



**United Nations  
Environment  
Programme**



Distr.  
GENERAL

UNEP/CHW.6/21  
23 August 2002

ORIGINAL: ENGLISH

---

CONFERENCE OF THE PARTIES TO THE BASEL  
CONVENTION ON THE CONTROL OF  
TRANSBOUNDARY MOVEMENTS OF  
HAZARDOUS WASTES AND  
THEIR DISPOSAL

Sixth meeting

Geneva, 9-13 December 2002

Item 6 (e) (ii) of the provisional agenda\*

CONSIDERATION OF THE IMPLEMENTATION OF THE BASEL CONVENTION

TECHNICAL MATTERS: PREPARATION OF TECHNICAL GUIDELINES

Technical guidelines for the identification and environmentally  
sound management of plastic wastes and for their disposal

Note by the secretariat

I. BACKGROUND

1. In its decision V/26 on the work programme of the Technical Working Group, the Conference of the Parties to the Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and their Disposal, meeting in its fifth meeting, adopted the work programme which provided, inter alia, for the finalization of the technical guidelines for the identification and environmentally sound management of plastic waste and for its disposal.

II. IMPLEMENTATION

2. At the sixteenth session of the Technical Working Group held in April 2000, experts had divergent views regarding the structure of the draft guidelines and on the inclusion of PVC wastes and other halogenated wastes in a separate chapter. It was then decided that the secretariat should prepare a revised draft taking into account additional written comments.

---

\* UNEP/CHW.6/1.

K0262466 160902

3. At its seventeenth session in October 2000, the Technical Working Group requested the secretariat to revise the draft technical guidelines making use of input from work carried out in other forums, including the European Commission's Green Paper and the studies associated with it. Other experts expressed concern over the reference to PVC in the guidelines and over matters related to the management of those wastes. During the eighteenth session of the Technical Working Group in June 2001 several delegations were of the opinion that the technical guidelines were ready for adoption and requested specific and technical comments to improve the document further.

4. The Technical Working Group at its nineteenth session in January 2002 considered the up-dated draft of the technical guidelines for the identification and environmentally sound management of plastic wastes and for their disposal, as contained in the annex to the present note and adopted it. The meeting also agreed that the secretariat finalize the draft technical guidelines adopted by the Technical Working Group, with a view to forwarding it to the Conference of the Parties at its sixth meeting for its consideration and eventual adoption.

### III. PROPOSED ACTION

5. At its sixth meeting, the Conference of the Parties may wish to consider adopting a decision along the following lines:

The Conference,

Welcoming the adoption of the technical guidelines for the identification and environmentally sound management of plastic wastes and for their disposal,

Noting with appreciation the roles played by Parties, non-governmental organizations and industry in the preparation of the technical guidelines,

1. Adopts the technical guidelines for the identification and environmentally sound management of plastic wastes and for their disposal contained in document UNEP/CHW.6/21;

2. Requests the secretariat to disseminate them to Parties, non-governmental organizations and industry in all United Nations languages as appropriate;

3. Invites Parties, non-governmental organizations and industry to use the technical guidelines.

Annex

**Technical Guidelines for the Identification and Environmentally Sound Management  
of Plastic Wastes and for their Disposal**

**Including:**

**Technical Guidelines on the Environmentally Sound Management of Plastic Coated Cables**

## CONTENTS

### I. Technical Guidelines for the Identification and Environmentally Sound Management of Plastics Wastes and for their Disposal

1.	Introduction .....	7
2.	Common types of plastics and their composition.....	8
3.	Sources of plastic waste .....	11
	3.1 Pre-user plastic waste .....	12
	3.2 Post-user plastic waste .....	13
4.	Environmentally sound and safe handling, compaction, transport, storage and shipping of plastic waste.....	14
	4.1 Environmentally sound and safe handling .....	15
	4.2 Compaction .....	15
	4.3 Transport .....	16
	4.4 Storage .....	16
	4.5 Shipping for recycling .....	16
5.	Health and safety issues .....	17
6.	Fire safety .....	18
7.	Second life applications for plastics materials .....	19
	7.1 Selective collection of plastic wastes .....	19
	7.2 Sorting for mechanical recycling .....	21
	7.3 Mechanical recycling .....	23
	7.4 Plastic recycling in practice.....	23
	7.5 Feedstock recycling.....	28
	7.6 Main blocking factors affecting the collection and recycling of plastic waste .....	29
8.	Energy recovery from plastic wastes.....	31
9.	Final disposal of plastic wastes.....	35
10.	Conclusions .....	36

### II. Technical Guidelines on the Environmentally Sound Management of Plastic Coated Cables Scrap

1.	Introduction .....	37
2.	Movement of cable scrap between countries .....	37
3.	Sources of scrap .....	37
4.	Use of plastics in cable manufacture .....	38
5.	Structure of the scrap processing industry.....	38
6.	Environmentally sound recycling processes .....	38
	6.1 Capability .....	38
	6.2 Cable chopping process description .....	39
	6.3 Cable stripping .....	41
7.	Sound environmental management of the plastic fraction in cable scrap .....	42
	7.1 Mechanical separation of tailings.....	42
	7.2 Cryogenic processing .....	42
	7.3 Sink and float (hydrogravimetric) processing .....	43

8.	Incineration.....	43
9.	Landfilling .....	44

## List of Tables

1.	Common polymers .....	9
2.	Typical plastics additives .....	10
3.	Basel Convention constituents of plastics .....	10
4.	UV Exposure and degradation of resins and virgin polymer .....	16
5.	Comparison of drop-off and kerbside collection.....	20
6.	Outline of separation and identification techniques of plastic .....	21
7.	Main blocking factors affecting collection and recycling .....	30
8.	Review of technologies for the recycling of plastic waste .....	30
9.	Fuel values of plastics wastes, mixtures and traditional fuels .....	32
10.	Use of neutralisation agent and production of residues due to incineration of PVC waste.....	34
11.	Use of Plastic insulation in cable products, 1997.....	37

## List of Figures

1.	Integrated approach to waste management.....	7
2.	Segregation of mixed Plastics at a Bottle Recycling Plant .....	24
3.	Mechanical recycling of post-user plastic waste by resin (Western Europe, 1997) .....	28
4.	Chemical recycling (themolysis) of plastic waste, basic principle .....	29
5.	Cable Scrap Process Flow Sheet .....	41

## List of Appendices

1.	References .....	45
2.	Plastics production and recycling flow sheet.....	47
3.	Health and safety information for plastics reclamation sites .....	48
4.	Data from fires at recycling plants .....	53
5.	Further information concerning fluoro-polymers.....	55
6.	Glossary of terms.....	56
7A.	Plastics identification marks .....	60
7B.	Plastics identification and marking for packaging .....	64
8.	European limits for Air Emissions for Incineration .....	65
9.	Address for more information on recycling.....	66
10.	Specification for cable and wire scrap .....	72
11.	Flowsheet on the separation of four plastics.....	73
12.	Type and quantity of plastic wastes for various processing methods .....	74
13.	Data of resin production world wide and plastic wastes in Europe.....	75

## **FOREWORD**

*The technical guidelines for the identification and environmentally sound management of plastic wastes and for their disposal aim at assisting common understanding and providing management advice, in particular, to the Parties to the Basel Convention for which the use of plastics is increasing. This document focuses mainly on the technical aspects of the management of plastic wastes, with particular emphasis on their recycling.*

*The environmental and health impacts of plastic wastes are not addressed thoroughly in the context of this document but introductory elements are provided. The generation of hazardous wastes in the context of the production of plastics and, in particular the classification of PVC, is also not addressed in this document.*

*These technical guidelines should be considered in conjunction with other technical guidelines adopted by the Conference of the Parties to the Basel Convention and governing the environmentally sound recovery and disposal of wastes, in particular, the Technical Guidelines for Incineration on Land (D10), Specially Engineered Landfill (D5), and on Wastes Collected from Households (Y46).*

*In addition, special regard should be given to the legal frameworks and the responsibilities of the relevant competent authorities.*

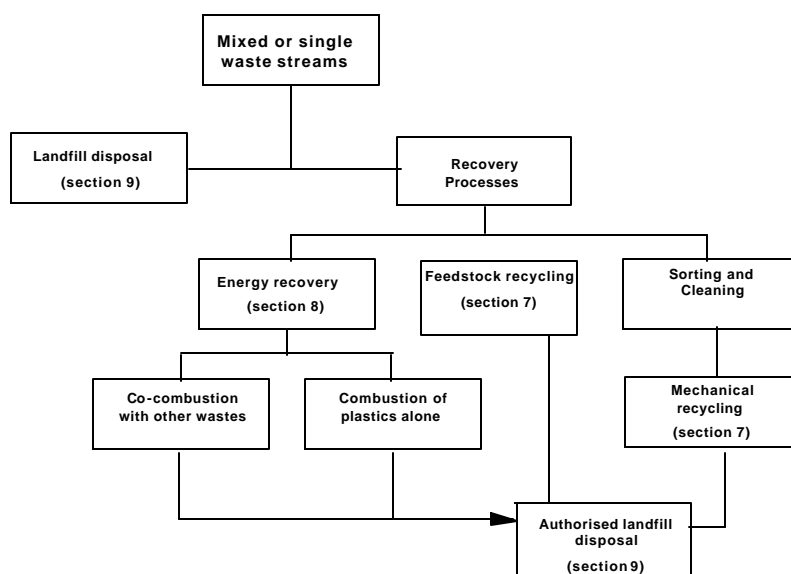
*This document has been prepared by the Technical Working Group of the Basel Convention. It is the result of the productive cooperation between the Parties to the Basel Convention, signatories and other states, industry and non-governmental organizations.*

## 1. Introduction

These technical guidelines provide general guidance on the identification, environmentally sound management and disposal (recovery<sup>a</sup> and final disposal<sup>b</sup> of plastic wastes). Normally, Basel Convention technical guidelines apply to those wastes which fall under Annex I of the Convention and possess any of the characteristics of Annex III, as well as to household wastes (Y46) listed under Annex II of the Convention which require special consideration. These technical guidelines have been deliberately extended to include all polymer and plastic types, not just those having an Annex I constituent (Y1 to Y45).

Waste management policy focuses on waste hierarchy giving priority to wastes prevention or reduction (including the elimination of impediments and distortions that encourage the over-production of wastes) followed by re-use, recycling, recovery and residual management. Such a strategy includes an integrated approach to waste management (see Figure 1) with an emphasis on material recycling.

Waste prevention or reduction involves both upstream alterations in product design as well as alterations in consumer habits. Such strategies assure that either or both the objectives of less waste (quantity) is produced and/or less hazardous constituents (quality) are utilized in production so that less hazardous wastes is generated. Waste prevention is a strategy that prevents waste and its associated risks from being produced in the first place.



1

**Figure 1. Integrated approach to waste management**

These technical guidelines provide technical information regarding:

- (a) Various common plastics and their composition;

<sup>a</sup> Recovery means the operations in Annex IV B of the Basel Convention

<sup>b</sup> Final disposal means the operations in Annex IV A of the Basel Convention

<sup>c</sup> For further information consult OECD Reference Manual on Strategic Waste prevention [ENV/EPOC/PPC (2000) 5/FINAL]

- (b) Labelling, safe handling, compaction, storage and transport of plastic wastes;
- (c) Environmentally sound recycling, recovery and final disposal of plastic wastes.

It was only in the 1950s that plastics began to come into wide use, yet within a few years, production rose at an unparalleled rate. World consumption is now comparable with that of all non-ferrous metals. The forecasts concerning the production of resins (see Appendix 13) give an indication of the importance of the amounts of plastic wastes both developed and developing countries will have to manage in the years to come, including the plastics with long working lifetime produced some decades ago and which are about to reach the end of their life span.

There are still technical, economic and structural problems to be overcome. The most intractable problem so far relating to plastics and the environment has been their disposal. In developed countries, approximately three quarters of plastics are landfilled, while the last quarter is recovered in the form of either new materials or useful energy. This recycling rate has been achieved to date through the use of legal and/or economic instruments. Hence, the potential for plastic waste recycling remains vast.

Landfilling on one hand is increasingly seen to pose problems of environmental impact, as the availability of suitable sites decreases. Questions are arising about the leaching of plastic additives into ground waters. On the other hand, uncontrolled burning of municipal solid waste (MSW) on dump sites is environmentally unacceptable. The controlled incineration of plastic waste is also raising concerns in some cases.

While for some materials recovery equates with recycling, for plastics there is a full range of recovery options available: material recycling (mechanical recycling or feedstock recycling), incineration with energy recovery, use as an alternative fuel source replacing traditional fuels for power generation or for material production. Post-user plastics present problems of identification, separation and also contamination. But where sufficient volumes of readily classifiable materials are available, recycling is successfully achieved.

Technical information on the environmentally sound management of plastic waste is critical for Parties to the Basel Convention, in particular developing countries, to prepare adequate programmes and policies in this field. In this regard, environmentally sound management is defined in the Basel Convention as taking all the practicable steps to ensure that hazardous wastes or other wastes (Annex II) are managed in a manner which will protect human health and the environment against adverse effects which may result from such wastes. Article 4 of the Convention also commits the Parties to minimise the generation of hazardous wastes and other wastes.

Many uses of plastics have a very long working lifetime and end-of-life plastics can often be recycled into a second-life application. The use of plastics can mean that:

- less material is used in a given application (e.g. packaging reduced by up to 80% over the last 20 years; due to better protection by packaging, less content is lost as waste),
- less energy is used in production than traditionally (e.g. conversion to low energy intensive plastics),
- less fuel is used in transport and handling (e.g. plastics in packaging and in cars),
- less pollutants are produced in manufacture and use,
- less end-of-life waste is produced (e.g. in volume and weight compared to traditional materials such as metal or glass).

Plastics have many benefits such as low permeability, resistance to chemicals, to impact, to moisture and to fire. Nevertheless the production, processing and use of plastics do generate wastes. It is essential that these wastes are properly managed to protect people and the environment; hence these guidelines.

## **2 Common types of plastics and their composition**

The elements most commonly found in plastics are carbon, hydrogen, nitrogen, oxygen, chlorine, fluorine and bromine. Some of these elements are hazardous when uncombined but become inert when incorporated into an organic polymer. The polymer types most likely to be available as plastic waste are listed in Table 1.



(Thermoset as opposed to thermoplastics, will generally not be found, unless at very low levels, in most plastics waste for recycling. That is why they are not taken into consideration in these guidelines.)

**Table 1: Common polymers**

<b>Polymer</b>	<b>Typical Applications</b>	<b>Typical Lifetime Range</b>
high density polyethylene (PE-HD)	packaging & industrial film, bottles, tubs, cups, closures, toys, tanks, drums, milk & beer crates, cable insulation, pipes, gasoline tanks, shipping containers, seating	up to 2 years up to 30 years
low density polyethylene (PE-LD,PE-LLD)	packaging film, cling-film, bags/sacks, lids, toys, coatings, flexible containers, tubing, irrigation pipes,	up to 2 years up to 5 years up to 20 years
polyester (PET)	bottles, food packaging film, strapping, recording tapes, carpets, vehicle tyre cords, fibres	up to 5 years up to 10 years
polypropylene (PP)	yoghurt & margarine pots, sweet & snack wrappers, packaging films, bottles/caps automotive battery cases, parts & body components, electrical components, carpet pile and backing	up to 5 years up to 10 years 15 years +
polystyrene (PS)	packaging applications, dairy product containers, cups & plates electrical appliances, tape cassettes,	up to 5 years up to 10 years
expanded polystyrene (EPS)	shock resistant packaging, cups & plates thermal insulation, building components,	up to 5 years up to 30 years
polytetrafluorethylene (PTFE)	cable insulation, heat -resistant coatings, electrical components, corrosion resistant fittings and seals	up to 30 years
polyvinylchloride (unplasticised PVC -U) (foamed PVC-E) (plasticised PVC-P)	<b>PVC-U</b> , window & door frames, ducting, water supply & drainage pipes, rainwater goods, <b>PVC-E</b> building components, building facades <b>PVC-P</b> flooring, cable & wire insulation, medical tubing & bags, shoes, cling film, food packaging, beer & milk & food processing tubing, concentrated chemicals packaging	up to 50 years up to 50 years up to 50 years up to 5 years

To meet the wide range of needs of polymer applications, there are sub-groups of polymers within these general classifications. Very few basic polymers (also known as resins) are processed or used alone and most plastics are a blend of polymers and additives so as to provide exactly the properties required for a particular application (see also Appendix 2). Thus:

**Plastics = Polymers + Additives**

In this respect, polymers are no different to steel or glass where a generic name covers many different formulations. The various types and quantities of additives are included in the polymer matrix. The use of additives, such as stabilisers against heat, light, or oxygen contained in air, allow for an extended product life or for specific applications (e.g. film for food wrapping, window frames, pipes, etc.) Typical additives are listed in Table 2.

**Table 2: Typical plastics additives**

<b>Material</b> (see Glossary - <b>Appendix 6</b> for explanation of purpose)	<b>Concentration range</b>
Antioxidants	up to 1%
Fillers	up to 40%
Foaming agents	up to 2%
Impact resistance enhancers/tougheners	up to 10%
Pigments and dyestuffs	up to 5%
Plasticisers	up to 40%
Heat/light stabilisers	up to 5%
Flame retardants	up to 15%

Some additives or plastics / polymers (see Table 3) appear among the material types which are found in the Annex 1 to the Convention.

**Table 3: Basel Convention Constituents**

<b>Constituent</b>	<b>Chemical name</b>	<b>Remarks</b>	<b>Content (% by weight)</b>
Y13	Waste from production, formulation and use of resins, latex, plasticisers, etc.	Resins (plastics without additives)	100% Resins
Y21	Hexavalent chromium compounds	minor constituent of pigments	Chromium up to approx. 0.3%
Y23	Zinc Stearate	lubricant/stabilizer	Zinc < 0.2%
Y26	Cadmium sulphides or stearates	pigments or heat stabilisers	Cadmium up to approx. 0.2%
Y27	Antimony oxide	fire retardant	Antimony, up to approx. 2%
Y31	Lead sulphates or phosphites	Heat or light stabilisers	Lead < 2.5%
Y45	Organo halogen compounds other than substances referred to in this Annex	Halogenated polymers	The halogen content caught in the polymer/plastic matrix will vary with its structure

PVC is the polymer employing the widest range of types and quantities of additives, the most important of which are stabilisers and plasticisers.

