

Prevention option	**Catching and re-use of overspray**
Option No	13-4-5
Type	TC/RU/RC
Group	2/3
Description	Overspray from the application of water-based paint can be recycled[1,2] using ultrafiltration if the overspray catching water is salt free. Overspray catched in water can be recovered using coagulants, and dried; re-use depends on modifications of the recovered paint; research towards stabilization of overspray paint and recovery with ultrafiltration and electroforese is going on[3].
Remarks	The application potential is limited to paints whose visual appearance need not to respond to prime quality requirements.
Economics	The first source (Euroenviron) mentions a pay-back time of less than three years for an overspray rate of 20 ton/year, under German waste taxing conditions.
Potential	*Low*

1 Euroenviron 1993
2 Umweltbundesambt, Fritz Schäfer 1991 - 1993.
3 Umweltbundesambt, Mercedes Benz 1993 - 1996.

SECTION 14

MANUFACTURE OF ELECTRICAL EQUIPMENT:

PRINTED CIRCUIT BOARDS

SECTOR REPORT

Contents :

NACE sectors involved in the present sector report:

Retained for analysis: 30 Manufacture of office machinery and computers
31 Manufacture of electrical machinery and apparatus n.e.c.
32 Manufacture of radio, television and communication equipment and apparatus

Excluded from analysis: --

14.1 SECTOR CHARACTERISATION [1]

This sector report is covering the sectors of codes 30, 31 and 32 of NACE, Rev.1 (1991) that includes manufacture of office machinery, computers, electrical machinery and apparatus, radio, television and communication equipment and apparatus. The different sectors include a wide variety of product groups.

The sectors were one of the largest industrial sectors in Europe in 1994 (along with metal products, machinery and equipment), employing about 2.3 million people. Total employment has dropped significantly from the 1991 level of 2.7 million; yet, levels have developed differently for the individual sectors and product groups. For example, employment decreased in consumer electronics but increased in measurement, control and automation. Total employment is expected to remain more or less stable in the following years.

The sectors are characterized by a high level of concentration. About 3 000 enterprise units (4.5% of all units) cover nearly 80% of total employment in the sectors. These plants are owned by a small number of very large manufacturers that cover nearly all product segments and operate on a world-wide basis. The number of small sized enterprises with less than 20 employees is approximately 59 000, with a share of 9% of total employment. Medium sized enterprises (20 - 99 employees) account for approximately 9 000 units and 12.5% of total employment. Germany is the largest EU producer (47%), followed by France (16%), the UK and Italy (14% each).

High levels of R&D are typical for these sectors, varying from 8 - 10% at electrical engineering to 15 - 20% at electronic components suppliers. In micro-electronics and telecommunications, R&D is often more costly than production.

14.2 PROCESSES AND WASTES

The manufacture of electrical equipment can be divided into the following groups:

- manufacture of electronic components, including production of semiconductor components, passive components such as resistors etc. and printed circuit boards and board-level assembly
- manufacture of intermediate specific products, including television screens, lamps, lighting equipment, insulated wires and cables, batteries and accumulators; a large variety of processes are applied, involving manufacture of metal products, heat treatment, plastic and (reinforced) resin processing, painting, etc.
- assembly and installation of electrical equipment, machinery and apparatus; this traditionally more labour-intensive activity, is rapidly evolving into sophisticated automated processes.

This sector report focuses on wastes from the manufacture of electronic components. As discussed below, the other two groups of electrical equipment manufacturing are covered mainly by other sector reports within this study[2].

Manufacture of electronic components includes the following steps:

---

1 Main source: European Commission, 1995

2 Other sector reports within this study that are relevant for these groups, include manufacture of plastic and rubber products (section 10) and manufacture of metal products (section 13). Relevant processes and wastes of these sectors are:

- Plastic processing: compounding scrap, plastic particles, solvent wastes, painting wastes, ink residues
- Fibre reinforced and composite plastic processing: resin residues, solvent wastes
- Metal surface treatment and plating: plating wastes
- Paint application: waste paint and sludges containing solvents

For waste prevention options related to these processes, the reader is referred to these sector reports as well.

- semiconductor component manufacturing and packaging, involving sophisticated techniques
- printed circuit board manufacturing, involving cleaning and rinsing operations, copper plating, pattern printing and masking, electroplating and etching
- printed circuit board assembly.

A further description of these processes is given shortly in Annex A.

In table 14.2.1 the major waste streams are listed, together with their process origin; the table includes a tentative priority ranking, based on the amount and the hazardous character of the waste. Further details on wastes are provided in Annex A.

Table 14.2.1: Electronics industry wastes

Process origin	Waste streams	Priority rank	Description and code according to EWC [3]	
Printed circuit board manufacturing	Spent cleaning solvents	-	Wastes from the electronics industry [4]	14 03 00
	Spent developer and resist solvents	- / o		
	Spent electroplating solutions	+	Liquid wastes and sludges from metal treatment and coating of metals	11 01 00
	Spent acid etchants	+		
	Contaminated (rinse) water and spent acid/alkaline solutions	o		
Printed circuit board assembly	Spent cleaning solvents	-	Wastes from the electronics industry	14 03 00
	Spent electroplating solutions	o	Liquid wastes and sludges from metal treatment and coating of metals	11 01 00

Priority rank: + : high significance, o : medium significance, - : low significance   EurEco/Witteveen+Bos 1997

Waste streams of minor significance, not included in the table, are:
- semi conductor manufacturing and packaging wastes: relatively small quantities of spent solvents, developers and photo resist waste and acidic waste water
- solid solder wastes
- board particles
- discarded transformers and capacitors containing PCB or PCTs (EWC 16 02 01)
- other discarded obsolete electronic equipment (e.g. printed circuit boards) (EWC 16 02 02)
- ion exchange resins
- clean room garments.

Waste streams with high significance arise from electroplating at the printed circuit board manufacture. These wastes include spent plating liquids and etchants containing metals and salts. The volume of electroplating wastes at printed circuit board assembly is less than at manufacturing and therefore ranked as medium significance waste.
Other medium significance wastes arise at pattern printing processes at the printed circuit board manufacture, and involve acid or alkaline waste water containing photochemicals and/or metals.

---

3 All waste streams included in this table are hazardous according to the European List of Hazardous Wastes.
4 According to EWC, these wastes include halogenated and halogen free solvents (as solvents, sludges or solid wastes).

Low to medium significance wastes are considered mixed solvents wastes from cleaning and pattern-printing (resist stripping) at printed circuit board manufacture and from cleaning (de-fluxing) at printed circuit board assembly. In the past, major solvent use was based on CFC-113 and 1,1,1-trichloroethane. However, these solvents are now prohibited by the Montreal Protocol. As a consequence, the electronics industry has adequately phased-out these solvents, which is achieved in most cases by no-solvent alternatives.

Other environmental issues than waste, related to manufacture and assembly of electronic components, are the production of waste water, air emissions of volatile solvents and of acid fumes from plating solutions and occupational exposure to chemicals used in the various processes.

14.3 WASTE PREVENTION

This section discusses waste prevention methods identified in literature. The major waste streams along with prevention options are summarized in the next table. The options are described in detail in Annex B.

Table 14.3.1: Overview waste prevention options for the electronics industry

Waste streams	Priority rank	Waste prevention method	Group	Potential
Printed circuit board manufacturing				
Spent cleaning solvents	-	14-1 Good operation practices 14-2 Alternative cleaning methods (IMC/TC) 14-3 Recovery of solvents (RC/RU)	1 1 1	- - -
Spent developer and resist solvents	- / o	14-4 Good operation practices 14-5 Aqueous processable resist (IMC/TC) 14-6 Alternative techniques (TC) 14-3 Recovery of photoresist stripper (RC/RU)	1 1 1/2/3 1	o - / o - -
Spent electroplating solutions	+	14-7 Good operation practices 14-8 Alternative materials/technology (IMC/TC) 14-9 Regeneration of baths (RC/RU)	1 1/2/3 1	- .. o / +
Spent acid etchants	+	14-10 Alternative materials/technology and optimization (IMC/TC) 14-11 Recovery of copper from spent etchants (RC)	1/3 1	.. o / +
Contaminated (rinse) water and spent acid/alkaline solutions	o	14-12 Good operation practices (GOP/TC) 14-13 Mechanical cleaning (IMC/TC) 14-14 Reducing chemicals for DI water (TC) 14-15 Recycle/filter/rinse DI water (RC/RU)	1 1 2 1	- / o - - o
Printed circuit board assembly				
Spent cleaning solvents	-	14-1 to 14-3 14-16 Alternative materials/technologies (IMC/TC)	1 1	- -
Spent electroplating solution	o	14-7 to 14-9	1/2/3	- / o

+ = high, o : medium, - : low, .. = insufficient data EurEco/Witteveen+Bos 1997

Many general prevention options, based largely on good operation practices, are available for the water or solvent based cleaning, rinsing, photoprocessing and wet electroplating processes.

The waste prevention potentials regarding *solvent based waste streams* are generally assessed as low or medium, principally because these waste streams are nowadays considered of low significance as discussed in the preceding chapter[5].

Prevention potentials for *photoprocessing and plating wastes* are generally assessed as low or medium, although many specific prevention options can be found and still be implemented in industry[6]. Regeneration of metal plating and etching solutions have the highest potential, as not all opportunities may have been exploited maximally. The general impression, however, is that a high level of waste prevention is already achieved, considering that production techniques are rapidly changing, thus providing periodic opportunities to install processes that have lower environmental impacts.

A decrease in waste associated with printed circuit board manufacturing can also result from new techniques applied by the *packaging operations of microchips*. Increased use of surface mount technology, reduces the size of printed circuit boards and consequently waste quantities. Use of injection molded substrate and additive plating can eliminate spent etchants wastes[7].

14.4 EVALUATION

Relatively, the sectors for manufacture of electrical equipment do not have large impacts on the environment. The early image of these sectors was a clean and environmentally friendly industry. However, increasing consumption focused attention on the environmental implications for ultimate disposal of equipment and appliances no longer used (e.g. refrigerators, TV's, electronic scrap etc.).

Within electronics industry, sophisticated techniques are applied and rapid changes take place. This facilitates opportunities for waste prevention, providing that technology modifications and materials substitutions account for roughly 50% of waste minimisation options in a typical plant.

Waste prevention methods for manufacture of intermediate electric products and the assembly of electrical equipment are largely covered by methods for manufacture of plastic and rubber products and for manufacture of metal products. However, additional information on specific processes appears not to be disseminated yet, as studies are mainly performed on individual plant level.

Summarizing it is concluded that there are good outlooks for further implementation of clean technologies within electronics industry, especially by using opportunities with new techniques and materials. Awareness of environmental issues has increased due to the influence of the Montreal Protocol and the attention for disposal problems of consumer end-products. For other sectors within electric equipment manufacture, it is concluded that outlooks for clean technologies in general are favourable, although for some specific processes information is scarce.

---

5 To facilitate the change-over from these solvents to alternatives, a great many studies were performed world-wide. Detailed information is to be found in, for example: Glas 1989, Ellis 1990, USEPA 1990, Gerven 1993 and UNEP IE 1994.

6 In UNEP IE 1994, mention is made of an Austrian study in 1993 in which 101 options were identified.

7 USEPA, 1990. These options are not included in the table as they apply to other operations, which are not under the control of most printed board manufacturers.

14.5 BIBLIOGRAPHIC REFERENCES

Ellis B.N. (1990), "Replacement of CFC-113 in industry", Swiss Federal Office of Environment, Forest and Landscape, 3003 Berne (also available in Germany and French).

European Commission (1995), "Panorama of EC Industry 95/96", Bruxelles-Luxembourg

Gerven J.A.M. van, et al. (1993), "Eliminatie van CFK's bij het reinigen van printpanelen" (CFC elimination at PCB cleaning), Philips Centre for Manufacturing Technology CFT, Environmental and Process Technology, Eindhoven, The Netherlands

Glas L., et al. (1989), "Replacement options for 1,1,1-trichloroethane in degreasing/cleaning and electronics", Swedish Environmental Protection Agency, Information Department, Solna, Sweden.

UNEP (1991), "Solvents, coatings and adhesives, Technical Report, Peer Review Draft, september 1991" United Nations Environmental Programme.

UNEP IE (1994), "Environmental Management in the Electronics Industry", United Nations Publications, Technical Report No. 23; UNIDO, Vienna, Austria and UNEP IE, Paris, France

UNEP IE (1995) Database, ICPIC diskette publication:

- Austria, 1993; PREPARE case study at AT&S; contacts (a.o.): Federal Ministry of Science and Federal Ministry of Environment, Wien, Austria; (source material in: UNEP IE document "Cleaner Production Worldwide", Volume II)
- BULL SA France; submitted by the French Office International de l'Eeau (1994), Limoges Cedex, France.
- DOCNO: UNEP01.52 101-010-A-011; US EPA
- DOCNO: UNEP01.52 201-001-A-002; US EPA
- DOCNO: UNEP01.52 306-001-A-027; US EPA
- ENEA; submitted by ENEA CRE Casaccia, Dip. Ambient (1994), Rome, Italy
- Hong Kong, Environmental Management Division, Hong Kong Productivity Council (source material: UNEP IE document "Cleaner Production in the ASIA and Pacific Economic Coorporation (APEC) Region")
- Praegitzer Industries Inc., Dallas, USA; (source material in: UNEP IE document "Cleaner Production Worldwide")
- SGS-Thomson Microelectronics, Malta.

US EPA (1990), "Guides to pollution prevention: The Printed Circuit Board Manufacturing Industry", USEPA/625/7-90-007, Office of Research and Development, Cincinatti, Ohio 45268

Winkel, P. (1992), "Wasser und Abwasser; Behandlung und Kreislaufführung in der Galvanotechnik und Metallindustrie", 2. Auflage, Leuze Verlag, D-7968 Saulgau/Württ, Germany

The Liaison Group of the European Mechanical, Electrical, Electronic and Metalworking Industries (Orgalime) has provided general information for the study and has been asked to comment the draft sector report. We did unfortunately not receive a reaction within the period made available for comments (beginning of December 1996 - mid January 1997)

SECTION 14

MANUFACTURE OF ELECTRICAL EQUIPMENT :

PRINTED CIRCUIT BOARDS

ANNEX A

PROCESSES AND WASTES DESCRIPTION

Contents :

A.1 OVERVIEW

The manufacture of electrical equipment can be divided into the following groups:

- manufacture of electronic components, including production of semiconductor components, passive components such as resistors etc. and printed circuit boards and board-level assembly
- manufacture of intermediate specific products, including television screens, lamps, lighting equipment, insulated wires and cables, batteries and accumulators
- assembly and installation of electrical equipment, machinery and apparatus.

This sector report focuses on wastes from the manufacture of electronic components, especially the manufacturing of printed circuit boards[1,2]. The other two groups of electrical equipment manufacturing are covered mainly by other sector reports within this study. These reports, that are relevant for all groups of processes in the electrical equipment manufacturing sector, include:

- manufacture of plastic and rubber products (section 16)
- manufacture of metal products (section 19)

The manufacturers of printed circuit boards (PCBs) are included as part of the electronics industry. The industry consists of large facilities totally dedicated to PCBs, medium sized enterprises and small job shops doing contract work, and specialty units doing low-volume and high-volume precision work.

Printed circuit boards can be classified into three basic types: single-sided, double-sided and multi-layered.

Raw materials used in the industry are:

- board materials (glass-epoxy, ceramics, plastic, phenolic paper, copper foil)
- cleaners (water or solvent based)
- plating and etching chemicals
- photochemicals (resists, sensitizers, resist solvents)
- resist strippers (acid or ammoniacal solutions or organic (halogenated) solvents)

Major wastes from the printed circuit board manufacturing industry are typically mixed solvents wastes or water-based acid/alkaline solutions, containing photochemicals and/or metals.