Lead stabilisers are the most commonly used. Cadmium stabilisers are been used in several applications, but are increasingly being replaced. Alternatives for lead stabilisers are increasingly becoming available as well. The most important application of both lead and cadmium is in batteries and accumulators. Nevertheless, stabilizers in PVC are an important application of lead.

Plasticisers in PVC are for nearly 90% phtalates. The use of phtalates is for 90% in PVC applications.

Some plastics contain flame retardants as an additive. The known products are antimony oxides, phosphata esters, MCCP (medium chain chlorinated paraffins) or BFRs (brominated flame retardants). Brominated Chemicals are the most widely used flame retardants for plastics in order to meet fire safety UL 94 standards. BFRs are used in particular in electrical and electronic appliances, coatings, automotive parts, coated textiles, furniture, building materials and packaging.

The total demand for brominated flame retardant chemicals is estimated at 150,000 tonnes per annum<sup>(1)</sup>. In June 1995 a voluntary industry commitment has been signed by the US and European producers covered under OECD's Risk Reduction Programme. The three most studied groups of families of BFRs are polybrominated biphenyls (PBBs), polybrominated diphenyl oxides (PBDOs), and tetrabromo-bisphenol A (TBBPA).

The additives listed are included in the polymer matrix. That matrix can be broken, for example at high temperatures (e.g. controlled incineration) or pressures. Certain additives listed in table 2 may be released from the polymer matrix during use as well as during disposal.

The composition of plastic waste does not only depend on the intrinsic composition of the different plastics included, but it may also contain certain impurities or contaminations. These may depend on the type of application of the plastic, the waste-generation process or the way the plastic waste is collected. For example, plastic food packaging may still contain food residues, films used in agriculture may contain high percentages of soil and plastic waste from cables may contain residual metal. When plastic waste is submitted to a treatment there is a need to take into consideration both the intrinsic composition of plastic as well as the contamination with foreign agents (see also section 6). Presence of these impurities and contaminations may influence the possibilities to manage the waste in an environmentally sound manner and should be addressed in an appropriate way.

### **3. Sources of plastic waste**

The total amount of plastic waste generated is considerably less than the amount of plastics produced. This is attributed to those applications in which plastics meet long term requirements before their disposal and therefore do not yet occur in the waste stream in big quantities.

The majority of plastic wastes come from the post-consumer market. Post-consumer wastes in OECD countries are found mainly in municipal solid waste (MSW), as well as in the following economic sectors: distribution and large industry, agriculture, construction and demolition, automotive, electronic and electric (see Appendix 13 the case of Western Europe, 1999). The characteristics and then subsequently the treatments of pre and post-consumer wastes are different.

Pre-consumer plastic wastes, which generally account for less than 10%, are generated during the manufacture of virgin plastic from raw materials (oil, natural gas, salt, etc) and from the conversion of plastics into plastic products. The criteria mentioned below for reuse or recycling of plastics are not there to indicate a hazard but rather to promote sound recovery and recycling. For the flow sheet of plastics production and recycling see Appendix 2.

### **3.1 Pre-consumer plastic waste**

The wastes generated by resin manufacturers are often usable. These can often be recovered and sold, although some intermediate grinding or other processing may be required. However, there are sources of plastic waste which are unsuitable as raw material for any process. This may be the case with:

- composite materials
- plastics that are too degraded and which cannot achieve the required properties for either processing or as a by-product
- contaminated wastes (e.g. floor sweepings)

Conversion industries are the usual source of these wastes. Appendix 12 lists the typical types and quantities of plastic wastes for different manufacturing processes. Overall, pre-user plastic waste tends to be well utilized. The limitation on recycling these wastes seems to be the quality of the material itself, not the lack of technology available to handle them.

#### **Polymer production**

While the industry strives to produce only first-grade material, it is likely that a small proportion of base polymer will be off-specification and unsuitable for the intended customer. This polymer may nevertheless find a proper usage in other specified applications, where it:

- meets regulatory limitations on monomer content and/or contaminants
- is blended with appropriate additives and complies with local regulations
- contains additives necessary to match the end-application

#### **Polymer compounding**

The process of compounding polymers with additives may give rise to material outside the specification required by one customer but suitable for other applications. The exact formulation or recipe of the quantities of resin(s) and different additives, may not have been respected, and a non specification material may have been used. This will result in the wrong colour, hardness or processing characteristics. Before recycling it is essential to ensure that such polymer compounds:

- are of known formulation, suitable for the new application
- are processed under appropriate conditions for that formulation
- meet regulatory composition requirements for the proposed application
- are single grades or a known mixture of closely related grades

#### **Plastics conversion (transformation)**

Moulding and extrusion factories may produce waste materials from start-up, shut-down and running conditions which cannot be re-used on-site because of quality or specification limitations. These waste materials might need to be shredded before being reused.

Such materials may nevertheless be used in other applications. It is essential to ensure that such wastes:

- are of known formulation
- are used in an appropriate application
- are processed under appropriate conditions for that formulation
- are not contaminated or degraded so as to make them unsuitable for processing
- are a single grade or a mixture of closely related grades, conditioned to the standards required for related virgin material

### **Plastics component assembly or installation**

Some plastics are supplied as semi-finished goods. When they are processed there are scraps or off-cuts which can be recycled into the same or alternative applications. For example, the off-cuts from PVC-U window frame assembly can be recycled into new window frames or into conduit and ducting. Off-cuts from the forming of cups from PS sheet can be recycled into cups or into cassette cases for example. The installation of PVC or PE pipes, ducting or rainwater goods will also give rise to recyclable off-cut material which can be recycled into pipes or ducting.

Such recyclates will perform best when:

- the wastes are sorted into individual types free from dirt
- foam materials are kept separate from solid grades
- processing conditions are chosen to take account of the processing history of the waste

### **3.2 Post-consumer plastic waste**

Plastics components often come to the end of their first-life application with the character of the plastics material substantially unchanged. Pre-consumer wastes are typically clean, segregated from other resins, physically close to the point where they can be recycled and well characterized in terms of origin and physical properties, but this is generally not the case for post-user plastic wastes. In addition, post-consumer wastes are often in the form of composite materials, in particular mixtures of different plastics and/or plastics and non-plastic waste. To be recycled, the plastic(s) must first be cleaned and separated into homogeneous materials. These factors contribute to the increased difficulties and costs of recycling post-user wastes when compared to pre-user wastes.

An increasing number of countries are enacting legislation requiring that end-of-life plastics be recovered for recycling. The return of end-of-life components to suppliers may also form part of commercial transactions. Extracting the plastics from equipment at the end of its life may be difficult and expensive but such materials can be recycled.

In Appendix 13, the example of Western Europe for 1994 is given in terms of generation of post-consumer plastic waste by source of waste and resin as well as for plastic packaging waste (by type).

Each source of waste has its own specificity, such as:

- municipal solid waste (MSW) and agricultural plastic waste are geographically more dispersed than distribution waste
- agriculture sector waste or distribution waste have a better material homogeneity than MSW or automotive waste
- construction/demolition waste or MSW are more polluted than electrical and electronics plastic waste

The four main plastics (PE, PP, PVC, PS) represented in Western Europe about 80% of the total plastics waste stream. Packaging products represented 55% of 1994 total plastic waste generated in Western Europe (Appendix 13).

### **Municipal/Domestic waste**

Municipal/domestic waste is in Category Y46 of Annex II of the Basel Convention and is regarded as 'a waste requiring special consideration'. Municipal Solid Waste (MSW) has only a low plastics concentration (around 8%). It is not directly the concern of this guideline but some Parties have in place waste legislation which requires that households, commerce and industry separate and collect plastics for recycling, which would otherwise be part of MSW. These materials are recyclable and may then be transported across boundaries for recycling. They will require sorting into separate polymer streams and cleaning before they can be satisfactorily recycled.

Of the plastics in MSW, it is estimated that 41% is PE, 18% is PP, PS/EPS and PVC are both estimated at 9% and 7% is PET (1993 figures for western Europe, Appendix 13). In general, household plastics consist of a mixture of various materials which are difficult to identify.

Examples of end-of-life plastics include:

Potable water and drainage pipes	PVC-U, PE-HD
Cable/cable insulation	PE-LD, PE-HD, PVC-P, PTFE
Window frames and construction off-cuts	PVC-U, PVC-E
Computer enclosures & keyboard frames	PVC-U, PS
Bottles	PET, PE-HD, PVC-U
Packaging film	PP, PE-LD, PE-HD, PVC-U, PVC-P

### **Commercial and large industrial plastic wastes**

This sector produces amounts of plastic wastes second only to MSW. It includes bags, drums and containers for the food and chemical industries, packaging films, discarded industrial equipment, crates, etc. The major plastics used include PE, PP, PS and PVC. In this sector collection of well-defined materials is easier than from households.

### **Agriculture plastic waste**

The agricultural sector in Western Europe uses PP, PE and PVC plastics, which generally have a short to medium life-span. Examples of short-lived products are plastic film for covering greenhouses and fertilizer sacks. Products with a medium life span are irrigation pipes and valves, containers, drums and tanks.

### **Construction / demolition plastic waste**

The construction industry in Western Europe uses predominantly PE and PVC plastics (Appendix 13). The construction sector typically uses plastics in applications for much longer than any other major industry sector, making it difficult to estimate the waste generated based on consumption. Construction industry sources have established that 10% of current consumption as a reasonable estimate of generated waste.

## **4 Environmentally sound and safe handling, compaction, transport, storage and shipping of plastic waste**

All plastics wastes can be recycled. The potential for recycling and the value (i.e. economically and in its application) of plastics are increased if plastic wastes are sorted by the type of plastics. Nevertheless, mixed plastics can be recycled but have fewer applications at present time and can seldom substitute virgin plastics.

#### 4.1 Environmentally sound and safe handling

Waste materials of all kinds - whether hazardous or not - need to be handled so as to minimise risk to human health. Waste from the polymer manufacturing and blending processes is most likely to be shipped in the form of powders or granulates contained in big bags or bulk containers. Waste from end-of-life applications is likely to be in bulky form, which requires compaction into baled or bagged material, as in many industrial activities. Employees should be supplied with appropriate protective clothing; they should also be trained in the safe handling of large/heavy containers and they should be equipped with handling equipment such as sack-barrows, pallet trucks and fork-lift trucks. The type of detailed guidance on environmentally sound and safe handling provided to managers of plastics sorting and recycling enterprises in the UK is illustrated in Appendix 3.

#### 4.2 Compaction

Plastic residues from semi-finished product conversion, packaging wastes and end-of-life wastes may be bulky and may contain more than one type of plastic wastes. For economical transport and storage some compaction is necessary. The commonest compaction processes are baling and shredding.

Shredding may be either a dry or a wet process. Wet shredding is used not only to achieve compaction but also to begin the process of cleansing the plastics residues from paper labels, glue and dirt. While both baling and shredding are established processes, each requires properly trained and equipped employees. Wherever possible, sorting into single product streams should be undertaken before the compaction process.

Mixed plastics and single plastic waste streams can be shredded but the following should be noted for environmentally sound and safe operations:

- some markets will not accept shredded material because quality standards beyond common sorting processes are required
- the shredder must be constructed and installed so as to protect the operator from flying fragments, entangling film waste and noise
- the shredder must be protected from metallic contamination by metal detector/removal systems
- mixed plastics residues should only be shredded if there is an assured application for the mixed product or if a post-shredding sorting system is available to produce single material streams of acceptable quality
- before shredded material is re-processed it must be dried/conditioned to the specifications used for virgin material

Baling is suitable for component, film and bottle wastes. It has the advantage that post-compaction sorting is a simple low-technology process. Safe and efficient baling requires attention to the following:

- over-compaction of baled plastics waste may weld the waste together in a solid mass very difficult to separate again
- compacted bales contain a great deal of energy. The rust-resistant steel or polyester strapping must be strong enough to contain the long-term load of the compacted material.
- care should be taken when opening bales to avoid injury caused by the sudden release of energy
- under-compacted bales will be unstable
- bales should only be handled by means of a pallet truck or fork-lift truck

### 4.3 Transport

The transport of baled or shredded plastics residues requires considerable attention to the stability and protection of the load. Bales and bags should be stacked no more than 2.5 metres high and the load should be secured either with strong ropes or tarpaulins. Loads should be protected from weather and vandalism in transit. When unloading plastics waste, particular care should be taken to ensure the safety of workers.

### 4.4 Storage

Ideally, all plastics for recycling in shredded or baled form should be stored on clean concrete floors. If plastic waste is stored indoors, sprinkler fire-prevention system should be available to prevent large fires and ease fire fighting if a fire were to occur. If plastic waste is stored outdoors then it should be protected from contamination or weather damage by means of tarpaulins or black polyethylene film. Contamination of plastics from dust and earth can be avoided by the use of pallets. Stacking should be strictly limited in height (e.g. no more than 3 bales high) to avoid hazard to employees if a bale falls. Polymers degrade with prolonged exposure to ultraviolet light, resulting in the deterioration of the physico chemical properties of the plastic.

Polymers stored outside should be covered with a UV-protective material. The need for protection varies according to virgin polymer as indicated in table 4. Additives can be added to virgin polymer to make them more resistant to UV exposure.

**Table 4: UV Exposure and Degradation of Resins/Virgin Polymer**

<b>Resins/Virgin Polymer</b>	<b>Maximum Unprotected Outside Storage</b>
PET	6 months
PE-HD	1 month
PVC	6 months
PE-LD	1 month
PP	1 month
PS	6 months
PTFE	Indefinite

Storage space should not be completely occupied by plastic wastes. There should be access to all areas for material handling equipment and also for emergency services vehicles. There should be many wide exit paths from the storage area for employees and they should be well marked and easy to find. The storage area should be secured against unauthorised entry and fire-fighting equipment should be readily available (see Section 7: Fire Safety). These precautions are similar to those for many other materials.

### 4.5 Shipping for recycling

Plastic wastes destined for recycling should only be shipped:

- appropriately packaged, such as bales for compacted materials or containers or bags for shredded material, to protect the materials in transit. The packed materials should meet the safe handling requirements of the receiving Party.
- when clearly labelled with the type of material, the point of origin and the name of a responsible contact at the despatching organisation
- when the customer has already received documentation which includes, the type or types of plastic wastes to be shipped and the appropriate handling instructions
- Packaging and shipments should be done according to the Guidelines of the UNCETDG. Plastics and plastic packaging do not need to be labelled according to UNCETDG guidelines because they are not considered as dangerous goods.



## 5. Health and safety issues

To ensure that clean plastics wastes are dealt with safely and efficiently, both the supplier and receiver of the materials should ensure that the following information is available, when required:

- the identity, quality and form of the shipment
- the safe handling instructions appropriate to the materials
- the protective clothing that should be worn by employees, including eye and ear protection, gloves, protective footwear, filter masks and hard hats, depending on the processing to which the material is subjected
- the safe storage of the compacted materials including mechanical handling equipment, stack heights/stability and stack spacing
- fire prevention, fire fighting, fire extinguishers, emissions from burning wastes, advice to fire fighters, means of dealing with fire residues

Contaminated plastic wastes may be a major or a minor hazard depending on the contaminant. Plastic wastes contaminated with dangerous substances, such as pesticides (Y4), should not be shipped to other parties for recovery but should, if possible, be retained in the country of origin for treatment there. The same applies to packaging of other dangerous substances.

To improve the knowledge regarding possible risk due to contamination, the origin of the waste and information on how the waste is generated will help improve recycling and reduce risk to employees. During the handling of packaging coming from the agriculture sector the presence of pesticides is of particular concern. Should no safe treatment be available in the country of origin then shipment to another party with appropriate facilities should only be allowed where it is acceptable under local or international regulations.

Contaminated plastics such as packaging of pesticides or other dangerous chemicals should be handled with specific care. It can constitute a hazardous waste, depending on the type and amount of contamination, in which case the waste should be treated according to the requirements for hazardous waste.

This may involve adequate packaging and labelling in accordance with the Guidelines of the UNCETDG. Such wastes may not be shipped as if it were included in Annex IX of the Basel Convention and the appropriate procedures should be followed in case of transboundary movement.

In certain cases it may be possible to remove contamination via a decontamination process. After an adequate decontamination process the plastic waste may be processed with technologies similar to those suitable for non-contaminated plastic waste, provided it is assured that the decontamination process has been effective. Residues from the decontamination process, in which the contaminants are concentrated, should be treated or be disposed of in an appropriate way. Waste water from these processes may require treatment according to local legislation.

Plastic wastes contaminated only lightly with traces of non-hazardous materials, such as food or drink for example, represent a risk similar to those for most other commercial shipments. When contaminated with larger quantities of food residues problems with micro-organisms, odour and attraction of pests may occur.

Reprocessing in another country may be carried out safely if the appropriate equipment and expertise are available and if local regulations permit. It is the responsibility of BOTH the supplying and the receiving parties to ensure that they are fully informed about the type of material and the nature of the contamination.

The following should be noted, whenever possible:

- Healthcare and biomedical wastes should not be shipped for recycling but should be retained in the country of origin for safe final disposal by incineration or other authorised<sup>(2)</sup> destructive technique
- Plastic containers used to supply hospitals with sterile water and other aqueous solutions may safely be recycled provided they have been kept separated from medical/clinical wastes
- Clean plastic wastes may become contaminated with water, insect pests and dirt during shipping and storage if not properly protected
- Plastic wastes suspected by the receiving party to be contaminated with hazardous substances should NOT be processed but should be returned in a safe manner to the supplying party or to another party with the appropriate authorised facilities

For handling of plastic wastes from healthcare facilities the technical guidelines on environmentally sound management of biomedical and healthcare wastes (Y1, Y3) should also be considered.

## **6. Fire safety**

### **General considerations**

Some polymers or plastics burn easily and have a high calorific value while others (such as PVC) do not burn easily. Some plastics contain flame retardants as an additive.

Plastics materials stored in preparation for transport or recycling are extremely unlikely to catch fire spontaneously but they may prove vulnerable to carelessness and vandalism. The following rules should always apply:

- Plastics materials for recycling should be stored outdoors unless indoor storage areas are provided with water sprinkler systems
- Smoking should be forbidden in plastics waste storage and processing areas and such areas should be protected by secure fencing
- Ready access to all parts of the storage area should be maintained by well-organised and supervised stacking patterns in order to ensure efficient working conditions, easy emergency escape routes for workers and ready access for emergency services vehicles
- Suitable extinguishers should be readily available in the storage area but staff should attempt to extinguish fires only in their very earliest stages
- A list of the quantities and types of wastes on the premises could be a useful tool for the emergency services to estimate the extension of the fire as many plastics have a high calorific value and once ignited burn rapidly
- Production emergency plans are also a useful tool to increase preparedness of the emergency services in case of a fire or other emergency situations

In the event of a fire (at any industrial operation):

- All staff should evacuate the premises immediately and assemble at recognised points and be counted
- The emergency services should be summoned immediately and should be reminded:
  - of the speed at which fire can spread in burning plastics
  - that burning plastics may form a mobile stream of burning material which can rapidly transfer the fire to other areas and can also block drains
  - of the need for self-contained breathing apparatus when entering a building in which any material is burning

## Smoke and toxic gases

It is recognised that the major cause of deaths in accidental fires is the inhalation of carbon monoxide and smoke<sup>(3)</sup>. Fire brigades usually regard the smoke and fumes from any accidental fire as toxic and employ self-contained breathing apparatus when entering a burning building whatever materials are involved.

Burning PVC and fluoropolymers emit acid gases but are much more difficult to ignite than other plastics and they burn very slowly. Hydrogen chloride released from burning PVC is considered by the firemen to have effects similar to carbon monoxide. Hydrogen fluoride from burning fluoro-polymers is more toxic than carbon monoxide but is unlikely to be present in any significant quantities.

The soot from burning materials, natural and man-made, contains small concentrations of more toxic materials and so it should be handled with care using appropriate protective clothing<sup>(4)</sup>. Toxic materials are firmly bonded<sup>(4)</sup> onto the surface of soot particles and so they are not very biologically active.

For further information on data from fires in recycling plants see appendix 4.

## 7. Second life applications for plastics materials

The need to protect human health and the environment and to conserve natural resources is one of the key objectives of the Basel Convention. In this connection, many governments have adopted policies for the environmentally sound waste management, minimising the amounts of waste materials going to landfill disposal and emphasising the value of mechanical recycling. Where recycling of plastics does not provide the most environmentally sound way of extracting value from waste, an alternative option is to use the material for feedstock recycling or for energy recovery, so that the intrinsic value of the plastics is not lost.

Two technological routes for plastic waste recovery have been developed in the industrialized countries on a large scale: incineration with energy recovery and mechanical recycling. However, the landfilling of plastic waste remains highly predominant compared to these two routes. For instance in Western Europe in 1994, one million tonnes of post-consumer plastic wastes were consumed for the manufacture of recycled plastics. For the same year, the distribution of all plastic waste streams within the EU was:

mechanical recycling	6.0 %
energy recovery	13.4 %
incineration without energy recovery	3.1 %
landfilling	76.0 %
waste exported outside western Europe	1.2 %
chemical recycling	marginal

### 7.1 Selective collection of plastic wastes

The collection and sorting of plastic wastes are typically the first two steps involved in post-user plastic waste recycling. The plastics may be sorted from non-plastics before being collected, or they may be separated from a mixed waste stream after collection.

#### Household plastic waste collection schemes

Household plastic packaging waste are recovered through collection programmes based on drop-off (street containers) or kerbside (in special bins or bags) systems. The instructions given to households and the scope of plastic waste collected differ from one case to another. Drop-off programmes are generally limited to bottles. In some OECD countries, kerbside collection refer to bottles only or cover all “dry and clean” plastic packaging waste. From the technical point of view, drop-off plastic collection remains quite simple and homogeneous. Kerbside collection is more diversified and varied in frequency (weekly, monthly), in equipment used, i.e. the classical MSW collection trucks, compartmentalized trucks, and in instructions to the households, such as separate collection of plastics or collection of mixed recyclables (see Table 5).

Experience in developed countries shows that many factors influence the cost of selective collection. The dissemination of quantities to collect and the low density of plastics are the most important factors explaining the high collection costs of plastic wastes compared with other recyclables such as paper and glass. Also, the level of participation of the population and their receptivity to selective collection schemes has been found to be very influential. Public participation in MSW plastic waste collection schemes will influence both the quantity and the quality of the plastic waste collected and thus the cost per recyclable ton of recyclables. Public awareness campaigns constitute an important element in assuring the participation of the population.

**Table 5: Comparison of drop-off and kerbside collection**  
 (Source: Elements for a cost effective plastic waste management in the EU, EC, 1997)

	<b>Drop-off</b>	<b>Kerbside</b>
<b>Principles</b>	Households bring plastic bottles to street containers	Plastics are collected regularly at each door
<b>Scope</b>	Plastic bottles only	Plastic bottles or all plastic packaging
<b>Techniques</b>	Almost standardized:  Containers + collection trucks	Various: <ul style="list-style-type: none"> <li>• Collection in binds or bags</li> <li>• Plastics collected separately or with other recyclables</li> <li>• Separate or simultaneous collection of recyclables and residual waste (compartmentalised trucks)</li> <li>• Different frequencies</li> </ul>
<b>Main factors influencing costs</b>	<ul style="list-style-type: none"> <li>• Low density plastic</li> <li>• Participation of the population</li> <li>• Local context (urban, rural)</li> </ul>	
	Density of containers	<ul style="list-style-type: none"> <li>• Collection frequency</li> <li>• Collection of plastic alone or mixed with other recyclables</li> </ul>
<b>Advantages</b>	<ul style="list-style-type: none"> <li>• The concentration of plastics is initiated by the households and therefore makes collection easier</li> <li>• Costs limited mainly to containers implantation</li> </ul>	<ul style="list-style-type: none"> <li>• Good quality of service</li> <li>• High recovery rate</li> </ul>
<b>Constraints</b>	Low recovery rate Visual impact	High collection cost

Collection costs can be quite different between one case to another. Experience will be gained in the near future on the costs and advantages of each solution, however, the schemes will probably remain quite diversified due to the constraints of each area and the different perceptions of the service by municipalities and populations.

The possibility of organizing selective collection schemes depends mainly on the quantities of recyclables collected separately and on the frequency of the MSW collection. The collection schemes will be much more difficult for drop-off systems than for kerbside systems and in rural areas rather than in urban or semi-urban areas. In rural area the visual impact of drop-off systems may be of concern. When selective collection is organized with compartmentalised trucks, both fractions (recyclables and residuals) are collected simultaneously.

### **Industrial and commercial plastic waste collection schemes**

Collection of industrial and commercial waste is usually organized with large drop-off containers rented by the waste producer and collected regularly by private operators. The same system applies to different kinds of waste: industrial waste, commercial packaging waste, and even agricultural waste (drop-off depot containers would be located in the cooperatives, for instance). Collection cost per tonne are often lower than for household wastes. The quality of the collected material is normally high.

### **7.2 Sorting for mechanical recycling**

Plastics materials from end-of-life applications must be separated from non-plastics materials and, when preferable and sensible, sorted into single plastics types before being reprocessed into a second-life application. This is imperative for economical plastic recycling. Plastics materials from end-of-life packaging will contain different materials which can often be hand-sorted because they carry a material identification mark of the type shown in Appendix 7b, although a limiting factor may be that some are not marked. Working conditions for workers involved in hand sorting require specific consideration.

Separating the plastics components into single plastic material streams requires considerable expertise unless the plastic components are marked clearly with the plastic type. Small plastic components may not be worth separating for recycling but can be used for energy recovery. Table 6 gives an overview of available separation and identification technologies and some of their characteristics.

**Table 6: Outline of separation and identification techniques of plastics, Identiplast, APME**

<b>Procedure</b>	<b>Principle</b>	<b>Efficiency evaluation</b>
<b>Swim-sink separation<sup>(5)</sup> (Appendix 11)</b>	Gravity of separation	Only separation of 2-3 plastics is effective, low separation effect, disturbance of fillers
<b>Separation by sorting centrifuge</b>	Gravity of separation	Purity between 95-99,9%
<b>Flotation (Appendix 11)</b>	Selective addition of air bubbles in aqueous media	Addition of reagents necessary, low efficiency, disturbance by additives or fillers
<b>Flotation Separation of plastics using selective depressants<sup>(6)</sup> (Appendix 11)</b>	4 plastics, namely PVC, PC, POM and PPE can be separated from their synthetic mixtures using common wetting agents like sodium lignin sulfonate, tannic acid, aerosol OT and saponin.	Purity between 87-90 %
<b>Electro separation<sup>(6)</sup></b>	Usage of electric charging in electric fields to separate PVC and PE from wire and cable	Purity between above 90 %, disturbance of pollution, surface coating

Procedure	Principle	Efficiency evaluation
<b>MIR spectroscopy (Mid Infrared)</b> <sup>(7)</sup>	Distinction between 11 grades of plastics: PE, PP, PVC, ABS, PC, PA, PBT, PPE, and EPDM. Reflection-spectroscopy 2,5-50 $\mu$ m, stimulation of group oscillations	Good identification of technical plastics, extensive sample preparation, not automatic, high time costs ( $\geq 20$ s/analysis)
<b>NIR spectroscopy (Near Infrared)</b>	Separation of PET, PVC, PP, PE, and PS (reflection-spectroscopy 800-2500nm, stimulation of harmonic oscillations and combined oscillations)	Good identification of packaging plastics, disturbance of fillers (soot), surface coating, geometry of sample Not able to identify black polymers as well as additives.
<b>Laser-Induced plasma spectroscopy supplemented by NIR spectroscopy</b> <sup>(8)</sup>	Focus a pulsed laser beam at the plastics which produces a flash due to high power density. The flash generates a high-density plasma which excites all atomic elements in the focal volume.	
<b>Fourier Transform Infrared Spectroscopy (FT-IR)</b> <sup>(7)</sup> <b>UV-VIS spectroscopy</b> <sup>(5)</sup>	Reflection spectroscopy 200-400nm, stimulation of vibrations and electrons	Works for all plastics but long measuring times are needed for black plastics due to sample preparation and measurement. Low identification for polymer, strong influence of additives (dye), inferior automaticity
<b>Laser PES</b> <sup>(5)</sup>	Separation of PET, PVC, PP, PE, and PS. Laser-plasma-atom emission spectroscopy/ thermal impulse response / IR thermography	Low identification for polymer, identification of heteroatom admixtures, on principle automatic
<b>X-ray fluorescence</b> <sup>(9)</sup>	Proof of elements by X-ray line spectra used as sensing method	Low polymer, identification of elements, inferior automaticity. Only effective for separating PVC from PETE plastics
<b>Optical scanning</b> <sup>(9)</sup>	Used as a sensing method. Optical inspection using photodiodes or Charge coupled device (CDD) machine vision	Useful for sorting plastics according to transparency and colour but is unable to provide chemical identification of polymers
<b>Mass-spectroscopy</b> <sup>(5)</sup>	Mass-spectroscopic detection of pyrolytic products	High time costs ( $\geq 1$ min.) low separation effect, difficult to automate
<b>Electrostatic separation</b> <sup>(6)</sup>	<ul style="list-style-type: none"> <li>- separation of plastics fluff of PVC and crosslinked PE from wire and cable</li> <li>- separation of comingled flakes of PVC and PET from bottle waste into PVC</li> </ul>	

Electrical and electronic goods are often complex mixtures of metals and plastics. Separation of the plastics from the metals is labour intensive but fairly simple.

Some mixtures of shredded materials may readily be separated using sink/float separation tanks. Thus PVC shreds which sink in water can be separated from polyethylene or polypropylene shreds which float. PET

shreds can be separated from polyethylene or polypropylene shreds in the same way. PVC and PET cannot be separated in this way because they have very similar densities and separation of the original plastics components is the only practical method. Mixtures of shredded film are more difficult to separate by sink/float methods.

Since application of any technology involves costs, there may be economical constraints applying these technologies in certain cases. Some of these technologies are already well established and available while others are still in the early stages of development.

### **7.3 Mechanical Recycling**

All polymers can successfully be recycled into second-life applications without significant impact on the environment. An overview of polymers and copolymers is given in Appendix 7A. Once the plastics have been cleaned and shredded, the process is much the same as for the production of plastics.

Recycling rates are highest where a regular supply of clean, single material waste stream is available. Polymer wastes can be satisfactorily processed only by companies with expertise in the blending of polymers with additives. Some mixtures of polymers can be processed together while others are incompatible.

### **7.4 Plastics recycling in practice**

#### **Plastic bottle recycling**

Plastic bottles are usually produced from one of three different polymers: PVC, PET and PE-HD. To achieve a viable recycling process for the millions of bottles in the waste stream, automatic separation into the individual polymer fractions has been a target for development work. Such automatic separation processes now exist at a number of locations across Europe. Figure 2 gives an example of a separator of different plastic types:

## PLASTIC BOTTLE RECYCLING PLANT

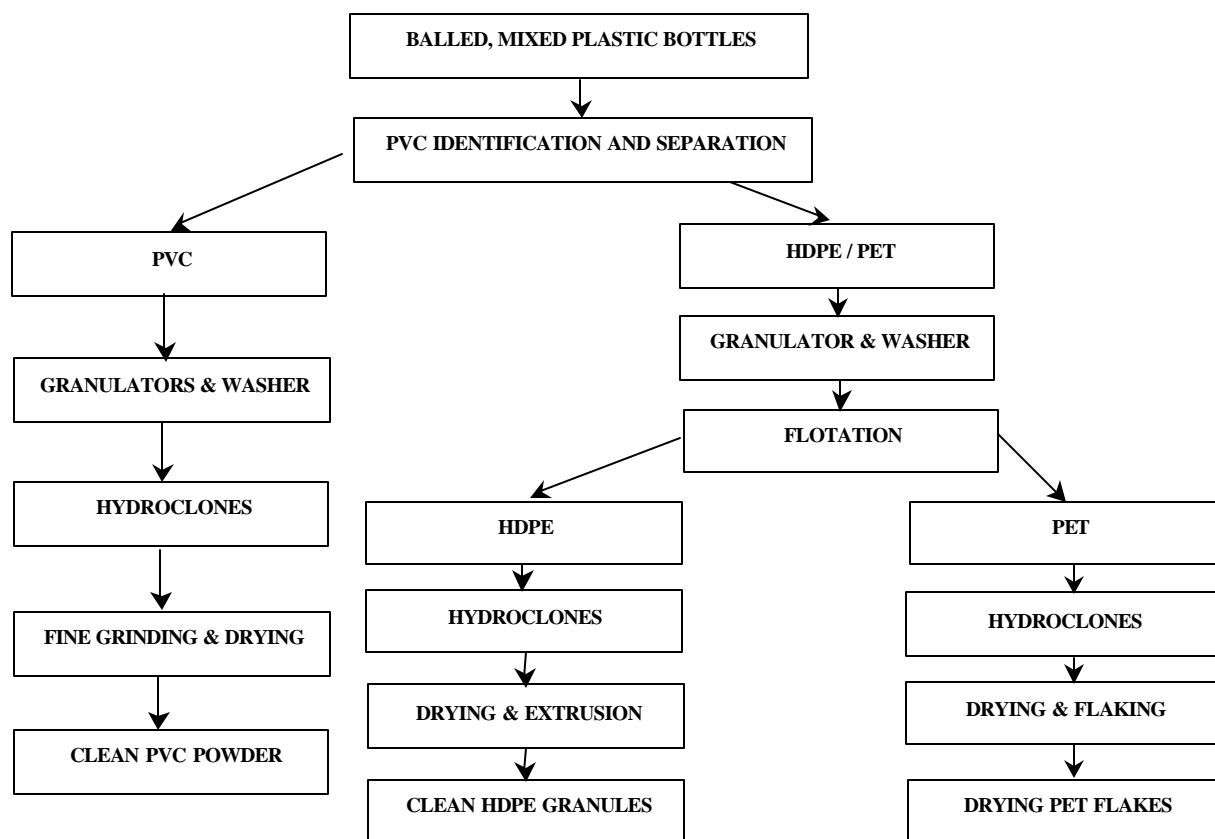


Figure 2: Segregation of mixed Plastics at an Automated Bottle Recycling Plant

### High density polyethylene (PE-HD)

PE-HD is used for example, to make film, bottles and drums. PE-HD film from commercial or industrial packaging is recycled but film used in retail sacks is not. Bottle or container material is being recycled either into new blow-moulded bottles or into much larger containers such as rainwater barrels and composting bins. Finely ground recyclate is also used in the rotational moulding process to make large or small containers. In Western Europe in 1999, PE-HD represents 18%<sup>(10)</sup> of the total post-user plastics waste that was mechanically recycled, equivalent to 329,000 tonnes.

### Low density polyethylene (PE-LD, PE-LLD, PE-X)

Much PE-LD is used in packaging and agricultural films. The PE-LD film recovered from delivery packaging is most commonly used in the manufacture of new film. Higher quality clear waste finds application in shopping bags for example, while lower quality material is used in rubbish bags. Plastic waste from agricultural applications is used to make new farm film. Some PE-LD film is used in the production of mixed plastics lumber replacement pallets, sound barriers and car park surfaces. Some 45%<sup>(10)</sup> or 823,000 tonnes of the post-use plastics recycled in 1999 in Western Europe was PE-LD or PE-LLD (linear low density polyethylene).



PE-LD is also used as cable insulation and sheathing. End-of-life cable<sup>(11)</sup> or cable production waste can be sorted into polymer types and conductor metal. The PE-LD recovered can be reblended with pigments and additives and used in sound barriers, furniture profiles, small containers and flower baskets for example.

PE-LD cable sheathing and insulation is sometimes treated chemically or with radiation to link the polymer molecules together in order to improve abrasion resistance. The material is then called cross-linked polyethylene (PE-X) and it cannot be mechanically recycled. It can be used for energy generation in authorised incinerators or in the feedstock recycling process.

PE-LLD is mostly used in industrial packaging and in delivery packaging. It can be recycled in similar second life applications when available as a separate stream. It can also be used in products made from mixed plastics.

### **Polyester (PET -Poly-Ethylene Terephthalate or teraphthalate)**

The largest non-fibre use of polyester is in bottles for water, soft drinks and foodstuffs. Some material may be available from polymer production and conversion processes but the majority of PET plastics waste for recycling is extracted from the municipal waste stream. There are well-established processes in a number of Parties to extract and sort PET bottles from other waste and to clean and granulate the waste for recycling. The main outlet for recycled PET is in the production of fibre, either fine yarn fibre for use in knitted fabrics or thicker fibre for insulating wadding.

PET contaminated with other polymers is not suitable for mechanical recycling but can be used in feedstock recycling. In Western Europe in 1999, some 12%<sup>(10)</sup> or 219,000 tonnes of mechanically recycled post-use plastics packaging waste was PET.