1 Main sources: UNEP 1994 and USEPA 1990.

2 Manufacture of electronic components involve sophisticated techniques for semiconductor manufacturing and packaging. The first process implies the actual production of chip or die from raw materials by crystal growth and wafer fabrication (epitaxy, oxidation, photolithography, etching, diffusion and ion implantation, metallisation and chemical vapour deposition). The second process involves the packaging of this chip into a discrete unit or an integrated circuit (die separation, soldering, post-solder cleaning, wire bonding and encapsulation using resins).

A.2 PRINTED CIRCUIT BOARD MANUFACTURING

* Process description

Manufacture of printed circuit boards involve the following steps:

- cleaning and rinsing operations of the copper laminated boards[1];
- electroless copper plating, applying a thin copper film through the holes in the board; this step involves catalytic reduction of cupric chloride or copper sulfate plating bath;
- pattern printing and masking; this involves the application of a layer of photoresist (screening or lithography), the resist is removed (stripped) by solvent based strippers (often dichloromethane) or by aqueous alkaline strippers; alkaline cleaners are used to remove residues and the boards are subsequently dipped in acid;
- electroplating, applying several layers of metals on the areas without the resist;
- etching, to take away the thin copper film of the non-circuit areas, after stripping of the resists; typical etchants are peroxide-sulphuric acid, sodium persulfate, ferric or cupric chloride or chromic acid.

* Waste description

Typical waste streams generated from the unit operations are summarized as follows:

- *Spent cleaning solvents*
  The cleaning of the boards before electroless plating can take place with organic (halogenated) solvents. Liquid waste streams arise from spent solvent baths.
- *Spent developer and resist solvents*
  Photosensitive inks or resists composed of epoxy vinyl polymers, halogenated aromatics, methacrylates and/or polyolefin sulphones may be used. Liquid waste streams produced can be spent resist removal solutions containing chlorinated hydrocarbons (e.g. dichloromethane).
- *Spent electroplating solutions*
  Electroless copper plating produces various liquid wastes, including spent copper plating solution containing acids and stannic oxide and solutions containing spent catalysts (e.g. palladium) and spent acid solutions. Electroplating involves various metals, producing spent plating liquid, containing copper, nickel, tin and tin/lead, gold, fluoride, cyanide and sulphate; and waste rinse water.
- *Acid etchants*
  Pattern plating is followed by etching, resulting in spent etchants containing ammonia, chromium, copper; and waste rinse water. An alternative method involves whole board plating and subsequent etching of non-circuit areas. This method produces more metal waste.
- *Contaminated (rinse) water and spent acid/alkaline solutions*
  The cleaning of the boards before electroless plating can take place as well with alkaline or acid cleaning. Liquid waste streams form this step can therefore include spent acid/alkalic cleaning agents.

---

1 Printed circuit board manufacturers often purchase boards that are already copper clad from independent laminators.

Other sources of contaminated (rinse) water are pattern printing and masking, electroplating and etching.
Electroplating and etching involve the regular rinse water streams.
Instead of the solvent/resist system for pattern printing and masking, aqueous-alkaline systems are often applied. For this method, use is made of poly-epoxide acrylate-based photoresists, that can be removed by a sodium carbonate solution (soda). Stripping can be performed by potassium hydroxide solutions. The process involves rinse wastewater and the alkalic waste waters containing developers and strippers.
Finally, acid wastewater may arise from solvent based pattern printing. The boards are dipped in acid to remove any oxide build up.

A.3 PRINTED CIRCUIT BOARD ASSEMBLY

* Process description

In assembly processes, the required electronic components are mounted on to the printed circuit boards. The component terminals are soldered in place either by hand or by advanced techniques, including for example immersion in solder baths. After soldering, cleaning is often required to remove fluxes. Cleaning can take place by:

- brush scrubbing (hand or automated) and a solvent or aqueous cleaning media
- dipping (automatically or by hand) the entire circuit board into a series of baths containing cleaning fluid; the baths can contain ultrasonic equipment, sprays, vapour phases etc.

Three basic technologies are in use: plated through-hole, surface mount technology and mixed technology. Surface mounted technology (SMT) is becoming major practice. It reduces the size of printed circuit boards and consequently of waste quantities. However, the method is more costly and complex.

* Waste description

- *Spent cleaning solvents*
  Post-solder cleaning is traditionally performed by halogenated solvents like CFC-113 and 1,1,1-trichloroethane. As these solvents are now prohibited by the Montreal Protocol, alternative cleaning methods are applied, including no-clean options, aqueous cleaning and terpene/semi-aqueous cleaning. However, halogenated solvents like dichloromethane, per- or trichloroethylene and HCFK's are sometimes used, as well as volatile non-halogenated solvents like alcohol.

- *Spent electroplating solutions*
  Electroplating in board assembly produces the same type of waste as in PCB manufacture: plating liquid, containing copper, nickel, tin and tin/lead, gold, fluoride, cyanide and sulphate; and waste rinse water.

SECTION 14

MANUFACTURE OF ELECTRICAL EQUIPMENT :

PRINTED CIRCUIT BOARDS

ANNEX B

PREVENTION OPTIONS

Contents :

Sector	Manufacture of electrical equipment (NACE 30, 31 and 32)
Process	Printed circuit board manufacturing
Waste stream	Spent cleaning solvents

Prevention option	**Good operation practices**[1]
Option No	14-1
Type	GOP
Group	1
Description	Solvents are used for cleaning operations at PCB manufacturing for board preparation, as well as at PCB assembly for defluxing. Depending on the type of cleaning process applied, the following good operation practices can be checked. *Reducing evaporation loss* Reducing air emission out of degreasing equipment (immersion baths or vapour degreasers) will indirectly prevent waste production, by better maintaining the composition of the solvents, thus reducing the need of replacement and disposal of residues; proven methods to reduce air emission losses include • apply covers and lids on tanks • increase freeboard space • addition of a freeboard chiller • reducing drag-out: slow speed of withdrawal of an object; limited cross-sectional area of the objects • no solvent sprays above the vapour zone. *Maintaining solvent quality* Halogenated solvents contain chemical stabilizers to neutralize and prevent acid formation. If a solvent is close to "going acid", new stabilizers might be added to increase the lifetime of the solvent bath. Water contamination, sludge formation and other solvents can lead to the mentioned acid formation and to a reduction of cleaning efficiency. To minimise water contamination, regular check and cleaning of the water/solvent separator that is installed on vapour degreasers is necessary, as well as checking of leakage of parts. Sludge that collects in the bottom in the tank should always be removed promptly.
Remarks	These options are generally valid for (vapour) cleaning processes for board manufacture before plating processes, for PCB assembly post-solder cleaning, as well as for post-solder cleaning in semiconductor manufacturing. Options 13-2-1 to 13-2-6 of section 13 provide more details and references regarding solvent cleaning processes.
Economics	
Potential	In the last decades, CFC-113 and 1,1,1-trichloroethane were commonly used solvents for a large variety of cleaning processes within the electronics industry. In consequence of the Montreal Protocol, these solvents are not used anymore and have been replaced in most cases by no-solvent alternatives. As the use of solvents has reduced considerably in the electrical equipment sector, the prevention potential of good-housekeeping has consequently been assessed as *low*.

1 Major solvents used for this purpose were CFC-113 and 1,1,1-trichloroethane. Both solvents are now prohibited due to the Montreal Protocol. To minimise emissions and waste of solvents, a great number of studies is available. Detailed information is to be found in, for example, Ellis 1990, Glas 1989, UNEP 1991, Gerven 1993 and UNEP IE 1994.