### **Polypropylene (PP)**

Polypropylene is used for example, for industrial and automotive mouldings, for pipes, for large and small containers, for beer crates and for packaging films. While the film is not usually recovered from the general waste stream, containers, beer crates, mouldings and pipes are readily recycled back into similar applications or into alternatives such as agricultural drainage piping. In 1999, Western Europe recycled mechanically some 169,000 tonnes<sup>(10)</sup> of post-use polypropylene waste.

### **Polystyrene (PS)**

Polystyrene is used in both solid and expanded forms. In solid form PS is used as packaging, cups and plates and in electrical appliances and tape cassettes. In expanded form it is used as shock resistant packaging, cups and plates and as thermal insulation and building component. Both forms of PS can be recycled.

- solid polystyrene components such as coffee cups can be recycled back into alternative applications such as video cassette cases, office equipment etc.
- expanded polystyrene foam waste loses its foam characteristics as part of the recovery process. The recovered material can be re-gassed but the product is then more expensive than virgin material. Instead it is used in solid form in standard moulding applications such as videocassettes or coat hangers.
- both expanded and solid polystyrene waste have been successfully recycled in extruded plastic timber/lumber

The 1999 total quantity of PS post-use packaging waste, mechanically recycled in Western Europe was some 107,000 tonnes<sup>(10)</sup>.

### **Fluoropolymers**

PTFE and its copolymers are usually employed in small components in specific complex applications such as electronic equipment, transport (cars, trains and airplanes) or as very thin layer coatings on fabrics and coiled metals. PTFE is used in larger amounts in chemical plant applications and can be recycled if not deteriorated. Where sufficient quantities of suitable PTFE can be recovered and may be sufficient to warrant recycling then they should be shipped to specialised recyclers (see Appendix 5). Fluoro-polymers can only be recycled by a limited number<sup>(19)</sup> of specialised recyclers but, like most other polymers, they can be reprocessed by normal extrusion and by moulding companies with little extra technology beyond that are used with virgin plastics.

A very substantial market exists for recovered PTFE as a low friction additive to other materials. The fluoro-polymers should only be incinerated in authorised incinerators. Preferably, non-recyclable materials should be sent to authorised incinerators with energy recovery. When landfilled, it should be done at authorised landfills where they will represent no hazard because they are inert.

### **Polyvinyl chloride (PVC)**

This material is produced in a wide range of grades for all of which there are recycling opportunities. Since many applications of PVC have very long lifetimes only small quantities are, as yet, available for recycling though there will be increasing quantities in the future. In 1999, Western Europe recycled mechanically some 540,000 tonnes<sup>(14)</sup> of PVC waste of which 100,000 tonnes came from post use which represents 3% of post-consumer PVC wastes.

A limited number of working examples are given here:

- PVC-U bottle waste can be incorporated into expanded rigid PVC-E grades at up to 100% level if the expanding agent, stabiliser and pigment levels are adjusted to the application
- PVC-U bottle waste is also moulded into pipe and ducting fittings and is incorporated into the foam core of tri-wall pipes for drainage applications
- PVC-U bottle waste is used in a solvent spinning process to make yarn quality fibre for use in knitted garments
- PVC-U pipes and window profiles can be recycled into similar applications as long as the heat stabiliser level is adjusted to the level used in first life applications. End-of-life window profile material is probably best used as the internal core of new window profiles, sheathed in virgin material. The same material can be used without modification in extruded cable ducting or conduits.
- PVC-U used in computer enclosures and keyboard frames can be used in an identical second-life application as long as the PVC-U is separated completely from the rest of the computer materials and the colour is re-adjusted
- foamed rigid PVC-E can be recycled back into its original application as blend with virgin material
- plasticised PVC-P cable insulation<sup>(11)</sup> production waste can be stripped from the complete cable. End-of-life cable can be granulated and sorted into metal and polymer fractions. The PVC fraction is recycled into industrial flooring, car floor mats, shoe soles, car mud flaps, sound barriers and garden hose. Cable scrap can be incinerated to obtain only the conductor metal using authorised incinerators. Only a few such incinerators have been authorised in the world.
- PVC flooring can be recycled into new flooring<sup>(13)</sup> or into the backing layer or for carpets after cleaning and grinding

- PVC roofing membrane<sup>(13)</sup> at the end of its life can also be recycled into new membranes after cleaning and grinding

The quantities in which PVC waste are recycled into new PVC applications are limited, due to technical, economical and logistical constraints<sup>(14)</sup>. The technical constraints are determined by the fact that:

- Each PVC application has its own compound composition
- For each application the compounds may differ depending on the producer or processor and over time (in particular for applications with a long lifetime such as window frames and pipes)

The economical constraints are related to the costs of collection, pre-treatment and recycling, in particular, for post-consumer wastes these costs exceed the costs of alternative waste management options such as incineration and landfilling due to the relatively high costs of collection and pre-treatment. It should be noted that similar economical constraints occur with other types of plastic waste as well.

The logistical constraints are related to the fact that some of these materials, in particular for post-consumer wastes which are generated in small quantities from disperse sources. This may change over time when more PVC waste will become available due to PVC products with long life times becoming available as waste in the coming years.

These constraints are largely related to post-consumer wastes. For production scrap it is easier to overcome these constraints, as illustrated by current recycling rates, which are much higher than for post-consumer waste.

Plasticised and unplasticised PVC wastes should best be recycled separately to obtain high quality products. For applications of plastic in products replacing timber or concrete, mixtures of PVC waste and of PVC waste with other polymers may be acceptable.

The presence of small amounts of polyolefines (such as PE en PP) does not influence the quality of the recycle too much. Presence of PET or rubber in PVC rich plastic waste may result in poor product quality.

### **Plastics containing polybrominated diphenyl ethers (PBDE)**

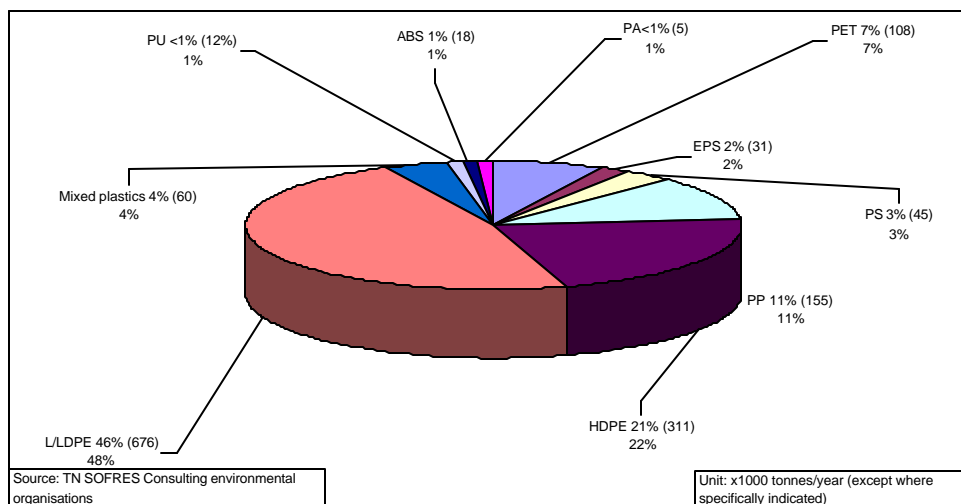
Plastic wastes which contain polybrominated diphenylethers (PBDE) should be excluded from material recycling because of the possibility of emitting dioxins and furans. Instead such plastic wastes should be treated in feedstock recycling facilities or in controlled incinerators recovering energy (see also section 8).

### **Mixed polymer waste recycling**

Mixed plastic waste should preferably be sorted into different fractions by using adequate processes, taking into account the energy consumption and the technical efforts. The sorted fractions should be recycled separately.

Mixed plastics waste, separated out of the municipal waste stream, is difficult to sort into individual plastics but it has proved possible to produce a washed blend which can be extruded or moulded into various timber or concrete component substitutes. These have applications such as in picnic tables, sound barriers, dockside fenders and fencing etc., where resistance to weather, corrosion and rotting are important.

An overview of the amounts of plastics recycled in Western Europe is given in figure 3.

**Figure 3: Mechanical recycling of post user plastic waste by resin, Western Europe, 1997**

### 7.5 Feedstock recycling and chemical recycling

Mechanical recycling uses the polymer as such to produce new polymer products. It is also possible to feed plastics into a range of processes to use the essential chemistry of mixed waste plastics to recover value. Those processes are generally referred to as feedstock recycling or chemical recycling. However, certain of these processes are best described as energy recovery. The technologies used include degradative extrusion, pyrolysis, hydrogenation, gasification, incineration with recovery of HCL, input as reducing agent into blast furnaces, glycolysis, hydrolysis and methanolysis. Currently some 70 initiatives have been developed<sup>(15)</sup>. In this document all different technologies will be referred to as chemical recycling. The basic principle of thermolysis is illustrated in figure 4.

Most of these technologies are being developed to handle a wide range of plastics in a single process producing products with the same quality as virgin products. Those technologies typically focus on the recovery of the organic compounds in the plastic. Some of the technologies are specifically designed to treat PVC waste. Those technologies mainly focused on the recovery of chlorine in a useful form and certain of these processes allow separation of heavy metals<sup>1</sup>. These processes are only in the early stages of development and commercialisation. In this regard, some difficulties of economic nature have been experienced by potential waste recyclers in using the latest technologies for the chemical recycling of PVC containing plastic wastes.

Chemical recycling/recovery can take the form of two different types of processes:

- The first is in chemical recycling where the objective is to rework the basic chemical components in the plastics materials for re-use in the chemical industry. The plastics waste is de-polymerised either into monomers which can be used again directly for polymerisation (chemolysis) or into lower molecular weight chemical feedstock (thermolysis or cracking) which can be used, like natural oil, in chemical reactions, including the production of polymers.
- The second is in iron production where the chemical reducing properties of waste plastics are used as a supplement to coke in blast furnaces. The potential of blast furnace use of plastics waste can be illustrated by the 100,000 tonnes which were employed in these processes in Germany during 1996. The more advanced process is already demonstrated by

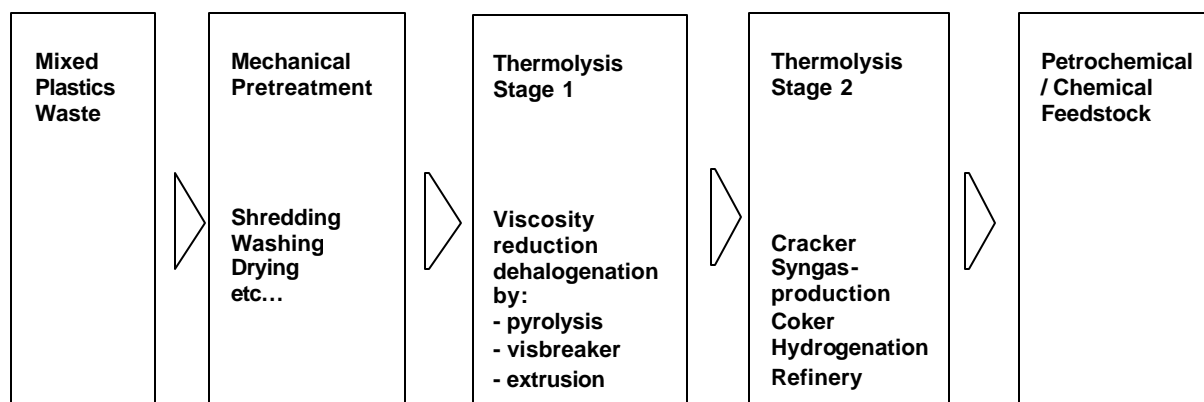
<sup>1</sup> For further information consult (reference to study by Denmark)

the capacity of 5,000 – 8,000 tonnes per year in Japan. Mixed plastics rich of PVC can be pyrolyzed in the kiln filled with nitrogen. The products are hydrochloric acid and char for the blast furnace. Similar pyrolysis process can be applied to cement industry. The pilot plant is tested and operated to charge hydrochloric acid to a VCM oxi-chlorination process.

Chemical recycling may be a viable option for those waste streams where mechanical recycling is problematic due to impurities or where recycling would require costly additional separation steps<sup>(15)</sup>.

Plastics waste should not be exported to another party for feedstock recycling until that importing party has in place a fully developed recycling plant, approved under local regulations.

**Figure 4 - Chemical recycling (thermolysis) of plastic waste - basic principle (APME)**



Technologies for chemical recycling generally generate relatively low quantities of residues. The production of feedstock for chemical production processes typically generates some slag form inert materials present in the plastic waste and filter cakes in case waste water is treated. Some processes have specific acceptance criteria in relation to ash content of the waste in view of reduction of the generation of slag.

Heavy metals in plastic waste, for example, those used in stabilisers for PVC will end up in the waste streams or, in case of steel production will be included in the steel. For steel production these heavy metals originating from the plastic waste generally are not the main source of heavy metals in these residues, due to the relatively low percentage of plastic used as input in the process.

## 7.6 Main blocking factors affecting the collection and the recycling of plastic waste

A number of factors impede the development of the plastic waste recycling sector, both in developed and developing countries. Table 7 shows the main blocking factors affecting the collection and recycling of each source of plastic waste in Western Europe. The table reveals that the largest source of plastic wastes, which is municipal solid waste, is also facing major blocking factors.

**Table 7 – Main blocking factors affecting the collection and recycling of plastic wastes**

<b>Blocking factors</b>	<b>1</b>	<b>2</b>	<b>3</b>	<b>4</b>	<b>5</b>	<b>6</b>
Geographical dispersion of waste	A	C	C	B	B	A
Difficulty in identifying the polymers	A	C	B	C	B	A
Difficulty of dismantling	C	C	A	C	A	A
Contamination	A	C	B	B	B	B
Multi-plastic products	A	C	B	C	B	C
Additives content	C	C	C	C	B	B

1. Municipal solid waste
2. Distribution
3. Car scraps
4. Agriculture
5. Electricity and electronics
6. Construction/demolition

A Critical blocking factor  
 B Major blocking, but which does not apply necessarily to all types of waste in the source considered  
 C Minor (or little) blocking

Source: Elements for a cost-effective plastic waste management in the European Union. Objectives and instruments for year 2000.

**Technological perspectives**

As outlined in the previous sections, the development of appropriate technologies will ease the consolidation of the sector of plastic waste recovery. Table 8 summarises these effects.

**Table 8 – Review of technologies for the recycling of plastic wastes**

<b>Technologies</b>	<b>I. Innovation Areas</b>	<b>II. Type of Waste</b>	<b>III. Impact on the Recycling Industry</b>
<b>MECHANICAL RECYCLING</b>			
<i>Identification and sorting</i>	Identification method: infra red, optical detection, x-ray, chromatography. Separation method: Density, thermic and electrostatic selection	Clean plastic wastes (essential mono resin) resulting from selective collections	Improvement of sorting output and of sorted products quality
<i>Processing</i>	Extrusion technology, adapted to recycling and to the improvement of quality of the recycled resin	Clean plastic waste (essentially mono resin) resulting from selective collections	Improvement of the quality of the recycled resin means an improvement of outlets for recycled products (quantity and quality) and decrease in processing costs
<b>CHEMICAL RECYCLING</b>			

Feedstock recycling	Pre-processing pyrolysis, hydrogenation, gasification	Mixed plastics (low level of pollution)	Improvement of waste acceptability and of the running of processes means an increase in the quantity of waste recyclable through chemical recycling and decrease in processing costs
Chemolysis (Monomer production)	Methanolysis, glycolysis, hydrolysis, saponification	Clean plastic wastes (essentially mono resins) resulting from selective collections	Unlimited outlets for plastic sorted by resin and production of high quality monomer
ENERGY USE			
	Mono or co-combustion and possibility to combine chemical recycling and use of the energy provided by the process	Plastic wastes with a low level of pollution or polluted	Increase in the possibilities of energy recovery

Source: Elements for a cost-effective plastic waste management in the EU, EC, 1997

## 8. Energy recovery from plastic wastes

While some waste plastics can be recycled resulting in environmental benefits, a lot of plastics waste consists of small items dispersed among other waste materials. Separating and cleaning this waste for recycling may have an environmental burden higher than the profit from recycling, without taking into account the economic cost. There may also be residues from the recycling process which cannot themselves be recycled.

If recycling cannot be justified then energy recovery<sup>(16)</sup> may be the cost-effective way of retrieving the intrinsic resource value of the plastics waste. It should be noted however that if energy recovery is applied the energy that was necessary for the production of the plastics is lost. For certain types of plastics the amount of energy needed to produce the material is in the same order of magnitude as the energy value of the plastics when incinerated.

Plastics in general have high energy values (see Table 9). Even those containing halogens have an energy value similar to paper and cardboard. On the other hand incineration may result in generation of large quantities of flue gas cleaning residues (see table 10). When mixed with other wastes, plastics assist in the incineration of wet or vegetable wastes.

Research and practice<sup>(18)</sup> developed over the past 10 years have indicated that, under strict operating conditions, plastic wastes, even if the mixture is rich in PVC, can be incinerated safely and effectively (see below). Consistent, high temperature combustion will recover the maximum energy from the fuel and ensure the complete breakdown of toxic organic compounds. The most effective energy recovery (up to 85%) takes place when the waste is incinerated to raise high-pressure steam for electricity generation, low - pressure steam for industrial use and hot water for domestic heating. Most energy-from-waste plants do not attempt all three. The fluidised bed gasification plants are operated in Japan. Unburned char, fly ash and gas are burned at high temperature generating molten slag flue gas separately.

Technical Guidelines concerned with Incineration on Land<sup>(2)</sup> have been prepared under the Basel Convention. They show that the environmental impact of energy recovery by incineration is affected by four key factors, namely:

- The nature of the waste to be incinerated
- Incineration conditions control
- Flue gas cleaning
- Residue disposal

### **The nature of the waste streams for energy recovery**

Plastics may be found in four different types of waste used in energy recovery processes, each with its own energy recovery value.

Municipal solid waste (MSW) is a waste listed in Annex 2 of the Basel Convention as needing special consideration. It is untreated household waste and waste from shops and restaurants, which is burned in large 'mass-burn' facilities in Europe, US, and Japan. MSW has an energy value of only 10 MJ/kg and a very low density. Its plastics content assists the incineration of wet or putrescible materials within the waste stream.