Sector	Manufacture of electrical equipment (NACE 30, 31 and 32)
Process	Printed circuit board manufacturing
Waste stream	Spent cleaning solvents

Prevention option	**Alternative cleaning methods**[1]
Option No	14-2
Type	IMC/TC
Group	1
Description	Liquid halogenated and halogen-free solvent wastes (and emissions into air) from metal degreasing can be avoided by switching to water based alkalic systems[2]. An aqueous cleaning system generally consists of various immersion baths, of which the last ones are for rinsing. Other alternative cleaning methods are semi-aqueous or terpenes. Terpenes are a naturally derived solvent, generally isoprene oligmers, but may include derivatives such as alcohols, aldehydes and esters. These hydrocarbon/surfactant cleaning solutions work at low temperature, are non-corrosive and remove both polar and non-polar contaminants. Cleaning equipment has to be especially designed and operated.
Remarks	Option 13-2-4 of section 13 provides more details and references regarding alkaline cleaning. Terpenes cleaning methods change the hazardous character of (halogenated) solvent wastes and reduce emissions to air.
Economics	
Potential	Due to the effects of the Montreal Protocol, many companies have already changed to water-based cleaning or other no-solvent alternatives. Therefore, the waste prevention potential has been assessed as *low*.

1 Major solvents used for this purpose were CFC-113 and 1,1,1-trichloroethane. Both solvents are now prohibited due to the Montreal Protocol. To minimise emissions and waste of solvents, a great number of studies is available. Detailed information is to be found in, for example, Ellis 1990, Glas 1989, UNEP 1991, Gerven 1993 and UNEP IE 1994.

2 Although only alkalic degreasing is mentioned, other water-based cleaning, like neutral or acidic, can constitute an efficient alternative as well. Alkalic cleaners are, however, generally employed to remove organic contaminants from surfaces (degreasing): acid cleaners are used to remove oxidation, scale and rust. Basically, a wide variety of chemicals are available and should be evaluated when a switch is considered. It is advised to request various suppliers of chemicals as well as of equipment.

Sector	Manufacture of electrical equipment (NACE 30, 31 and 32)
Process	Printed circuit board manufacturing
Waste stream	Spent cleaning solvents

Prevention option	**Recovery of solvents**[1]
Option No	14-3
Type	RU/RC
Group	1
Description	Methods for recovering of solvents from spent solvent wastes are distillation processes, such as vacuum distillation or thin-film evaporation[2]. With such systems solvent bath life time of more than two years may be achieved without the need to replace the solvent. *Batch-type distillation units* are commercially available in ranges from 20 to 200 litre units. Commercial *continuous-feed distillation* equipment is available for large volumes of contaminated solvents waste production. Since distillation removes most stabilizers and other additives of solvents (if present), these chemicals need to be added again if the same usage of the solvent is required. Good housekeeping measures facilitate solvent recovery: • keep different solvents separated • minimise solids for efficient solvent reclamation • control solvent concentration (to be maintain above 40%) • label waste and specify its origin. In-house recycling of halogenated solvents is often possible for larger units[3]. For small quantities, off-site reclamation is well suited.
Remarks	Solvent recovery can be applied for solvent wastes from cleaning processes at board manufacture and assembly, as well as for photoresist stripping solvents (e.g. dichloromethane) at pattern printing and masking.
Economics	Initial investment ranges from 2 000 ECU for a 20-litre batch distillation unit to more than 20 000 ECU for a 200-litre unit[4]. Benefits are related to lower solvent purchase costs and reduced hazardous waste management expenses.
Potential	For large enterprises with high consumption rates of solvents, recycling is a feasible and economically attractive option, that reduces this waste stream significantly. However, solvent use has already been reduced significantly due to the effects of the Montreal Protocol. Therefore, the waste prevention potential has been assessed as *low*.

1 Major solvents used for this purpose were CFC-113 and 1,1,1-trichloroethane. Both solvents are now prohibited due to the Montreal Protocol. To minimise emissions and waste of solvents, a great number of studies is available. Detailed information is to be found in, for example, Ellis 1990, Glas 1989, UNEP 1991, Gerven 1993 and UNEP IE 1994.

2 UNEP IE 1995, ENEA: This case study reports on recovery of perchloroethylene at a plant producing electronic microcircuits. To check degradation of this washing solvent the company performed chemical analysis at regular close intervals. The company as well replaced CFC-113 used for defluxing by using welding pastes and fluxes that are hydrosoluable. The payback for the process is estimated at 1.5 years.

3 In literature (US EPA 1990) is indicated that recycling is economical when at least 10 m^3 solvent is generated per year.

4 US EPA reference included in sector report 10, option 10-3.

Sector	Manufacture of electrical equipment (NACE 30, 31 and 32)
Process	Printed circuit board manufacturing
Waste stream	Spent developer and resist solvents

Prevention option	**Good operation practices**[1]
Option No	14-4
Type	GOP
Group	1
Description	Good operation practices for reducing developer or photoresist stripper wastes are listed below. • *Regular decanting and filtering of stripper solution baths*[2] The baths become contaminated with photoresist residues (small flakes) that can adhere to the circuit boards; by removal of these residues, the stripper solution can be used much longer. • *Automated photoresist dispensing*[3] By the application of automated dispensing systems, a maximum of usage of photoresist is provided from the supply bottles. A 50% reduction in photoresist waste was obtained. This special dispense system did not require modifications or adjustments to the existing system on spinner tracks.
Remarks	
Economics	Low costs are involved with these measures. The automated dispensing system had a payback of less than one year.
Potential	It is expected that the implementation of these measures is already substantial. The prevention potential is therefore assessed as *low*.

1 Major solvents used in pattern printing and masking are the halogenated solvents 1,1,1-trichloroethane and dichloromethane. The first solvent is now prohibited due to the Montreal Protocol. To change-over from this solvent, many studies are performed. Much information is to be found in, for example, USEPA 1990, UNEP 1991 and UNEP 1994.

2 USEPA, 1990

3 UNEP 1995. DOCNO UNEP01.52 201-001-A-002.
Contact: Semiconductor Industry Association (SIA), Environmental and OSHA Affairs, CA 95014 USA.

Sector	Manufacture of electrical equipment (NACE 30, 31 and 32)
Process	Printed circuit board manufacturing
Waste stream	Spent developer and resist solvents

Prevention option	**Aqueous processable resist**[1]
Option No	14-5
Type	IMC/TC
Group	1
Description	Instead of the solvent/resist system for pattern printing on the copper coated boards, aqueous-alkaline systems are available. A similar application is the attachment of dry-film solder masks to finished printed circuits. For this method, use is made of poly-epoxide acrylate-based photoresists. The unexposed photoresists can be removed by a sodium carbonate solution (soda). After the resist is developed, the boards are washed in a cascade water rinse and dried by hot air. Stripping can be performed by potassium hydroxide solutions (instead of dichloromethane in the solvent based process). After stripping, the board is again rinsed and dried with hot air. The process still involves wastes, namely the alkaline waste water containing developers and strippers. Batch treatment of this waste water by pH adjustment, precipitation of resist and floating of strippers, produces sludges for disposal. Ultrafiltration may reduce the batch volume to be treated substantially, hence reducing acid requirement for pH adjustment[2].
Remarks	Where solvent resists can be used for all techniques and processes, aqueous-alkaline systems have certain limitations and are not suitable for fine line circuits and when certain base materials (polyimide laminates) are used in direct etching and stripping is done afterwards. However, in general, aqueous-alkaline dry resists can be used in all standard procedures, with solvent-comparable yields and higher productivity in automatic production lines. In a case study[3], chemical consumption in the aqueous-alkaline process could be reduced significantly with only minor process modifications, after detailed experiments. Hence, recommendations of the chemical and process equipment suppliers appeared to have certain safety charges in reserve. For solder-masking, aqueous-alkaline systems were reported to have some draw-backs. There are other alternatives for solvent-based solder-masking, which are described in the next option (14-6).
Economics	A complete production line using aqueous-alkaline systems requires investments of the same order as those for solvent systems. Operating costs are lower due to savings in purchasing solvents and reduced waste-disposal costs.
Potential	Because of the advantages, use of aqueous alkaline systems was already in 1991 reported to have reached approximately 50% in Europe. As further implementation since then seems likely, the actual prevention potential is estimated as *low to moderate*.

1 Main sources for the information provided in this option are: UNEP, 1991 and Winkel, 1992.
2 UNEP IE 1995, BULL SA, France: In this case study, effluents from the alkaline-aqueous system were treated with ultrafiltration, resulting in metal-free and biodegradable filtrate; period of amortization of the unit was 2.5 years.
3 UNEP IE 1995: Austria 1993.

Sector	Manufacture of electrical equipment (NACE 30, 31 and 32)
Process	Printed circuit board manufacturing
Waste stream	Spent developer and resist solvents

Prevention option	**Alternative techniques**
Option No	14-6
Type	IMC/TC
Group	1/2/3
Description	Some general principles to reduce wastes at the photoprocessing industry apply as well to pattern-printing and masking[1]. Listed below are techniques for pattern printing and masking in printed circuit board manufacturing[2]. • Use of screen-printing in place of photolithography to eliminate the need for developers. As the application of aqueous-alkaline systems for solder masking has certain limitations, the mentioned method (also including modern silk screen-printing techniques) provides an alternative substitution. There are many other specific alternatives available, some of them using halogen-free solvents[3]. • Use of Asher dry photoresist removal method to eliminate the use of organic resist stripping techniques.
Remarks	Screen-printing techniques are developed which can provide high degrees of resolution. However, many printed circuit board manufacturers are still using photolithographic techniques, for very fine circuits. According to <USEPA, 1990>, the dry photoresist was only applied in the semiconductor industry, where resists are much thinner than the printed circuit board layers.
Economics	Modern silk-screening techniques are reported uneconomical for short runs. No further information on costs is obtained.
Potential	Aqueous alkaline systems are the major alternative for solvent processable resists and these systems are applied already often in Europe; further, the alternative techniques mentioned above have certain limitations for many applications. For these reasons, the prevention potential is estimated as *low*.

1 For options related to photoprocessing, the reader is referred to sector report 8 on publishing, printing and reproduction of recorded media. Main reference mentioned in sector report 8 for photoprocessing prevention options is USEPA 1991.

2 USEPA, 1990

3 UNEP, 1991

Sector	Manufacture of electrical equipment (NACE 30, 31 and 32)
Process	Printed circuit board manufacturing
Waste stream	Spent electroplating and electroless plating solutions

Prevention option	**Good operation practices**
Option No	14-7
Type	GOP
Group	1
Description	Examples of good operation practices are discussed below. The life time of baths can be prolonged by protecting the baths from contamination. The main source of external contamination is the drag-out from preceding operations. The amount of drag-out depends on various factors and can be reduced by: • reducing the speed of withdrawal of the workpiece from the baths; • allowing ample drainage time for the workpieces withdrawn form the baths; • the use of surfactants, reducing the surface tension of the plating solution that therefore adheres less on the workpieces; • lowering the concentrations of plating bath constituents, resulting in a reduced amount of hazardous substances dragged out as well as in a reduced volume due to the lower viscosity of the plating solution; • proper positioning of the workpieces on the plating rack, allowing maximum drainage. In addition to the contamination by drag-out losses, the lifetime of baths is limited by the accumulation of other impurities. These impurities can be caused by the racks, anodes, water make-up and the air. Hence, the lifetime can be prolonged by: • cleaning the racks prior to operation • using purer metal for anodes • use of demineralized water as make-up • periodic filtering of the bath solution • installing lids on the baths to protect them against depositions from the air. Recovery of electroplating metals is facilitated by the reduction of the amount of water used for washing and rinsing. Further, in-plant separation of waste water streams will facilitate the production of mono sludges (sludge containing only one metal compound). Finally, good housekeeping measures should be implemented to avoid accidents, spills and the generation of contaminated effluents.
Remarks	
Economics	Low cost measures.
Potential	The prevention potential has been estimated as *low* because most options involve well-known principles, likely to be applied often.

Sector	Manufacture of electrical equipment (NACE 30, 31 and 32)
Process	Printed circuit board manufacturing
Waste stream	Spent electroplating and electroless plating solutions

Prevention option	**Alternative materials/technology**
Option No	14-8
Type	IMC/TC
Group	1/2/3
Description	Prevention options that involve alternative materials or technology are listed below. • *Mechanical board production methods/systems*[1] To eliminate all operations involving chemicals, mechanical board production methods are available. Circuit boards are designed on a computer and the pattern is then etched on the copper-clad board with the use of a mechanical stylus. This method is suited for low-volume facilities, for example for development/research laboratories. • *Pure tin electroplating*[2] Electroplating processes for PCB manufacturing involves traditionally electrodepositing of a tin/lead alloy onto the copper circuit of the PCB. This alloy coating provides protection during the etching process. The tin/lead electroplating bath constitutes a hazardous waste containing a lead and fluoroborate-based solution. An alternative process was introduced, in which pure tin was used as the coating with sulphate-based plating. • *Use of non-chelating cleaners*[3] Chelators are employed in cleaning, electroplating and etching baths to allow metal ions to remain in solution beyond their normal solubility limit. However, in waste water treatment, these chelating compounds inhibit precipitation of the metals and additional treatment chemicals must be used, contributing to more waste sludge production. Common chelators used in PCB manufacturing are ferrocyanide, EDTA, phosphates and ammonia. Alternatives are available but have certain limitations. Also mild-chelators are available. The disadvantage of non-chelating cleaners is the need to continuously remove and filtrate solids from the baths. • *Use of non-cyanide baths and non-cyanide stress relievers*[4] In the case of electroless copper plating, polysiloxanes are reported to be able to replace the hazardous cyanide-containing compounds.
Remarks	The pure tin process has been in operation for two years before UNEP publication. The process does not affect other manufacturing processes nor product quality.
Economics	Initial investment of the pure tin process is reported to be low, as only one bath needed to be replaced. Costs for waste water treatment are reduced, which offsets the increased material costs for pure tin.
Potential	Although some options have a low prevention potential considering their limitations, not sufficient information is available for assessing the over-all prevention potential.

1 USEPA. 1990
2 UNEP IE 1995, Hong Kong.
3 USEPA. 1990
4 USEPA. 1990.

Sector	Manufacture of electrical equipment (NACE 30, 31 and 32)
Process	Printed circuit board manufacturing
Waste stream	Spent electroplating and electroless plating solutions

Prevention option	**Regeneration of baths**
Option No	14-9
Type	RC/RU
Group	1
Description	Electroless copper plating and electroplating spent bath solutions contain valuable metals that can be recovered by proven electrolytic processes[1]. Further decrease of copper concentrations in waste water can be achieved by ion exchange. Other methods for recovery of metals are reverse osmosis, liquid membranes and electrodialysis. Besides recovery of metals, other compounds can be recovered for economical and environmental reasons. The recovery of EDTA, besides of copper, from electroless plating wastes is possible by crystallisation of EDTA at low pH (1.6 to 1.8)[2].
Remarks	Option 13-3-5 of section 13 provides more details and references regarding regeneration of plating baths.
Economics	Recycling is economically attractive, especially for high-valued metals as applied in printed circuit board manufacturing.
Potential	Waste streams need to be evaluated systematically for possible direct re-use or opportunities for other applications. It is estimated that printed circuit board manufacturers may not have assessed the potential for reusing waste materials. Therefore, the prevention potential has been estimated as *medium to high*.

1 UNEP IE 1995. DOCNO: UNEP01.52 101-010-A-011; case study (1986), reviewed in 1994, on electrolytical recovery of copper from the copper plating line and solder (tin/lead) line. The company converted the primary rinse tank into a static dragout tank and installed the recovery unit. The compact and simple units consist of stainless steel cathode and columbium or titanium anode in a small rectangular box.