Refuse derived fuel (RDF) is produced by removing all the non-combustible components such as metals, glass and putrescible materials from MSW and then pelletizing the combustible material. As this is processed MSW, RDF has a higher concentration of plastics waste than MSW and consequently a higher energy value. It may be environmentally acceptable to transport RDF short distances from its place of manufacture to authorised energy recovery plants.

Packaging derived fuel (PDF) consists mainly of paper and plastics waste kept separate from the generality of waste and prepared in pellet form designed to give an even higher energy value. Trans-boundary transport of PDF between Parties may be environmentally acceptable if authorised incinerators are available and the practice is allowed by the local regulations in both Parties.

Polymer fuel (PF) consists of plastics waste alone, either from recycling processes or separated from the general waste stream and processed to yield a fuel of specified polymer content and energy level. Transboundary shipment of PF may be acceptable if authorised incinerators<sup>(2)</sup> are available and the regulations of both Parties permit it. Many constructed incinerators may not be designed to withstand the temperatures generated when such a high calorific value is used alone. The fuel should be diluted with material of lower calorific value.

Both PDF and PF may originate from industry, distribution or municipalities through the 'drop-off' or 'kerbside' collection systems.

**Table 9: Energy values of plastics wastes, mixtures and traditional fuels**

Single polymers/fuels	Net calorific value (MJ/kg)
PE-LD/PE-HD	45
PP	45
PS	41
ABS , Oil	40
Coal	25
PET	23
PVC	22
PDF	20



<i>RDF</i>	15-17
<i>MSW, Wood</i>	8 -10
<b>Mixtures (PF)</b>	
PE-LD/PP/PE-HD (food packaging)	45
PP/ABS/PE-HD (computers)	43
PE-LD/PP/PVC (mixed packaging)	37
PP/PE-LD/PVC (non food packaging)	37
PU/PP/PVC/ABS (bumpers/fuel tanks)	33

### **Incineration conditions control**

The primary determinants for low emission incineration are plant design and monitoring of key parameters. The operating parameters, such as oxygen levels, the residence time and temperature of combustion, are key to safe and effective operations.

The conditions for the optimal incineration of materials are:

- high temperature. Temperature of 850 °C – 1100 °C for hydrocarbon wastes, and 1100 °C – 1200 °C for halogenated wastes
- sufficient (gas) residence time in the incinerator (EU legislation requires 2 seconds as a minimum)
- good turbulence
- excess of oxygen

The role played by chlorinated polymers in the formation of dioxins in waste incinerators has been a matter of controversy. It has been shown that the removal of chlorinated polymers from mixed waste will not bring about a proportionate reduction in dioxin formation and even if all the PVC is removed from mixed waste, the chlorine remaining is sufficient to form dioxin levels which warrant flue gas treatment<sup>(18)</sup>.

Burning plastic wastes with BFRs (brominated flame retardants) is a special concern. One of the main reasons for the current controversy surrounding BFRs, in particular PBBs and PBDOs, is the possible formation of dioxins and furans during combustion of both BFRs themselves and flame retarded materials.

Special regard must be given to the obligations and responsibilities set out in the Stockholm Convention on Persistent Organic Pollutants (POPs) with respect to the goal of preventing the formation of unintentional POPs from incineration operations.

### **Flue gas cleaning from incinerators**

The cooling gases from the combustion chamber will contain a range of materials such as carbon dioxide, sulphur dioxide, hydrogen chloride or fluoride and dust. Any toxic organic materials formed in the cooling flue gases are likely to be absorbed onto the surface of the dust particles. It is essential to filter out the dust from the gases and this is normally done with fine-mesh fabric filters. Modern incinerators have been able to operate regularly with dioxin emissions well below the 0.1 nanograms/m<sup>3</sup> (see Glossary) level demanded by some governments (see Appendix 8 for the emission standards required in the EU). This requires usually further gas cleaning equipment like cleaning systems based on activated carbon or activated coal or special catalysts.

To meet modern emission standards, sulphur dioxide, hydrogen fluoride and hydrogen chloride must also be removed from the flue gases (see Annex 8). This is done either by reacting the gases with wet solid alkali, with alkaline solutions or with water alone depending on the location of the incinerator. Neutralising the acid with chalk produces a solid waste which must be deposited in an authorised landfills<sup>(19)</sup>. Neutralising the acids with sodium bicarbonate gives a salt solution from which salts can be recycled under certain conditions. Absorbing the acid gases in water produces a solution from which those gases can be processed for commercial use. Only a limited number of such recovery plants are available.

PVC is an important source of chlorine in Municipal Solid Waste (MSW). On the average in the EU 50% of the chlorine in the input of incinerators of MSW comes from PVC (range 38 – 66%)<sup>(20)</sup>. During incineration, chlorine (including the chlorine in PVC) is transformed into hydrochloric acid, which has to be neutralised to meet emission standards. As an example, the emission standard for HCL in the EU is 10 mg/Nm<sup>3</sup> (see Appendix 8). After neutralisation a reaction residue from flue gas cleaning remains. To avoid problems with the landfilling of these residues, every effort must be made to ensure that wherever possible PVC wastes be sorted from the waste flow and sent to another treatment. Table 10 gives an overview of the amount per kg PVC of neutralisation agent needed and the amount of residue generated in the different flue gas cleaning systems in operation<sup>(20)</sup>.

**Table 10: Use of neutralisation agent and production of residues due to incineration of PVC waste**

Flue gas cleaning system Neutralisation Agent (NA)		Dry		Semi-dry	Wet	Semi wet-wet
		Lime	Bicar	Lime	Lime	Lime
NA kg Per kg PVC	Min	0.52	0.62	0.44	0.29	0.29
	Max	1.11	1.32	0.94	0.61	0.61
	Average	0.94	1.12	0.79	0.52	0.52
Residue kg per kg PVC	Min	0.78	0.46	0.70	0	0.54
	Max	1.65	0.97	1.48	0	1.15
	average	1.40	0.82	1.26	0	0.98
Liquid effluent (dry material) (kg per kg PVC)		0	0	0	0.42 – 0.88	0

These figures are based upon the average composition of PVC waste. Soft PVC will generate less residues than rigid PVC, due to the lower chlorine content.

Both procurement of neutralisation agent and the treatment of the flue gas cleaning residue involve costs.

### Disposal of incineration residues

Fly ash from flue-gas cleansing usually contains materials such as heavy metal compounds which could damage the environment if released. These residues should always be considered as hazardous and be deposited only in authorised<sup>(19)</sup> landfills after leaching tests. Sometimes it is found valuable to stabilise the residues with cement before deposition. Bottom ash from incinerators may be inert enough to be a substitute aggregate in road building but its inertness must be established before it is used in this way.

In the context of the incineration of plastic wastes it is also important to consider the Technical Guidelines concerned with Incineration on Land (D10)<sup>(2)</sup>. For the disposal of incineration residues it is also important to consider the Technical Guidelines on Specially Engineered Landfill (D5).

## 9. Final disposal of plastic wastes

Where there is no possibility of employing the recovery processes listed above then plastics residues may be deposited in authorised<sup>(19)</sup> landfills. Incineration without energy recovery is used to reduce the volume of the residues deposited in the landfill but it is essential that the incinerator is authorised<sup>(2)</sup> and meets the same environmental criteria as incinerators for energy recovery.

### Incineration without energy recovery

The main difference between incinerator or installations with energy recovery and those without energy recovery is the use of waste as a potential source of heat - through steam, or electricity by the conversion of stream. The emission standard can be met by both types of installations.

The same key factors are important:

- The nature of the waste to be incinerated
- Incineration conditions control
- Flue gas cleaning
- Residue disposal

Since incineration without energy recovery does not contribute to saving of resources or reducing the production of climate change gases this process should be replaced by as far as possible processes where energy is recovered.

### Landfill

Landfill is the least preferable option for the management of plastic waste since no use is made of any of the resources represented by plastics. Although it requires space, it is still the most commonly practised waste disposal method in the majority of countries. Due to the low costs of landfilling alternative waste management options are often unattractive from the economics point of view.

The Basel Convention has produced technical guidelines<sup>(19)</sup> on the establishment of specially engineered landfills used for wastes which exhibit one or more hazardous characteristics. These guidelines also consider the issue of existing sites which require strict control and often, remedial treatment. Only those landfills meeting the requirements of the Basel Convention guidelines should be employed.

Landfills have caused concern when organic materials in them are broken down by biological action to produce flammable methane gas. There have been concerns that some additives (phthalates) used in plastics could be leached out into the ground water in the landfill. Losses of plasticisers from soft PVC are widely documented in literature<sup>(21)</sup>. Both phthalates and their degradation products can be detected in landfill leachate.

DEHP, the most commonly used plasticiser in soft PVC has been classified by the International Agency for Research on Cancer as group 3 (not classifiable as to its carcinogenicity for humans). The PVC polymer itself is generally regarded as being resistant under soil-buried and landfill conditions<sup>(21)</sup>. The stabilisers in rigid PVC are generally bound in the matrix of the polymer and do not leach out readily. PVC does not contribute significantly to the amounts of heavy metals stored in the landfill body, irrespective of any possible release<sup>(21)</sup>.

Although the reported releases of cadmium, lead organotin and phthalates are considered to be of minor relevance in terms of quantities introduced and released in landfills or because of the retention capacity of the waste matrix and biodegradation in landfills, they are only controllable if landfills are equipped with adequate liner and leachate<sup>(21)</sup> collection and treatment system.

It is important also to consider the technical guidelines governing the environmentally sound recovery and disposal of wastes such as the Technical Guidelines for Incineration on Land (D10), and Technical Guidelines on Specially Engineered Landfill (D5).

## **10. Conclusions**

Environmentally sound management (ESM) is defined in the Basel Convention as taking all practicable steps to ensure that hazardous wastes or other wastes (Annex II) are managed in a manner which will protect human health and the environment against any adverse effects which may result from such wastes. ESM should apply to all wastes, hazardous or not.

This technical guideline provides general guidance on the identification, environmentally sound management, recovery and final disposal of plastic wastes. All polymer and plastic types have been deliberately included, not just those having Annex I constituents (Y1 to Y45).

The reuse of plastics can make a significant contribution to conserving natural resources, reducing energy consumption and to minimising the generation of wastes. Many uses of plastics have a long working lifetime and end-of-life plastics can often be recycled into a second life application. Nevertheless, the production, processing and use of plastics do generate wastes. It is essential that these wastes are properly and safely managed to protect human health and the environment.

All plastic wastes can be recycled under environmentally sound conditions. However, a number of problems exist for the recycling of plastic wastes:

- many types of plastics are used
- plastics are containing a wide range of additives
- many objects contain plastics and other materials.
- sorting of plastics may be technically difficult or expensive

The final disposal of plastic wastes is a concern as for any waste generated nationally. If plastic wastes cannot be recycled, they can be landfilled or incinerated under certain conditions. The incineration of plastics, with or without energy recovery, under high temperature and with the appropriate abatement techniques for flue gases can be performed under environmentally sound conditions. Incineration under environmentally sound manner with energy recovery should be the preferred option compared to landfilling or incineration without energy recovery.

## II. TECHNICAL GUIDELINES ON THE ENVIRONMENTALLY SOUND MANAGEMENT OF PLASTIC COATED CABLES SCRAP

Due to the concern of the Parties regarding the end-of-life cables during the process of metal recovery, it is considered important to include within the technical guidelines on the environmentally sound management of plastic wastes a guideline on plastic coated cables scrap.

### 1. Introduction

Insulated wire and cable scrap (hereafter referred to as cable scrap) are generated world-wide. This scrap contains on average about 60% metal and 40% plastics. The conducting metal in this scrap is primarily copper, although, power transmission cables have aluminium as the conducting metal. Utilities use insulated aluminium power cable as outside distribution cable, and primarily insulated copper wire for inside distribution wire. Building, communication, electronics and automotive markets normally use copper as the conducting metal.

### 2. Movement of cable scrap between countries

Cable scrap is a domestic issue for all countries, OECD and non-OECD. Most scrap cable is recycled domestically in OECD countries, and only an estimated 15% of cable scrap is exported, not so much because of lack of domestic capability but because of market forces. The USA, W. Europe, Japan, Canada, Singapore and Australia ship cable scrap to the developing countries; in particular, China, Vietnam, S. Korea, Mexico, Indonesia, Malaysia, Thailand, Taiwan, India, Pakistan, Argentina, Brazil and Chile. About 30% of the scrap cables exported annually from the USA, Japan and Europe to developing countries are re-used rather than recycled. Cable scrap is shipped according to widely accepted trade specifications and classifications, see Appendix 10.

The principal plastic materials used in insulated cables are PVC and polyethylene. In the USA, these plastics are used almost in equal quantities. In Western Europe and Japan the use of PVC is greater than the use of polyethylene. Approximate world-wide breakdown of the coated cables by the jacketing material is given in table 11:

**Table 11: Use of plastics insulation in cables**

<b>Use of Plastics Insulation in Cable products, 1997</b>			
<b>(unit : 1000 tonnes)</b>			
<b>Plastic</b>	<b>North America</b>	<b>W. Europe</b>	<b>Japan</b>
<b>PVC</b>	205	455	330
<b>PE</b>	205	230	155
<b>Other</b>	30	10	15
<b>TOTAL</b>	440	695	500

### 3. Sources of scrap

Cable scrap is generated by cable manufacturers and end-users such as utility and telephone companies, manufacturers of electronic and electrical equipment, and electrical contractors. This is pre-consumer scrap. On the other hand, cable scrap recovered while replacing old cable lines with new ones or from end-of life electronic equipment is called post-consumer scrap. Utilities, which are a major source of scrap, generate pre-consumer scrap in the installations of new lines -- reel ends etc. -- and post-consumer scrap from dismantling old lines. This scrap arises in all countries whether OECD and non-OECD, therefore each country will require some form of domestic treatment for this coated cable scrap. As raw materials have become more expensive and companies are more environmentally conscious over the past decade, many continuous improvement programmes have started to bring a reduction in waste production.

Pre-consumer cable scrap is preferred by the cable scrap processor, because it is a “known” waste material. For example, a power cable manufacturer generates a waste stream that usually contains only aluminium metal and polyethylene, while a manufacturer of communication cable often generates a waste stream that contains only copper metal and PVC. Post-consumer scrap is the same material as pre-consumer but the wastes are more dispersed and need dismantling. These wastes require transport and coordination to be environmentally and cost-effectively recycled.

#### **4. Use of plastics in cable manufacture**

As mentioned above the two main plastics used in coated cables are PVC and polyethylene. Both plastics are thermo-plastics and can therefore be remelted during the recycling.

PVC contains additives such as calcium carbonate and clays as well as plasticiser and carbon black (primarily in jacketing) and is usually lead stabilised (Y 31). Lead stabilisers are di-basic lead phthalates, tri-basic lead sulfate, lead carbonate and stearate, and are usually less than 2.5% by weight of the PVC composition. Lead stabilisers are encapsulated into the polymer matrix and are not available for environmental or human exposure under normal conditions. Recently some jacketing PVC is made with non-lead stabilisers (non-heavy metals), such as calcium/zinc and barium/zinc etc.

Polyethylene (PE) includes both low and high density (PE-LLD, PE-LD and PE-HD). Some cables are manufactured with cross-linked PE (PE-X) which means that the chemical structure has changed in such a way that the plastics can no longer be recycled through a melting process. The PE additives may include heat and light stabiliser and flame retardants.

#### **5. Structure of the scrap processing industry**

Cable scrap is valuable, mainly because it contains copper and aluminium metal, although the plastics also has value and can be recycled or reused. An industry has been specifically developed to recover these metals. The participants include the following: (1) cable manufacturers, (2) metal scrap dealers who process all types of metals, as well as those who process only non-ferrous metals, or those who only process cable scrap, (3) metal scrap dealers who only collect cable scrap, and (4) brokers or traders who do not take ownership of the cable scrap but deal with scrap producers and cable scrap processors.

Furthermore, some cable scrap processors process scrap generated by wire and cable manufacturers and end-user companies as well as scrap from those who only collect cable scrap. Some processors process under a tolling arrangement.

A metal scrap dealer who sells insulated cable scrap to a processor will often sort this scrap before it is sold to increase the value of the metal and plastic part. The most valuable scrap is the pre-consumer cable scrap noted above that consists of one metal (aluminium or copper). This scrap frequently contains primarily PVC or polyethylene insulation and jacketing.

#### **6. Environmentally sound recycling processes**

##### **6.1 Capability**

The main way of recovering the metal from cable scrap in the developed countries is automated cable chopping. Information regarding this type of equipment can be provided by organisations such as ISRI and BIR (See Appendix 9). The technology is available all over the world. Most cable chopping plants process only copper cable scrap, a few only process aluminium cable scrap, and some operate both a line for aluminium and another for copper cable scrap.

Systems vary in size from 225-680 kg/hr. to 4,770-5,455 kg/hr. and costs, based on 1997 prices, vary from \$150,000 for small machinery to \$1,800,000 for larger automated machines. Cable processors in Europe tend to install small to medium-sized lines handling 0.5 - 3 tonnes/hr and which tend to produce an overall

finer chop grind than U.S. cable processors. U.S. cable choppers typically use larger lines with capacities reaching at least 5 tonnes/hr. Many of these systems are suitable for developing countries.

In North America, about 100 plants operate wire chopping lines with a production of 550,000 – 650,000 tonnes/yr. Cable chopping lines in Japan process some 500,000 tonnes of cable scrap in approximately 100 plants, including 10 major ones. There are also cable chopping lines in Western Europe, Morocco, Tunisia, Australia, Brazil, Argentina, and Chile. China has 6-7 cable chopping plants, and Russia recently acquired one or two plants from a US manufacturer.

## 6.2 Cable chopping process description

The environmentally sound recovery of cables by wire chopping typically includes the following steps (see figure 5):

- pre-sorting
- cable chopping
- granulation
- screening
- density separation

### Pre-sorting

Pre-sorting includes the separation of long cable sections, type of insulation, conductor diameter, plated or unplated conductor, densely baled cable, and pieces of ferrous and non-ferrous metal from loose cable that can be fed directly to the shredder. Most importantly, pre-sorting includes sorting copper- from aluminium-containing cable.

The pre-sorting is the most important element of the environmentally sound management of cables scrap. It also allows maximum value to be obtained for the recovered metal scrap, and makes further separation of plastics easier. Long cable sections are sheared into lengths of about 1m so that they can be fed into the granulator, while densely baled cable has to be broken up into loose streams. These machines process anything from 8 cm diameter cable to thin cable of about 26-gauge. Material not well-suited to such automated systems can be separated out beforehand, for example superfine “hair wire” and grease or tar-filled cables that can obstruct the system (these can be manually separated).

In the past PCB was added to PVC for certain cable systems for high voltage applications to improve insulation performance and to certain low voltage cables as flame retardant<sup>(14)</sup>. The presence of these cable systems should be determined before starting the recycling process.

### Cable chopping

Chopping is normal in larger plants but optional in smaller plants and is usually desirable for processing long cable sections. It is the first step in reducing the size of the cable chop. Compared to shredding, cable chopping produces little if any filter dust.

### Granulation

In the primary granulator, stripping of the insulator and jacketing is only partially accomplished, as the cable chops are typically about 7-8 cm in length. The secondary granulator produces maximum lengths of about 0.6 cm. Such fine chopping usually liberates most of the insulation from the cable but inevitably small amounts of metal remain imbedded in the plastics.

### **Screening**

To enhance the recovery of metal, some chopping lines also use screening to yield the desired chop size. The smaller the chop size the more efficient the removal of the metal. Some systems use vibrating screens that prepare the chops for final metal separation. Here the “fines” containing metal, plastic, fibres, and dirt drop through the bottom screen. The metal is recovered, while an aspirator sucks up the non-metallics. Dust collection using a cyclone collector occurs at many points throughout the system and filter system further cleans the air before exhausting.

### **Density separation**

Similar-size fractions of the chops that collect on the screens are then discharged and fed to an air table that is slanted in two directions. The chips enter from the rear of the table, and the mix is fluidised by air — lighter particles are lifted higher than heavier ones. Consequently, the heavier metal particles move up the table, while the lighter particles of plastic residue or “tailings” float downslope. The fluidised bed separator produces two fractions: clean metal product and essentially metal-free tailings. Generally, “middling” fractions are reprocessed again in the system or can be re-tabled.

Though all cable processors seek the best metal recovery, some metal — both loose and imbedded — eludes capture. Metal content of residue streams can vary from less than 1% to more than 15%. Some cable processors have installed dry electrostatic systems. For example, electrostatic separators can reduce the metal content of tailings from 5-15% to less than 0,1%. The use of electrostatic precipitators or separators reduces the metal content in the tailings, therefore increases the value of the recovered plastic.



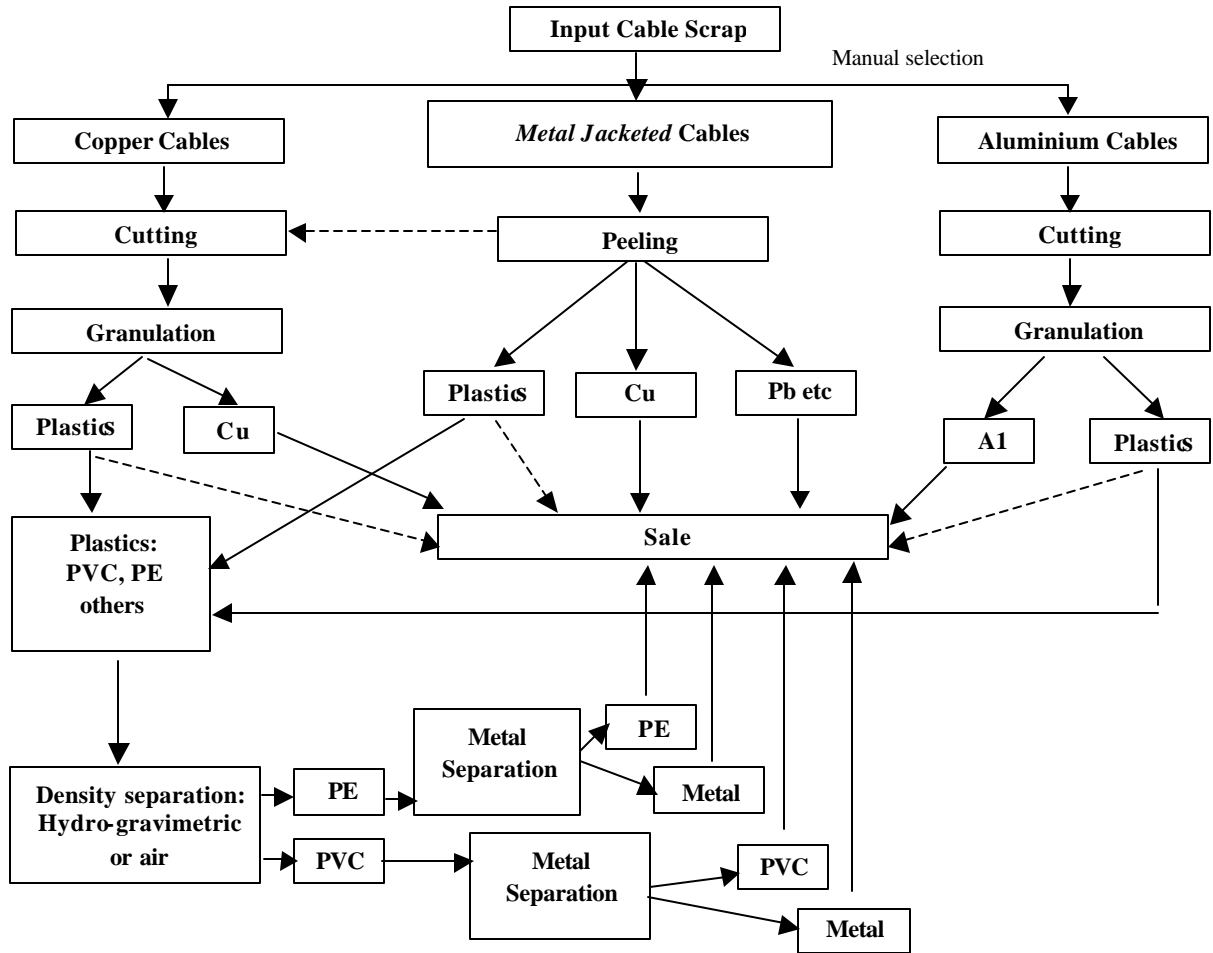


Figure 5: Cable Scrap Chopping Process Flow Sheet

### 6.3 Cable stripping

Another environmentally sound and less costly process for material separation is cable stripping, but it is a process with much lower throughput. Such equipment is designed to handle only single strands of cable waste at rates up to 60 m/min. or 1,100 kg/min with cable that is as thin as 1.6 mm or as thick as 150 mm. In 2000, machines that operate at 24 m/min. sell for about \$5,000, whereas small tabletop machines that operate at rates of only 8 m/min. sell for as little as \$1,800 in the U.S.A. and Europe. These machines are manufactured in many countries (information can be provided by ISRI and BIR, see Appendix 9). Many of the developing countries use these machines rather than the more expensive cable chopping machines. For example, Cyprus, India, Israel, Jordan, Latvia, Lebanon, Russian Federation, Saudi Arabia, United Arab Emirates, Vietnam, Pakistan, China and others use these machines. Cable stripping machines are also used in most developed countries, where these machines are used by utilities, cable manufacturers, cable chopping companies and metal scrap dealers.

The advantages of stripping, in contrast to chopping, is the purity of the recovered jacketing and insulation materials. It is completely free of conducting metal and, if the user is careful in segregating the cable scrap before it is processed, the tailings can consist of one type of polymer. In this way, the tailings, both metal and polymer, become more easily recyclable.

Processors in the developing countries have found that the stripping process is attractive, because they can recycle the tailings, such as plasticised PVC, with relative ease. The capital and operating costs for these machines are also very affordable. Moreover, some processors in those developing countries with low-cost labour simply strip the cable wastes by hand. For example, a processor in Hong-Kong does this and then recycles the recovered PVC jacketing by selling it to others or using it in-house.

## **7. Sound environmental management of the plastic fraction in cable scrap**

Processors of cable scrap recover the more valuable copper and aluminium metals, which are reused by cable manufacturers and others. They are then left with tailings consisting of the polymers used as insulation and jacketing materials. Furthermore, these tailings from chopping can include small amounts of paper, and/or small amounts of metal that are embedded in plastics and loose fine metal. These tailings can be sorted further before being reprocessed.

On the other hand, tailings remaining from stripping operations are mostly free of metal and frequently contain only one type of polymer. In the recovery of tailing materials for re-use this has resulted in second generation products. For example, PVC is recycled in pallets or directly reused to manufacture insulation of electric cable, insulation tape, car mats, carpet lining, flooring and footwear, etc.

### **7.1 Mechanical separation of tailings**

Sound environmental mechanical separation requires that the operator segregate both according to the type of metal and to the type of insulation material covering the cable before being processed. This is true regardless of the separation process used. The technology used should be adapted to the types of cables.

Processors that recover the tailings from stripping operations are in a favoured position to recycle these tailings, which usually contain either PVC or polyethylene. Chopping operations allow not only the separation of coated cables but also coated cable insulated with paper and plastic, which would mean an additional separation step to remove the paper from the plastic. The physical properties of the recovered PVC and the re-use market will depend to a large extent on the purity of the material. Clean PVC tailings with low contamination will have good physical properties. Common second life applications are floor mats, garden hoses, shoe soles, floor tile, sound absorbing materials, bumper guards and traffic cones. As an example, properties and appearance of cable insulation containing up to 30% of recycled material have been proven to be equivalent to virgin cable insulation.

Normally, a stripping operation uses a pre-segregated feedstock that produces a defined waste stream of one plastic. Accordingly, in the developing countries, where stripping processes are widely used, plasticised PVC or other plastic insulation should not represent a disposal problem, if managed in an environmentally sound manner. It is often more than 99.5% pure and can be recycled into sheets, industrial floor tiles, shoe soles, and co-extruded tubings.

If the cable chopper uses a pre-segregated feedstock of cable wastes such as PVC-coated cable and removes essentially all residual metal using the electrostatic process, this process, too, can produce a relatively high-purity PVC (90-95% pure) that can similarly be recycled.

### **7.2 Cryogenic processing**

Some cable choppers sell relatively high-purity PVC and polyethylene (PE) to companies that operate cryogenic equipment that can further purify the various plastics to purity levels higher than 99%. For example, if the impurity is PVC or PE in the mixture of metal and plastics, it is easily removed in a cryogenic process. At liquid nitrogen temperatures, PVC shatters into small particles when it is impacted, while polyethylene and some other plastics do not. Therefore, screening the relatively large contaminant fragments from the PVC small ones can produce a purer PVC. Typically, the resulting different plastics are then compounded with virgin PVC and used as a sound-barrier material in automobiles or in other high-value applications.

Although this is a state of the art technique, it is quite costly (energy and installation) and not widely used even in OECD countries.

### **7.3 Sink and float (hydrogravimetric) processing**

Today mixed plastic tailings are being recycled to a certain extent either "as is" or after separation.

Cable choppers can sell mixed plastic tailings to companies that uses a sink/float tank with water to isolate a clean polyethylene (specific gravity less than 1.0) that floats, and the PVC fraction (specific gravity greater than 1.0) that sinks. The "floats" are used for the injection moulding of such products as flower pots, etc., while the "sinks" are used for injection moulded truck mud flaps, floor mats, and other moulded products.

Some cable choppers have installed sink/float tanks with water to carry out this separation and sell the "floats" and "sinks" to others who carry out the moulding and market the moulded products. In Japan, a project on separation techniques through improved sink and float processes is now underway.

In recent years, in Europe and the USA, cable chopping companies and plastic processing companies have used these "as is" mixed plastic tailings with no separation of the plastics in special low-pressure injection moulding machines. The products from these machines are usually thick cross-section items such as traffic sign bases, speed bumps, and parking bumpers--replacing wood and concrete. One U.S. cable chopping company has used these plastic tailings to make large planters, again replacing concrete.

## **8 Incineration**

Open burning is not an environmental acceptable solution for any kind of waste. Special regard must be given to the obligations and responsibilities set out in the Stockholm Convention on Persistent Organic Pollutants (POPs) with respect to the goal of preventing the formation of unintentional POPs from incineration operations.

In case of plastic coated cables, even under strictly controlled atmosphere, burning changes re-usable plastics into ash and also has a direct effect on the metal as it is oxidized by the fire, and will therefore have a far lesser value. Open burning must not be applied to processing of cable scrap. Thus with development of pre-sorting technique and expanded chopping capacity with better tailings separation technique, recovery of metal and plastics by peeling and/or chopping are now prevailing world-wide as the most economical and environmentally designed processing. As exceptional case, insulated fine wires with contamination like grease are processed in controlled atmosphere furnaces with details as mentioned in Part 1.

Burning in controlled atmosphere furnaces can only be managed in an environmentally sound manner by using state of the art flue gas cleaning which meets strict emission standards (e.g. EU standards, Appendix 8). In this process, the energy should be recovered as far as possible.

The burning of the plastic, to recover the metal has not only some effects in terms of emission but also in terms of quality of the metal. Recyclers do not always obtain the same value for the copper processed by this method if it is oxidised, as some old furnaces cannot avoid the oxidation of metal. State of the art furnaces using micro-processor can control better the furnace conditions.

Major manufacturer of furnaces supply cable recovery companies world-wide. Since 1969, many furnaces have been supplied to metal scrap dealers and several cable chopping companies. More than 700 of these furnaces were in operation worldwide at their peak and still in use now. These furnaces can use natural gas, propane, or fuel oil.

Furnaces can be connected to appropriate gas cleaning systems for all plastics, such as scrubbers that remove the hydrochloric acid generated when burning PVC. For flue gas cleaning details refer to the section "8 Energy recovery from plastic waste" in part-I. Based on 2000 figures, the cost of the total system is

estimated between \$150,000 to \$250,000, and without scrubbers between \$70,000 and \$130,000. Scrubber systems are the main cost of such installations.

By development of pre-sorting technique and expanded chopping capacity and improved tailing separation technique, recovery of metal and plastics by stripping and/or chopping are now prevailing world-wide as the most economical and more environmentally designed processing.

### **Flue gas cleaning from incinerators**

The cooling gases from the combustion chamber will contain a range of materials such as carbon dioxide, sulphur dioxide, hydrogen chloride and fluoride, and dust. Any toxic organic materials formed in the cooling flue gases are likely to be absorbed onto the surface of the dust particles. It is essential to filter out the dust from the gases and this is normally done with fine-mesh fabric filters. Using such methods, modern incinerators were able to operate regularly with dioxin emissions well below the 0.1 nanograms/m<sup>3</sup> (see Glossary) level demanded by environmental authorities.

To meet modern emission standards, sulphur dioxide, hydrogen fluoride and hydrogen chloride must also be removed from the flue gases (see Appendix 8). This is done either by reacting the gases with wet solid alkali, with alkaline solutions or with water depending on the location of the incinerator. In the case of halogenated polymers it is important to check whether the design of the incinerator can cope with the higher amount of acid gases. This reaction will create salts which would need to be landfilled, if they are not recycled.

Neutralizing the acid with chalk produces a solid waste that must be deposited in an authorized landfill<sup>(19)</sup>. Neutralizing the acids with sodium bicarbonate gives a salt solution from which salts can be recycled. Absorbing the acid gases in water produces a solution from which those gases can be retrieved for commercial use. Only a limited number of such recovery plants are available.

In Japan, a process is being developed to use completely the mixed tailings containing PVC as a reducing agent for making steel. In this process chlorine is recovered as hydrochloric acid for pickling of steel products.

Today, polyethylene tailings are being used as a fuel both in North America and in Europe.

## **9. Landfilling**

Only the tailings that could not be recovered should be disposed of in landfills for non-hazardous industrial wastes. In this regard, it is important to consider the technical guidelines governing the environmentally sound recovery and disposal of wastes such as the Technical Guidelines on Specially Engineered Landfill (D5).

## APPENDIX 1

### References

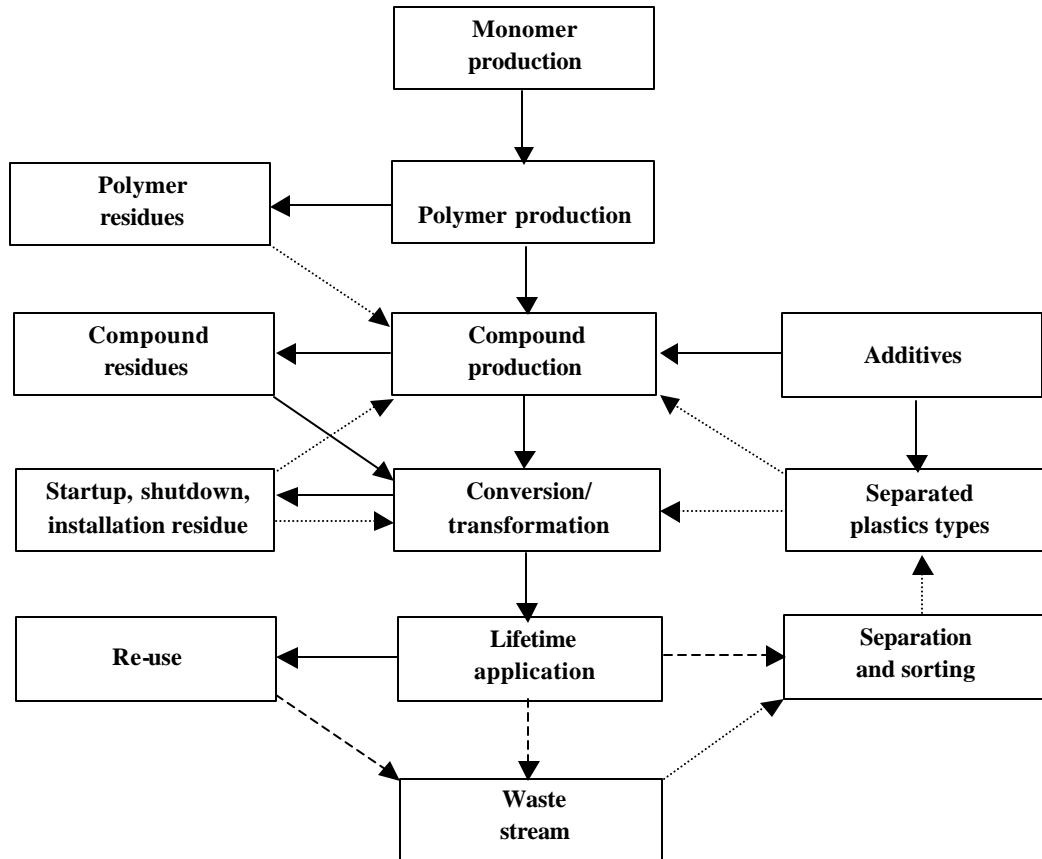
#### Part I

1. 'Report on incineration of products containing brominated flame retardants', OECD, 1998
2. 'Technical Guidelines on Incineration on Land (D10)', published by a Technical Working Group of the Basel Convention.
3. Fardell. P., 1993, 'Toxicity of plastics and rubber in fire', RAPRA Review `Reports - No. 69.
4. 'Recommendations for cleaning buildings after fires', German Federal Health Gazette 1/90, 32-43.
5. I. Burmester, H. Haferkamp, 'Fast And Automatic Thermographic Plastic -Identification For The Recycling Process, Laser Zentrum Hannover, Hollerithallee 8, 30419 Hannover, Germany
6. 'Outlin e Of Separation Technology', Akira Miyake, speech 27-28 October 1998, IdentiPlast Brussels, Sumito Chemical Co. Ltd/ Japanese Plastics Waste Management Institute.
7. 'MIR: A Proven Technology For Identification Of Engineering Plastics', Bernd Willenberg, Bruker Analytische Messtechnik and Klaus Vornberger BMW, speech 27-28 October 1998, IdentiPlast Brussels.
8. 'Laser Spectroscopy Plastics Analysis/A Supplement To NIR -Systems', Hartmut Lucht, speech 27-28 October 1998, IdentiPlast Brussels, Laser Labor Adlerhoff/LLA, Berlin.
9. 'Techniques For Rapid identification And Sorting Of Plastics', Edward J. Sommer, Jr., speech 27-28 October 1998, IdentiPlast Brussels, National Recovery Technologies, Inc.,
10. SOFRES/APME. 1995, 1997
11. 'Method to recover and recycle telephonic and electric cables', Technometal paper presented at international conference of M.E.I.E., Paris, 1996.
12. 'Guide to the safe handling of fluoropolymer resins', Association of Plastics Manufacturers in Europe (APME) publication, Brus sels, 1995.
13. 'The recycling of PVC floorings and roofing membranes', APME publication, 1997.
14. Prognos, 'Mechanical recycling of PVC wastes', Study for the European Commission, DG Environment, 2000.
15. TNO, 'Chemical recycling of plastic waste' study for the European Commission, DG Industry, 1999.
16. 'A Fuel for the Future', APME publication, 1996.
17. Mark F.E., 'Energy recovery through co-combustion of mixed plastics waste and MSW', APME report, 1994.