2 Winkel, 1992

Sector	Manufacture of electrical equipment (NACE 30, 31 and 32)
Process	Printed circuit board manufacturing
Waste stream	Acid etchants

Prevention option	**Alternative materials/technology and optimization**
Option No	14-10
Type	IMC/TC
Group	1/3
Description	Waste minimization options for the etching process include[1]: • *Use of non-chelating etchants* (group 1) Non-chelate mild etchants (e.g. sodium persulfate and hydrogen peroxide/sulfuric acid) can replace ammonium persulfate chelate etchants. • *Use of non-chrome etchants* (group 1) Non-chromium etchants reduce the toxicity of the waste produced. Alternatives are common etchants like ferric chloride and ammonium persulfate. • *Pattern versus panel plating* (group 1) With pattern plating, only the holes and circuits are copper plated instead of the entire board with panel plating. The amount of non-circuit copper to be etched away is consequently much lower. • *Additive instead of subtractive method* (group 1) The additive method involves deposition of metals onto the board only in the pattern dictated by the circuit. Since the board doesn't initially have any copper in non-circuit areas, a copper etching is thus eliminated, reducing considerably the amount of wastes. • *Thinner copper claddings* (group 1) Thinner copper foil cladded on the boards consequently reduces the amount of copper to be etched away later. Thinner copper cladded materials are widely available. • *Differential plating instead of conventional electroless plating* (group 3) This experimental method results in a faster copper depositing on the hole walls of the boards. This reduces the amount of copper to be etched away later.
Remarks	Most options identified for electroplating and electroless plating solutions apply as well to etching wastes.
Economics	No information on cost was available in literature available. Many options, though, are very often applied (group 1), meaning that costs will not state an important hindrance.
Potential	Some options, like the subtractive method, can result in significant reduction of wastes generated. Furthermore, most options are considered as group 1. Therefore the prevention potential of these options might be considered high, however, as the degree of implementation is uncertain, the potential has been assessed as *unknown*.

1 UNEP IE, 1994 and USEPA, 1990

Sector	Manufacture of electrical equipment (NACE 30, 31 and 32)
Process	Printed circuit board manufacturing
Waste stream	Acid etchants

Prevention option	**Recovery of copper from spent etchants**
Option No	14-11
Type	RC
Group	1
Description	Acid solutions of cupric or ferric chloride, chromic acid, peroxide/sulfuric acid, ammonium and sodium persulfate, are generally used for PCB etching, taking away the unwanted copper. During etching with *cupric chloride*, the copper dissolves and cupric chloride is reduced to cuprous chloride. A standard method for regenerating these etching solutions is by oxidizing the cuprous ion with acidified hydrogen peroxide. Copper is precipitated as copperoxide. Other available techniques are oxidizing through direct chlorination or involve the use of electrolytic cells[1,2]. For regeneration of spent *chromic acid* an electrolytic diaphragm cell can be used, that oxidizes trivalent chromium to hexavalent chromium[3]. The quality of the etchant is equal to or better than fresh etchant. *Ammoniacal etching solutions* can cause problems in waste water treatment due to the formation of very stable amine-complexes. Methods for regeneration of these etchants were already available around 1980 and were based on liquid-liquid extraction[4]. Recovery of *hydrochloric acid* can be achieved by mixing the spent etchant with sulfuric acid, followed by distillation of the hydrochloric acid for re-use. Copper can be electrolytically removed from the residue, whereas sulfuric acid becomes available for re-use in the distillation process[5].
Remarks	The process of regenerating copper by using hydrochloric acid, hydrogen peroxide and sodium chloride can be optimized by using other spent solutions[6]. Most options identified for electro- and electroless plating apply as well to etching.
Economics	By recovering copper, high value pure flakes are obtained, whereas disposal costs for copper are virtually eliminated. Payback times of less than 2 years are reported.
Potential	No information has been obtained towards the degree of implementation within European industry. However, it is estimated that printed circuit board manufacturers may not have assessed the maximal potential for reusing waste materials. Therefore, the prevention potential has been estimated as *medium to high.*

1 UNEP IE 1995, Praegitzer Industries. In this case study, simultaneous regeneration of the etching solution and recovery of the unwanted copper proved possible by using a divided electrolytic cell. A special PVC-based membrane allows hydrogen and chloride ions to pass through, but not the copper. The copper is transferred via a bleed valve and recovered at the cathode as pure flakes. Based on 50 tons of copper recovered per year, the payback of the system 18 months.

2 UNEP IE 1995, DOCNO: UNEP01.52 306-001-A-028. In this case study, an electrolytic recovery cell was part of a closed-loop system that follows the etching operation. The copperless rinsewater is recirculated. The recovered copper at the cathode is sold.

3 USEPA, 1990

4 Winkel, 1992

5 Winkel, 1990

6 UNEP IE 1995, Austria 1993. In this case study, instead of using fresh hydrochloric acid, spent hydrochloric acid - following rinsing - is used. Uniform concentration of the spent acid was obtained through the use of a buffer tank.

Sector	Manufacture of electrical equipment (NACE 30, 31 and 32)
Process	Printed circuit board manufacturing
Waste stream	Contaminated (rinse) water and spent acid/alkaline solutions

Prevention option	**Good operation practices**
Option No	14-12
Type	GOP/TC
Group	I
Description	The volume of consumed rinse water and spent acid/alkaline solutions can be reduced by implementing various types of measures: • installation of flow meters, allowing to identify the priority for waste prevention at individual sources; • determination of the minimum required rinse water for a specific operation by a trial and error method; • installation of flow restrictors to keep the flowrate constant and permitting only supervisors to make changes; • replacing flow rinse tanks by a counter-current rinse water cascade, where the water flows in the opposite direction of the workpieces; • ensuring complete mixing of the rinse water within the rinse tank. Reduction of drag-out losses can be achieved by: • reducing speed of withdrawal of the workpiece from the baths; • allowing ample drainage time for the workpieces withdrawn form the baths; • proper positioning of the workpieces on the plating rack, allowing maximum drainage.
Remarks	These options apply as well for plating wastes.
Economics	Installing counter-current rinsing systems may amount to considerable costs; however, significant benefits are obtained from savings in water supply charges and effluent disposal charges. Most other measures involve minor costs.
Potential	The impact of these measures on waste quantities is modest, although they should not be neglected. Further, it is estimated that these good-operation practices are not applied extensively yet in industry. Therefore, the prevention potential has been estimated as *low to medium*.

Sector	Manufacture of electrical equipment (NACE 30, 31 and 32)
Process	Printed circuit board manufacturing
Waste stream	Contaminated (rinse) water and spent acid/alkaline solutions

Prevention option	**Mechanical cleaning methods instead of aqueous cleaning**
Option No	14-13
Type	IMC/TC
Group	1
Description	This option applies for aqueous cleaning and surface preparation steps that take place before further processing of the copper laminated board. As an alternative for aqueous cleaning, mechanical cleaning using abrasives can be applied[1]. Abrasive blast cleaning uses plastic, ceramic or harder media such aluminum oxide. Abrasives can also be used in vibratory cleaning or in tumbling barrels. Specially designed mechanical device are reported that use rotating brushes and pumice as an abrasive to clean the copper sheet metal surface.
Remarks	-
Economics	No information has been obtained.
Potential	Applications of this alternative are limited, so the prevention potential is assessed as *low.*

1 USEPA. 1990

Sector	Manufacture of electrical equipment (NACE 30, 31 and 32)
Process	Printed circuit board manufacturing
Waste stream	Contaminated (rinse) water and spent acid/alkaline solutions

Prevention option	**Reducing chemicals in the production of deionized water**
Option No	14-14
Type	TC
Group	2
Description	The microelectronic production processes in general require large volumes of deionized water. Methods as reverse osmosis and ion exchange are employed for producing deionized water. In the situation of a case study[1], relatively high salinity city water was used, putting a high load on the ion-exchange system, requiring considerable amounts of chemicals. In this case study, a reverse electrodialysis process was installed as pre-treatment for removing dissolved solids from city water upstream of the de-ionized water system. As the reverse osmosis unit further reduces dissolved solids, this considerably lengthens the operating cycle on the ion exchange column between generation of the resin. A drastic reduction of chemicals is also achieved. Also there is less frequent disposal of spent resin waste.
Remarks	Operation efficiency of the reverse osmosis system improved as well due to this pretreatment system.
Economics	The investment for the installation was USD 275 000 (1989 prices). The payback period was 5.4 years.
Potential	The application of this method is limited to situations with a high salinity in intake water. The prevention potential is estimated as *low*.