18. UN-ECE Expert meeting on Best Available Techniques to control dioxin and furan emissions, Rome, 1997.
19. 'Draft Technical Guidelines on Specially Engineered Landfill (D5)', published by the Technical Working Group of the Basel Convention, March 1994.
20. Bertin Technologies, 'The influence of PVC on quantity and hazardousness of flue gas residues from incineration', study for the European Commission, DG Environment, 2000.
21. Argus, 'The behaviour of PVC in Landfill', study for the European Commission, DG Environment, 1999.

APPENDIX 2

Manufacture, Use, Reuse and Recycling of Plastics



—————▶  
**Manufacture, use  
 or reuse route**

.....▶  
**Recycling route**

-----▶  
**Waste disposal  
 route**

## APPENDIX 3

### Health & Safety Information for Materials Reclamation Facilities (MRF) (This has wider application than just for plastics)

#### 1 Safety Information

The following information should form part of the site Health and Safety manual. This information refers in particular to the operation of the equipment supplied for the storage, sorting and baling of plastics waste. It is recommended that the procedures outlined in the safety manual are reviewed regularly to ensure that the information is appropriate and relevant to the equipment and working practices in the MRF.

It is recommended that the information contained within the safety manual should form part of the training of personnel employed within the MRF and also that sections of the information are made available to those activities associated with the MRF such as transport of materials to and from the MRF and the reception of visitors.

- 1.1 It may be necessary to harmonise some of these recommendations with existing site rules and local regulations.
- 1.2 These safety instructions apply to those involved with the operation of the MRF and visitors.
- 1.3 All personnel involved in the operation of the MRF including those involved in the delivery and despatch of materials should be made aware of, and agree to, observe the safety instructions outlined in the site 'Safety Manual'.

#### 2 Fire

- 2.1 The emergency services should be made aware of the types and quantities of recyclates being stored.
- 2.2 The potential danger of fire, when dealing with waste plastics is high. Materials should only be stored in agreed and defined areas.
- 2.3 A "No Smoking" policy should be established and enforced in the MRF for everybody - including visitors and contractors.
- 2.4 Emergency escape routes to a defined assembly point, external to the building or site, should be clearly identified by notices and always kept free.
- 2.5 Suitable fire extinguishers should be provided both within the MRF and in the storage areas. Staff should be trained in the use of fire fighting equipment.
- 2.6 The need for "good operating practices" is paramount, in order to maintain good working conditions, high standards of hygiene, and to avoid the unnecessary storage of flammable materials/waste.
- 2.7 Flammable liquids and gases should not be stored within the MRF or storage areas.
- 2.8 An emergency fire alarm system should be available and regularly tested once per week.



- 2.9 Evacuation routes should be established and evacuation procedures should be practiced.
- 2.10 All personnel should be aware of the emergency procedures in the event of a fire. It is recommended that an emergency telephone should be located within the MRF and that numbers for local emergency services should be clearly displayed.

## **1 Accidents**

- 3.1 In areas where there is machinery and/or many vehicle movements there is a higher potential for accidents. Adherence to safe working practices, the regular maintenance of equipment and the appropriate training of personnel will help to minimise accidents.
- 3.2 Personnel working in the MRF have a duty to ensure that they do not endanger themselves or others. Particular care must be taken when there are visitors on the site.
- 3.3 Safe working practices and instructions must be observed at all times. Only fully trained personnel should operate the MRF machinery.
- 3.4 Fork truck/loading shovel drivers should be trained and should hold the appropriate licence or certificate.
- 3.5 At least two members of staff should be trained in basic first-aid procedures. First-Aid boxes, suitably equipped and adjacent to a sink should be provided.
- 3.6 Operators should wear appropriate clothing. Additional protection should be provided for certain conditions outlined below:
  - Head protection is needed if staff are working in areas where tipping of materials occurs and where materials could fall from higher levels.
  - Face and eye protection is needed if there is a risk from corrosive or irritant substances or impact from moving objects.
  - Respiratory protection is needed if staff are subject to dust, fumes or vapours.
  - Hand protection is needed to protect against sharp irritant or corrosive materials.
  - It is recommended that supervisory management working in the MRF wear and use the appropriate personnel protection clothing, to set an example and to emphasise the standards required.
- 3.7 Personnel sorting recyclables are advised to be inoculated against tetanus infection.
- 3.8 Equipment maintenance should be carried out as recommended by the supplier and only by trained technicians. On no account should protective guards or shields be removed, unless for authorised maintenance.
- 3.9 The safety stop systems employed on the equipment be tested each week.
- 3.10 Personnel should not climb on protective fences.
- 3.11 Foolish behaviour should not be permitted.

#### **4 Baling Machines and Bales**

- 4.1 The manufacturers operating instructions must be strictly observed. Incorrect use of baling equipment can lead to potentially very dangerous situations.
- 4.2 If strapping of bales is not carried out properly or there is a defect in the strapping material the bale strapping can fail. In the event that this occurs the bale can expand rapidly. If this occurs before or during the release of the bale door, the force of the expanding bale can cause the baler door (where fitted) to open at a dangerous speed.
- 4.3 Only the approved specification of strapping should be used.
- 4.4 Servicing of the baler should only to be carried out by an authorised maintenance engineer.
- 4.5 No unauthorised alterations to the baler should be made.
- 4.6 All balers used for baling plastic bottles should be fitted with an hydraulic baler door speed restriction device.
- 4.7 A yellow striped restricted area should be marked around the baling machine. This area should only be entered by MRF operators involved in the strapping and removal of baled materials.
- 4.8 Should it be necessary to cut the high tension steel strapping great care should be exercised and only approved safety cutters should be used.
- 4.9 Bales typically weigh between 200-400 kg depending upon the density of materials. Adequate handling equipment is essential. Bales should be moved from the baling machine by hand pallet trucks or fork lift trucks. A fork lift truck should be used for local transport and stacking.
- 4.10 Bales should not be stored more than three bales high. Fork trucks should have side clamp units fitted to their forks for the safe movement and stacking of bales.
- 4.11 Visitors on the site should not be allowed in areas in which bales are stacked.

#### **5 Baler Maintenance (Cleaning, Removal of Materials)**

- 5.1 Before any maintenance work is carried out on the balers, the power must be switched off and the machine isolated electrically.
- 5.2 Baling machines occasionally need to be cleaned internally as a result of continual use or as a result of contamination. No operator should ever enter a baling machine without first gaining approval from the supervisor.
- 5.3 The supervisor should ensure that the mains electricity is isolated and locked off with a padlock system. The supervisor should retain the key. Any residual hydraulic power should be released in the event that hydraulic accumulators are used within the baling machine hydraulic circuit.

- 5.4 A notice should be placed on the machine clearly identifying that an operator is cleaning/maintaining the machine. Removal of the notice and restoration of power should ONLY be undertaken by the supervisor when the operator is safely clear of the machine and the machine is in a safe condition to enter service.
- 5.5 Always take special care when operating the door locking mechanism to avoid personal injury.
- 5.6 Keep all parts of the body clear of the door locking mechanism.

## **6 Intermediate Storage Skips**

- 6.1 Care should be taken when moving these skips to ensure that clear driver/operator visibility is maintained.
- 6.2 Parked skips should not obstruct any emergency exit routes, or working areas.
- 6.3 Intermediate storage skips should only be stacked two units high.
- 6.4 Ensure that the entry to any baler feed pit is closed and secured after baling operations.

## **7 Supervisor**

- 7.1 It is recommended that the supervisor of the MRF should be a person active within the facility on a daily basis.
- 7.2 The supervisor should allow only fully trained people to work in the MRF.
- 7.3 In addition to operator safety, the supervisor has the following areas of responsibility.
- 7.4 Before switching on the MRF equipment, the supervisor should ensure that it is not obstructed and that personnel are well clear of all moving parts. Alarm systems should be installed to provide advanced warning of machinery start-up.
- 7.5 The supervisor should be trained in fire drill and first aid procedures, the methods of contacting the emergency services, the emergency access and escape routes, and should ensure that the first aid equipment is in a clean and well stocked state. A site accident book should be available and it should be used to record any accidents or potentially hazardous situations. Emergency escape routes should be inspected regularly to ensure that they are kept clear.
- 7.6 The supervisor should insist that good housekeeping standards are maintained. Areas of tipped materials, gangways and fire escapes should be defined and kept clear at all times.
- 7.7 The supervisor should ensure that there is no foolish behaviour on the premises.
- 7.8 There should be emergency lighting and it should be regularly tested.
- 7.9 At the end of the operational shift, the supervisor should ensure that all power is switched off, that all people are clear of the site and that the site is locked and secured before leaving.

## **8 Operators**

- 8.1 The following instructions have been written specifically for the operators, however, they should be read in conjunction with the other local site instructions.
- 8.2 fully trained personnel should operate the MRF machinery.
- 8.3 Operators must not wear loose items of clothing and long hair should be retained by suitable head gear and kept away from moving equipment.
- 8.4 Protective clothing should be worn when working on the sort line, or as required in other areas.
- 8.5 On no account should operators climb upon conveyor belts.
- 8.6 On no account should operators enter sorting chutes.
- 8.7 On no account should operators enter material feed pits.
- 8.8 On no account should operators enter the baling machines.
- 8.9 In the event of an emergency situation the operator should activate the emergency stop system and not attempt to free the machinery until the equipment has been switched off and isolated.
- 8.10 Operators should at all times be aware of vehicle movements within the MRF.
- 8.11 Any hazardous situation should be reported immediately to the supervisor.

## **9. Visitors**

- 9.1 The site supervisor should organise and supervise any site visit.
- 9.2 The tour guide of any visit should be conversant with the safety instructions for the site.
- 9.3 No visitor should touch or operate machinery. They must be advised of and agree to obey all safety instructions such as fire evacuation procedures and no smoking rules, etc. before entering the MRF.
- 9.4 Vehicle movements and other operations of a potentially hazardous nature should not be undertaken during a visit.
- 9.5 The MRF supervisor should ensure that visitors remain within specified areas of the MRF.
- 9.6 A record of individuals entering the MRF should be kept using an entry/exit log system.
- 9.7 Visitors should be provided with appropriate safety protection eg. safety spectacles, hearing protection and high visibility jackets.

## APPENDIX 4

### A. Data from fires at German recycling plants

At **Mulheim** in the Ruhr valley, a warehouse belonging to a haulage contractor was burned out in a major fire. The fire consumed 340 tonnes of PVC and 150 tonnes of polyethylene. The regional office for environmental protection carried out a careful examination of the pollution caused by the fire. It was concluded that the fire gases contained less dioxins than is emitted by many refuse incinerators.

A second fire in 1992, at **Lengerich**<sup>2</sup> in North Rhein Westphalia, in a plastics recycling plant, consumed 1500 tonnes of plastics including 500 tonnes of PVC. Both the local authorities and the regional Environmental Ministry were involved in the investigation of dioxin emissions. The regional Environmental Ministry published a press release which listed the following key conclusions:

- Offices and dwelling houses up to 100 metres from the fire were examined, giving no cause for concern
- Neither the sewage treatment plant nor the ground water seemed unsafe
- Root crops were declared safe and only leaf crops were subject to a single season ban on consumption
- The 26 people most exposed to the fire gases showed low blood-dioxin levels
- A wider university study confirmed that no one was significantly contaminated
- Similar conclusions were drawn from 4 other major fires at Grossefahn, Achim, Siegburg and Isny

These conclusions correspond well with the results of a study of firefighters carried out by the Universities of Bochum and Düsseldorf on the instructions of the NRW Ministry of Labour, Health and Environment.

**Ministry of the Environment, Planning and Agriculture, North Rhine-Westphalia, Germany, 1994.**

### B. Data from fire at the Hamilton Plastimet recycling plant

The fire at the Plastimet recycling facility was a devastating event for the entire community of Hamilton. It was a preventable incident that could have been avoided had the facility met the national Fire Code regulations governing the storage of plastic materials. When stored and handled properly, plastic recycling including vinyl, are safe and provide many benefits for the environment.

The Ontario Ministry of the Environment and Energy (MOEE) response to the Plastimet fire was timely and appropriate, an internal review committee has concluded. Its technical report analysed the results of 8,500 samples by the MOEE on 500 samples of air (using trace atmospheric gas analysers), water, soil, soot and vegetation. The report found that with days after the fire was extinguished, ambient levels of substances tested returned to normal ranges, except in situations where prior contamination of soil and storm sewer water existed.

---

<sup>2</sup> 'Documentation on a major fire at Lengerich', Ministry of the Environment, Planning and Agriculture, North Rhine-Westphalia, Germany, 1994.

The fire lasted three days (Wednesday-Friday, July 9-12, 1997). There was no evacuation the first two days due to weather conditions which allowed the fire's smoke plume to go directly into the upper atmosphere. It was not until Friday when the weather forecasts indicated a wind shift (inversion) coming, which could pose a problem to surrounding residents, that it was decided to evacuate 650 nearby residents from their home on a voluntary basis as a precaution. Levels of benzene had also increased. This was subsequently carried out on Friday and residents then were allowed to return home less than 24 hours later after the fire had been successfully extinguished.

MOEE have collected samples for analysis: air, soot fallout, soil and vegetation. The Medical Officer of Health advised residents to not eat garden vegetables which cannot be peeled.

**Technical Report released by the Ontario Ministry of the Environment and Energy  
30 October 1997**

## APPENDIX 5

### Further data concerning fluoro-polymers

#### 1. Alternative names

In **Table 1** PTFE is used as a 'typical' fluoro-polymer. Other materials in the fluoro-polymer family include Ethylene/Tetrafluoroethylene (ETFE) and Co-polymers of Tetrafluoroethylene and ethylene (TFE) (see **Appendix 7a** for other examples).

#### 2. Polymer characteristics

The fluoro polymers (PTFE, ETFE and other TFE copolymers) are high-performance polymers with unique properties. These include chemical stability (resistant to most chemicals, acids and bases) and low reactivity (thermal stability, UV resistance, weather resistance and electrical insulating properties). None of these polymers are listed as hazardous in national legislation and fluoro-polymer waste is not listed as hazardous material by the EU or the OECD.

#### 3. Polymer properties

The fluoro-polymers are a Y45 constituent but their polymeric format radically modifies the chemical characteristics of that constituent. Fluoro-polymers are not explosive, flammable, spontaneously combustible, oxidising materials, organic peroxides, or corrosive. Hence hazard characteristics H1, H3, H4, H5, H6.2, H8, H10 are not applicable.

Hazard characteristics of more interest are H6.1 (acutely toxic), H11 (delayed or chronic toxicity), H12 (ecotoxicity), and H13 (capable of yielding another material, e.g. leachate). None of these fluorinated polymer wastes exhibit acute toxicity under any reasonable circumstances of the solid polymer as well as to dust of these substances. Their stability and low reactivity also mean that they do not exhibit ecotoxicity if released to the environment. The wastes of these polymers are solid with a rather high degree of biological and chemical inertness, even if left totally exposed to the environment for very long periods of time, they remain stable. It is unlikely that any reasonable interpretation of H13 would apply. Because of the stability of fluoropolymers there is unlikely to be any leachate or gaseous product if the material is landfilled. Open burning or uncontrolled burning should not be considered an environmentally sound recovery method.

#### 4. Polymer recycling

Fluoro-polymers can be recycled in an environmentally sound manner and their high economic value (12-45 times higher than commodity plastics) makes recycling attractive. During the recycling processes the polymers are either ground and sintered or melt-formed into second-life applications. The processes employed are no more hazardous than when using the virgin polymer. Under normal processing conditions it is unlikely that harmful by-products will be produced. The processes employed, however, are specialized and not readily available outside the OECD. Trans-boundary transport for recycling should take place only when the supplying and receiving Parties **are assured** that the appropriate recycling processes are available.

## Appendix 6

### A GLOSSARY OF TERMS

#### **Additives**

Materials which are blended with polymers to make them easy to process, to give the physical properties required in the end-application and to protect them from the effects of weather.

It could be said that: 'polymers + additives = plastics'.

#### **Alkali/alkaline solution**

Substances or solutions of substances which are able to neutralise acids to give more inert substances.