1 UNEP IE 1995. SGS-Thomson Microelectronics Malta

Sector	Manufacture of electrical equipment (NACE 30, 31 and 32)
Process	Printed circuit board manufacturing
Waste stream	Contaminated (rinse) water and spent acid/alkaline solutions

Prevention option	**Recycling of deionized water**
Option No	14-15
Type	RC/RU
Group	1
Description	Many processes in semi conductor and PCB manufacturing require large amounts of de-ionized water. In order to reduce water and chemical consumption and subsequent reduction of waste water flow and ion exchange resin waste amount, deionized rinsing or coolant water may be reused. In a case study[1], coolant water was recirculated via a storage tank and a reverse osmosis filtration unit.
Remarks	-
Economics	Cost calculation were not provided in this case. However, the installation resulted in 80% reduction in deionized water demand and reduced plant effluent significantly (> 50%).
Potential	Optimization and investigation of recycle opportunities of deionized water may often be useful. It can result in considerable effects on water usage and effluent, resulting as well in significant waste reduction. The prevention potential is estimated as *medium*.

1 UNEP 1994.

Sector	Manufacture of electrical equipment (NACE 30, 31 and 32)
Process	Printed circuit board assembly
Waste stream	Spent cleaning solvents

Prevention option	**Alternative materials/technologies**
Option No	14-16
Type	IMC/TC
Group	1/2/3
Description	The principal use of (halogenated) solvents in PCB assembly is for defluxing, that is, the removal of residues from boards after soldering. Most solvents are lost as emission into air; besides, spent contaminated baths remain as a hazardous liquid waste. Various alternatives for the use of solvents are available[1], for example: • no-clean methods, including controlled atmosphere soldering • water soluble fluxes and water cleaning • rosin fluxes + saponifier + water cleaning • rosin & SA[2] fluxes + hydrocarbon/surfactant (terpenes) + water cleaning • rosin & SA fluxes + light hydrocarbon (including alcohol) solvent cleaning
Remarks	
Economics	
Potential	As the use of solvents has reduced considerably in post-solder cleaning, the actual prevention potential of the alternatives has consequently been assessed as *low*.

1 Major solvents used for this purpose were CFC-113 and 1,1,1-trichloroethane. Both solvents are now prohibited due to the Montreal Protocol. To facilitate the change-over from these solvents to alternatives, a great number of studies is available world-wide. Detailed information is to be found in, for example, Ellis 1990, Glas 1989, UNEP 1991, Gerven 1993 and UNEP IE 1994.

2 SA fluxes: Synthetically activated fluxes, that are more active than rosin fluxes, but less active than water-soluble fluxes.

European Commission

Clean technologies for waste minimisation
Final report

Document

Luxembourg: Office for Official Publications of the European Communities

1998 — VIII, 417 pp. — 21 x 29.7 cm

ISBN 92-828-2121-8

Price (excluding VAT) in Luxembourg: ECU 62.50

Venta • Salg • Verkauf • Πωλήσεις • Sales • Vente • Vendita • Verkoop • Venda • Myynti • Försäljning

BELGIQUE/BELGIË

Moniteur belge/Belgisch Staatsblad
Rue de Louvain 40-42/Leuvenseweg 40-42
B-1000 Bruxelles/Brussel
Tél. (32-2) 552 22 11
Fax (32-2) 511 01 84

Jean De Lannoy
Avenue du Roi 202/Koningslaan 202
B-1060 Bruxelles/Brussel
Tél. (32-2) 538 51 69
Fax (32-2) 538 08 41
E-mail: jean.de.lannoy@infoboard.be
URL: http://www.jean-de-lannoy.be

Librairie européenne/Europese Boekhandel
Rue de la Loi 244/Wetstraat 244
B-1040 Bruxelles/Brussel
Tél. (32-2) 295 26 39
Fax (32-2) 735 08 60

DANMARK

J. H. Schultz Information A/S
Herstedvang 10-12
DK-2620 Albertslund
Tlf. (45) 43 63 23 00
Fax (45) 43 63 19 69
E-mail: schultz@schultz.dk
URL: http://www.schultz.dk

DEUTSCHLAND

Bundesanzeiger Verlag
Breite Straße 78-80
Postfach 10 05 34
D-50667 Köln
Tel. (49-221) 20 29-0
Fax (49-221) 202 92 78
E-mail: vertrieb@bundesanzeiger.de
URL: http://www.bundesanzeiger.de

ΕΛΛΑΔΑ/GREECE

G. C. Eleftheroudakis SA
International Bookstore
Panepistimiou 17
GR-10564 Athina
Tel. (30-1) 331 41 80/1/2/3
Fax (30-1) 323 98 21
E-mail: elebooks@netor.gr

ESPAÑA

Mundi Prensa Libros, SA
Castelló, 37
E-28001 Madrid
Tel. (34-1) 431 33 99
Fax (34-1) 575 39 98
E-mail: libreria@mundiprensa.es
URL: http://www.mundiprensa.es

Boletín Oficial del Estado
Trafalgar, 27
E-28010 Madrid
Tel. (34-1) 538 21 11 (Libros)/
384 17 15 (Suscripciones)
Fax (34-1) 538 21 21 (Libros)/
384 17 14 (Suscripciones)
E-mail: webmaster@boe.es
URL: http://www.boe.es

FRANCE

Journal officiel
Service des publications des CE
26, rue Desaix
F-75727 Paris Cedex 15
Tél. (33) 140 58 77 01/31
Fax (33) 140 58 77 00

IRELAND

Government Supplies Agency
Publications Section
4-5 Harcourt Road
Dublin 2
Tel. (353-1) 661 31 11
Fax (353-1) 475 27 60

ITALIA

Licosa SpA
Via Duca di Calabria, 1/1
Casella postale 552
I-50125 Firenze
Tel. (39-55) 64 54 15
Fax (39-55) 64 12 57
E-mail: licosa@ftbcc.it
URL: http://www.ftbcc.it/licosa

LUXEMBOURG

Messageries du livre SARL
5, rue Raiffeisen
L-2411 Luxembourg
Tél. (352) 40 10 20
Fax (352) 49 06 61
E-mail: mdl@pt.lu

Abonnements:

Messageries Paul Kraus
11, rue Christophe Plantin
L-2339 Luxembourg
Tél. (352) 49 98 88-8
Fax (352) 49 98 88-444
E-mail: mpk@pt.lu
URL: http://www.mpk.lu

NEDERLAND

SDU Servicecentrum Uitgevers
Externe Fondsen
Postbus 20014
2500 EA Den Haag
Tel. (31-70) 378 98 80
Fax (31-70) 378 97 83
E-mail: sdu@sdu.nl
URL: http://www.sdu.nl.

ÖSTERREICH

Manz'sche Verlags- und Universitätsbuchhandlung GmbH
Siebenbrunnengasse 21
Postfach 1
A-1050 Wien
Tel. (43-1) 53 16 13 34/40
Fax (43-1) 53 16 13 39
E-mail: auslieferung@manz.co.at
URL: http://www.austria.EU.net:81/manz

PORTUGAL

Imprensa Nacional-Casa da Moeda, EP
Rua Marquês de Sá da Bandeira, 16 A
P-1050 Lisboa Codex
Tel. (351-1) 353 03 99
Fax (351-1) 353 02 94, 384 01 32

Distribuidora de Livros Bertrand Ld.ª
Rua das Terras dos Vales, 4/A
Apartado 60037
P-2701 Amadora Codex
Tel. (351-1) 495 90 50, 495 87 87
Fax (351-1) 496 02 55

SUOMI/FINLAND

Akateeminen Kirjakauppa/Akademiska Bokhandeln
Pohjoisesplanadi 39/
Norra esplanaden 39
PL/PB 128
FIN-00101 Helsinki/Helsingfors
P./tfn (358-9) 121 41
F./fax (358-9) 121 44 35
E-mail: akatilaus@stockmann.mailnet.fi
URL: http://booknet.cultnet.fi/aka/index.htm

SVERIGE

BTJ AB
Traktorvägen 11
S-221 82 Lund
Tfn (46-46) 18 00 00
Fax (46-46) 30 79 47
E-post: btjeu-pub@btj.se
URL: http://www.btj.se/media/eu

UNITED KINGDOM

The Stationery Office Ltd International Sales Agency
51 Nine Elms Lane
London SW8 5DR
Tel. (44-171) 873 90 90
Fax (44-171) 873 84 63
E-mail: jill.speed@theso.co.uk
URL: http://www.the-stationery-office.co.uk

ÍSLAND

Bokabud Larusar Blöndal
Skólavördustig, 2
IS-101 Reykjavik
Tel. (354) 551 56 50
Fax (354) 552 55 60

NORGE

NIC Info A/S
Ostenjoveien 18
Boks 6512 Etterstad
N-0606 Oslo
Tel. (47-22) 97 45 00
Fax (47-22) 97 45 45

SCHWEIZ/SUISSE/SVIZZERA

OSEC
Stampfenbachstraße 85
CH-8035 Zürich
Tel. (41-1) 365 53 15
Fax (41-1) 365 54 11
E-mail: uleimbacher@osec.ch
URL: http://www.osec.ch

BĂLGARIJA

Europress-Euromedia Ltd
59, Bld Vitosha
BG-1000 Sofia
Tel. (359-2) 980 37 66
Fax (359-2) 980 42 30

ČESKÁ REPUBLIKA

NIS CR — prodejna
Konviktská 5
CZ-113 57 Praha 1
Tel. (420-2) 24 22 94 33, 24 23 09 07
Fax (420-2) 24 22 94 33
E-mail: nkposp@dec.nis.cz
URL: http://www.nis.cz

CYPRUS

Cyprus Chamber of Commerce & Industry
Griva-Digeni 38 & Deligiorgi 3
Mail orders:
PO Box 1455
CY-1509 Nicosia
Tel. (357-2) 44 95 00, 46 23 12
Fax (357-2) 36 10 44
E-mail: cy1691_eic_cyprus@vans.infonet.com

MAGYARORSZÁG

Euro Info Service
Európa Ház
Margitsziget
PO Box 475
H-1396 Budapest 62
Tel. (36-1) 111 60 61, 111 62 16
Fax (36-1) 302 50 35
E-mail: euroinfo@mail.matav.hu
URL: http://www.euroinfo.hu/index.htm

MALTA

Miller Distributors Ltd
Malta International Airport
PO Box 25
LQA 05 Malta
Tel. (356) 66 44 88
Fax (356) 67 67 99

POLSKA

Ars Polona
Krakowskie Przedmiescie 7
Skr. pocztowa 1001
PL-00-950 Warszawa
Tel. (48-22) 826 12 01
Fax (48-22) 826 62 40, 826 53 34, 826 86 73
E-mail. ars_pol@bevy.hsn.com.pl

ROMÂNIA

Euromedia
Str. G-ral Berthelot Nr 41
RO-70749 Bucuresti
Tél. (40-1) 210 44 01, 614 06 64
Fax (40-1) 210 44 01, 312 96 46

SLOVAKIA

Slovak Centre of Scientific and Technical Information
Nàmestie slobody 19
SK-81223 Bratislava 1
Tel. (421-7) 531 83 64
Fax (421-7) 531 83 64
E-mail: europ@tbb1.sltk.stuba.sk

SLOVENIA

Gospodarski Vestnik
Zalozniska skupina d.d.
Dunajska cesta 5
SLO-1000 Ljubljana
Tel. (386) 611 33 03 54
Fax (386) 611 33 91 28
E-mail. belicd@gvestnik.si
URL: http://www.gvestnik.si

TÜRKIYE

Dünya Infotel AS
Istiklâl Cad. No: 469
TR-80050 Tünel-Istanbul
Tel. (90-212) 251 91 96
Fax (90-212) 251 91 97

AUSTRALIA

Hunter Publications
PO Box 404
3167 Abbotsford, Victoria
Tel. (61-3) 94 17 53 61
Fax (61-3) 94 19 71 54

CANADA

Subscriptions only/Uniquement abonnements.

Renouf Publishing Co. Ltd
5369 Chemin Canotek Road Unit 1
K1J 9J3 Ottawa, Ontario
Tel. (1-613) 745 26 65
Fax (1-613) 745 76 60
E-mail: renouf@fox.nstn.ca
URL. http://www.renoufbooks.com

EGYPT

The Middle East Observer
41, Sherif Street
Cairo
Tel. (20-2) 393 97 32
Fax (20-2) 393 97 32

HRVATSKA

Mediatrade Ltd
Pavla Hatza 1
HR-10000 Zagreb
Tel. (385-1) 43 03 92
Fax (385-1) 43 03 92

INDIA

EBIC India
3rd Floor, Y. B. Chavan Centre
Gen. J. Bhosale Marg.
400 021 Mumbai
Tel. (91-22) 282 60 64
Fax (91-22) 285 45 64
E-mail: ebic@giasbm01.vsnl.net.in

ISRAEL

ROY International
17, Shimon Hatarssi Street
PO Box 13056
61130 Tel Aviv
Tel. (972-3) 546 14 23
Fax (972-3) 546 14 42
E-mail royil@netvision.net.il

Sub-agent for the Palestinian Authority:

Index Information Services
PO Box 19502
Jerusalem
Tel. (972-2) 627 16 34
Fax (972-2) 627 12 19

JAPAN

PSI-Japan
Asahi Sanbancho Plaza #206
7-1 Sanbancho, Chiyoda-ku
Tokyo 102
Tel. (81-3) 32 34 69 21
Fax (81-3) 32 34 69 15
E-mail: psijapan@gol.com
URL: http://www.psi-japan.com

MALAYSIA

EBIC Malaysia
Level 7, Wisma Hong Leong
18 Jalan Perak
50450 Kuala Lumpur
Tel. (60-3) 262 62 98
Fax (60-3) 262 61 98
E-mail: ebic-kl@mol.net.my

PHILIPPINES

EBIC Philippines
19th Floor, PS Bank Tower Sen.
Gil J. Puyat Ave. cor.Tindalo St.
Makati City
Metro Manilla
Tel. (63-2) 759 66 80
Fax (63-2) 759 66 90
E-mail eccpcom@globe.com.ph

RUSSIA

CCEC
60-letiya Oktyabrya Av 9
117312 Moscow
Tel. (70-95) 135 52 27
Fax (70-95) 135 52 27

SOUTH AFRICA

Safto
5th Floor Export House,
CNR Maude & West Streets
PO Box 782 706
2146 Sandton
Tel. (27-11) 883 37 37
Fax (27-11) 883 65 69

SOUTH KOREA

Kyowa Book Company
1 F1. Phyung Hwa Bldg
411-2 Hap Jeong Dong, Mapo Ku
121-220 Seoul
Tel. (82-2) 322 67 80/1
Fax (82-2) 322 67 82
E-mail: kyowa2@ktnet.co.kr.

THAÏLANDE

EBIC Thailand
Vanissa Building 8th Floor
29 Soi Chidlom
Ploenchit
10330 Bangkok
Tel. (66-2) 655 06 27
Fax (66-2) 655 06 28
E-mail: ebicbkk@ksc15.th.com

UNITED STATES OF AMERICA

Bernan Associates
4611-F Assembly Drive
MD20706 Lanham
Tel. (800) 274 44 47 (toll free telephone)
Fax (800) 865 34 50 (toll free fax)
E-mail: query@bernan.com
URL: http://www.bernan.com

ANDERE LÄNDER/OTHER COUNTRIES/ AUTRES PAYS

Bitte wenden Sie sich an ein Büro Ihrer Wahl / Please contact the sales office of your choice / Veuillez vous adresser au bureau de vente de votre choix

NB. Country order EU, EFTA, EU applicant countries, others

CR-09-97-325-EN-C

Price (excluding VAT) in Luxembourg: ECU 62.50

ISBN 92-828-2121-8

9 789282 821213

OFFICE FOR OFFICIAL PUBLICATIONS
OF THE EUROPEAN COMMUNITIES

L-2985 Luxembourg