#### **Anti-oxidant**

Substance added to a polymer to make it resistant to the effects of weather or the environment.

#### **« As is »**

As it is, in the existing state.

#### **Blend/blending**

The product/process of mixing materials together.

#### **Bottom ash**

The ash formed beneath the combustion chamber in an incinerator. It may be in the form of dust or of lumps or clinker.

#### **Commingled**

Mixed together, blended.

#### **Compatibility**

Ability to form a consistent mixture as can alcohol and water; the converse of oil and water which show incompatibility.

#### **Compound**

In the plastics industry, a compound is the product of mixing materials together vigorously, often with the application of heat. **No** new chemical substances are formed. Thus polymers are mixed with additives to form compounds.

#### **Compounding**

An extrusion process during which various additives are added to resin(s) mixed and heated/compressed to form a plastic. The additives are fixed in the matrix.

#### **Computer enclosure**

The outer **case** or shell of a personal computer or PC.

#### **Conversion/transformation**

The process of moulding or extruding plastics compounds into finished goods or components of finished goods.

#### **Copolymer**

A polymer made from two or more different monomers.

#### **Degassing**

The process of converting a foamed plastic into a solid plastic.



**Extrusion**

The process of forcing a plastics melt through a shaped orifice to produce a pipe or profile.

**Fabric filter**

A bag or diaphragm of fine-mesh cloth through which flue gases pass on their way out of the chimney. Serves to filter all fine dusts out of the gases.

**Feedstock recycling**

Feedstock recycling is a process in which the polymer chains are broken down into their basic components. For many polymers the basic units are hydrocarbons while for the halogen-containing polymers the basic units are hydrocarbons plus hydrogen chloride or fluoride. The plastics waste is de-polymerised either into monomers which can be used again directly for polymerisation (chemolysis) or into lower molecular weight chemical feedstock (thermolysis or cracking) which can be used, like natural oil, in various chemical reactions including the production of polymers.

**Filler**

Usually a finely powdered mineral, such as chalk or talc, which is compounded with a polymer either to change its properties or to make it cheaper.

**Flue gas**

The gases produced in an incinerator and flowing up the incinerator chimney into the environment.

**Fly ash**

Finely divided particulate material, produced in the incinerator and entrained in the flue gases.

**Foamed plastics**

Plastics into which gases, generated by a foaming agent, have been introduced during the moulding or extrusion processes so as to make them lighter and less dense.

**Formulation**

Selection of components (additives such as stabilisers, colorant, hardeners, plasticisers, filters, etc.) of a product mixture to provide the optimum specific properties for the end use desired. Formulation by experienced technologists is essential for products intended to meet specifications or special service conditions.

**Grade**

Another word for a formulation or blend. Often associated with a 'grade reference' which indicates the type of material.

**Impact resistance enhancer**

Usually another polymer added to a polymer blend to increase its resistance to impact damage.

**Jacketing**

Insulation around cable and wires which are manufactured out of a plastic, such as PVC or PE, but also possibly by oily paper depending on the use of the wire or cable.

**Lumber**

A generic word for planks, panels and profiles made from wood. Often used as an alternative to timber.

**Mould/ moulding**

A shaped cavity into which plastics material is forced. After cooling the moulding retains the shape of the mould.

**MRF**

Material Reclamation Facility

**MSW**

Municipal Solid Waste

**Nanogram**

A thousand millionth part of a gram ( $10^{-9}$ )

**Off-cuts**

Pieces of plastics sheet, bar or profile which are surplus to the component or structure which is being manufactured.

**Plasticiser**

These are organic compounds, sometimes mixed with polymers to make a more flexible plastic. The commonest plasticisers are the phthalates.

**Polymer**

An organic material composed of long chains of molecules made up of many monomer units. Most plastics have a chain backbone of carbon atoms. Polymers are almost always blended with additives before use. Plastics = polymers + additives.

**Potable water**

Water fit for drinking.

**Resin**

A man-made high polymer resulting from the chemical reaction between two or more substances, usually with heat or a catalyst. This definition includes synthetic rubber, silicones (elastomers).

**Self-contained breathing apparatus**

A cylinder of compressed air connected to a mask which excludes the fire gases and smoke from the air breathed by a fireman fighting a fire.

**Semi-finished goods**

Sheets, profiles, bars, pipes made out of plastics which will be further processed before they become part of finished goods.

**Shredding**

The process of cutting up large plastics pieces or components into small pieces suitable for reprocessing.

**Sintered or Cindered**

Reduced to ashes

**Soots**

A black deposit consisting of fine particles formed by the combustion of a fuel.

**Tailings**

The material yielded after the first recovered material (e.g. metal or plastic) has been separated from waste or scrap.

**Thermoplastic**

A polymer that softens when exposed to heat (the temperature depends on the type of plastic) and returns to its original condition when cooled to room temperature.

**Thermosetting**

A polymer that solidifies or “sets” irreversibly when heated. This property is usually linked with cross-linking reactions induced by heating or radiation. In many cases it is necessary to add curing agents (organic peroxides or sulphur). The materials can still be recycled, after grinding, they can be added as additives to other polymers.

**Virgin material**

Newly produced materials about to be processed for the first time.

**Water sprinkler system**

A system of water spray jets built into the structure of a building which automatically begins to operate when an accidental fire is ignited within the building.

## Appendix 7a

**ISO 1043-1: 1987 Plastics - Symbols (excerpt)**  
**Part 1: Basic polymers and their special characteristics**

**Symbols for homopolymeric and natural polymeric materials**

---

<b>Symbol</b>	<b>Material</b>
CA	Cellulose acetate
CAB	Cellulose acetate butyrate
CAP	Cellulose acetate propionate
CF	Cresol-formaldehyde
CMC	Carboxymethyl cellulose
CN	Cellulose nitrate
CP	Cellulose propionate
CTA	Cellulose triacetate
EC	Ethyl cellulose
EP	Epoxide : Epoxy
FF	Furane-formaldehyde
HFP	Hexafluoropropylene
MC	Methyl cellulose
MF	Metamine- formaldehyde
PA	Polyamide
PAI	Polyamide/imide
PAN	Polyacrylonitrile
PAUR	Poly(ester urethane)
PB	Polybutane -1
PBA	Poly(butyl acrylate)
PBT	Poly(butylene terephthalate)
PC	Polycarbonate
PCTFE	Polychlorotrifluoroethylene
PDAP	Poly(diallyl phthalate)
PE	Polyethylene
PEEK	Polyetheretherketone
PEI	Poly(ether imide)
PEOX	Poly(ethylene oxide)
PES	Poly(ether sulfone)
PET	Poly(ethylene terephthalate)
PEUR	Poly(ether urethane)
PF	Phenol-formaldehyde
PFA	Perfluoro alkoxy alkane
PI	Polyimide
PIB	Polyisobutane: Polyisobutylene
PIR	Polyisocyanurate

PMI	Polymethacrylimide
PMMA	Poly(methyl methacrylate)
PMP	Poly-4-methylpentane-1
PMS	Poly- $\alpha$ -methylstyrene
POM	Polyoxymethylene (polyacetal): polyformaldehyde
PP	Polypropylene
PPE	Poly(propylene ether)
PPO	Poly(phenyloxide)
PPOX	Poly(propylene oxide)
PPS	Poly(propylene sulfide)
PPSU	Poly(propylene sulfone)
PS	Polystyrene
PSU	Polysulfone
PTFE	Polytetrafluoroethylene
PUR	Polyurethane
PVAC	Poly(vinyl acetate)
PVAL	Poly(vinyl alcohol)
PVB	Poly(vinyl butyral)
PVC	Poly(vinyl chloride)
PVDC	Poly(vinylidene chloride)
PVDF	Poly(vinylidene fluoride)
PVF	Poly(vinyl fluoride)
PVFM	Poly(vinyl formal)
PVK	Polyvinylcarbazole
PVP	Polyvinylpyrrolidone
SI	Silicone
SP	Saturated polyester
TFE	Tetrafluoroethylene
UF	Urea-formaldehyde
UP	Unsaturated polyester

**Symbols for copolymeric materials**


---

<b>Symbol</b>	<b>Material</b>
A/B/A	Acrylonitrile/butadiene/acrylate
ABS	Acrylonitrile/butadiene/styrene
A/CPE/S	Acrylonitrile/chlorinated polyethylene/styrene
A/EPDM/S*	Acrylonitrile/ethylene-propylene-diene/styrene
A/MMA	Acrylonitrile/methyl methacrylate
ASA	Acrylonitrile/styrene/acrylate
E/EA	Ethylene/ethyl acrylate
E/MA	Ethylene/methacrylic acid
E/P	Ethylene/propylene
EPDM*	Ethylene/propylene/diene
E/TFE	Ethylene/tetrafluoroethylene
E/VAC	Ethylene/vinyl acetate
E/VAL	Ethylene/vinyl alcohol
FEP	Perfluoro(ethylene/propylene) : Tetrafluoroethylene/hexafluoropropylene
MBS	Methacrylate/butadiene/styrene
MFA	Per fluoro alkoxy alkane: Tetrafluoroethylene/Per fluoro methylvinyl ether
MPF	Melamine/phenol-formaldehyde
PEBA	Polyether block amide
PFA	Per fluoro alkoxy alkane: Tetrafluoroethylene/Per fluoro propylvinyl ether
SAN**	Styrene/acrylonitrile
S/B	Styrene/butadiene
SMA	Styrene/maleic anhydride
S/MS	Styrene/á-methylstyrene
VC/E	Vinyl chloride/ethylene
VC/E/MA	Vinyl chloride/ethylene/methyl acrylate
VC/E/VAC	Vinyl chloride/ethylene/vinyl acetate
VC/MA	Vinyl chloride/methyl acrylate
VC/MMA	Vinyl chloride/methyl methacrylate
VC/OA	Vinyl chloride/octyl acrylate
VC/VAC	Vinyl chloride/vinyl acetate
VC/VDC	Vinyl chloride/vinylidene chloride

- \* EPDM is a rubber symbol; for definitions see ISO 1629
- \*\* In Japan and the USA the symbol 'SAN' is a re

PVC-U	unplasticised PVC
PVC-P	plasticised PVC
PVC-E	expanded PVC (foamed)

## Appendix 7b

## Material Identification Marking for packaging

The separation of plastics materials for recycling is made much easier if the products made from plastics carry an identifying marking. There is now general agreement that plastics packaging items should be marked using the code developed by the Society of the Plastics Industry in America. The symbols used in this code are illustrated below.



Materials originating in Europe will carry modified versions of those above:

**PETE = PET**                      **polyethylene terephthalate**

**HDPE = PE-HD**                **high density polyethylene**

**V = PVC**                         **polyvinyl chloride**

**LDPE = PE-LD**                **low density polyethylene**

**PP = PP**                         **polypropylene**

**PS = PS**                         **polystyrene**

**Other**                              **Other polymers or blends**

For non-packaging applications the marking on plastics components is likely to be marked according to ISO 11469; 1993 (E), Plastics - Generic identification and marking of plastics products.



## Appendix 8

Emission standards for waste incinerators (in mg/m<sup>3</sup> at 11 % O<sub>2</sub> dry) set by the European Union

Pollutant	EC Directive Incineration of Waste (2000/76/EC)		
	daily average limit	A - half hour average limit 100 % <sup>2)</sup>	B - half hour average limit 97 % <sup>2)</sup>
HCl	10	60	10
HF	1	4	2
SO <sub>2</sub>	50	200	50
NO <sub>x</sub>	200 (> 6t/h) 400 (< 6t/h)	400	200
CO	50	100	50
Organic substances	10	20	10
Dust	10	30	10
Heavy metals	average emission limit over respective sampling time		
	[½ - 8 h]		
Σ Cd and Tl	total 0,05		total 0,1 <sup>3)</sup>
Hg	0,05		0,1 <sup>3)</sup>
Σ As, Sb, Cr, V, Sn, Pb, Co, Ni, Cu, Mn	total 0,5		total 0,1 <sup>3)</sup>
	[6 - 8 h]		
Dioxins and furans (as toxic equivalent values)	0,1 x 10 <sup>-6</sup> TE <sup>1)</sup>		

1) = 0,1 ng TE/m<sup>3</sup>

2) either none of the half-hourly average values exceeds any of the emission limit values set out in column A or, where relevant, 97 % of the half-hourly average values over the year do not exceed any of the emission limit values set out in column B

3) until 1 January 2007 average values for existing plants for which the permit to operate has been granted before 31 December 1996 and which incinerate hazardous waste only

## Appendix 9

For more information on plastics recycling contact:

<b>REGIONAL ASSOCIATIONS</b>
APME (Association of Plastic Manufacturers in Europe) Avenue E Van Nieuwenhuysse 4 Box 3 B-1160 Brussels BELGIUM Tel: 32 2 675 3258 / Fax: 32 2 675 4002 E-Mail: <a href="mailto:info@apme.org">info@apme.org</a> Website: <a href="http://www.apme.org">http://www.apme.org</a>
<b>NATIONAL INSTITUTES</b>
ÖKI-Österreichisches Kunststoffinstitut Franz grill Strasse 5 A-1030 Wein AUSTRIA

For more information on cable scrap recycling (machinery suppliers or processors) contact:

<b>INTERNATIONAL ASSOCIATIONS</b>
BIR Bureau of International Recycling Avenue Franklin Roosevelt, 24 B-1050 Brussels BELGIUM Tel: 32 2 627 5770 / Fax: 32 2 627 5773 E-Mail: <a href="mailto:info@bir.org">info@bir.org</a> Website: <a href="http://www.bir.org">http://www.bir.org</a>
<b>REGIONAL ASSOCIATIONS</b>
<b>EUROMETREC</b> European Metal Trade & Recycling Federation c/o BIR Avenue Franklin Roosevelt, 24 B-1050 Brussels BELGIUM Tel: 32 2 627 5770 Fax: 32 2 627 5772 Website: <a href="http://www.eurometrec.org">http://www.eurometrec.org</a>
<b>NATIONAL ASSOCIATIONS</b>
<b>AUSTRALIA</b>  ACOR Australian Council of Recyclers Level 11, Elisabeth Towers 418A Elisabeth Street AUS - Surrey Hills, NSW 2010 AUSTRALIA Tel: 61 2 9282 6400 / Fax: 61 2 9281 2546

## AUSTRIA

## BUNDESGREMIUM DES SEKUNDÄRROH-STOFFHANDELS

Wiedner Hauptstraße 63

PO Box 440

A - 1045 WIEN

AUSTRIA

Tel: 43 1 501 05 35 61 / Fax: 43 1 505 38 51

E-Mail: [bggr3@wkoesk.wk.or.at](mailto:bggr3@wkoesk.wk.or.at)

## BELGIUM

## COBEREC ASBL

Rue des Comédiens, 16/22

Boîte 7

B - 1000 BRUSSELS

BELGIUM

Tel: 32 2 2230801 / Fax: 32 2 2190022

E-Mail: [info@coberec.be](mailto:info@coberec.be)Website: <http://www.coberec.be/>

## BULGARIA

## BAMT Bulgarian Association of Metal Traders

26 Hristo Botev Boulevard, ap 12, floor 4

1000 SOFIA

BULGARIA

Tel: 359 2 52 60 98 or 9533288 / Fax: 359 2 52 60 98

E-Mail: [b\\_a\\_m\\_t@yahoo.com](mailto:b_a_m_t@yahoo.com)

## CHINA

## China Environment Protection Industry Development Corporation

25 Yuetan North Street

Xicheng District

100834 BEIJING

CHINA

Tel: 86 10 6 8334022 / Fax: 86 10 6 8334099

E-Mail: [mailto:crcc@mx.cel.gov.cn](mailto:mailto:crcc@mx.cel.gov.cn)

## CHINA

## CAMU - CHINA ASSOCIATION OF METAL SCRAP UTILISATION

3504 No. 17B Xichangan St.

CN - 100031 BEIJING

CHINA

Tel: 86 10 6 6085516/6 6013515

Fax: 86 10 6 6085450

Website: <http://www.sinosteel.com/>

CUBA

UERMP Union De Empresas De Recup De Materias Primas  
Director General: Miguel MACIAS SAINZ  
Av. Primera E/t 16 - 18 No. 1604  
Miramar, Playa  
CU - HABANA  
CUBA  
Tel: 55 7 53 24 06 82  
Fax: 55 7 53 24 06 81  
E-Mail: [casa.compra@uermp.columbus.cu](mailto:casa.compra@uermp.columbus.cu)

CZECH REPUBLIC

SPDS - APOREKO SVAZ PRUMYSLU DRUHOTNYCH SUROVIN  
Skrétova ul. 6  
CZ - 120 59 PRAHA 2  
CZECH REPUBLIC  
Tel: 420 2 242 32 414 / Fax: 420 2 242 32 414

DENMARK

NRF - NORDIC RECYCLING FED. C/O H.J. HANSEN HOLDING A/S  
c/o H J Hansen Holdings A/S  
Verstergade 97/101  
PO Box 927  
DK - 5100 ODENSE C  
DENMARK  
Tel: 45 63 12 82 00 / Fax: 45 63 12 82 19  
E-Mail: [nrf@nordic-recycling.org](mailto:nrf@nordic-recycling.org)  
Website: <http://www.nordic-recycling.org/>

FRANCE

FEDEREC  
Rue de Prony 101  
F - 75017 PARIS  
FRANCE  
Tel: 33 1 40 54 01 94  
Fax: 33 1 40 54 77 88

GERMANY

VEREIN DEUTSCHER METALL- HÄNDLER EV. - VDM  
Ulrich-von-Hassell-Straße 64  
D - 53123 BONN  
GERMANY  
Tel: 49 228 25901 0  
Fax: 49 228 25901 20  
E-Mail: [metallverein@t-online.de](mailto:metallverein@t-online.de)  
Website: <http://www.metallverein.de/>

## GERMANY

BVSE - BUND.SEKÜNDÄRROHSTOFFE UND ENTSORGUNG E.V.

Hohe Strasse 73

D - 53119 BONN

GERMANY

Tel: 49 228 988 49-0

Fax: 49 228 988 49-99

E-Mail: [info@bvse.de](mailto:info@bvse.de)Website: <http://www.bvse.de/>

## HUNGARY

NATIONAL ASSOCIATION OF RECYCLERS (HOE)

Ajtosi Dürer Sor 5, III. Em1

H - 1146 BUDAPEST

HUNGARY

Tel: 36 1 3430556/3522579

Fax: 36 1 3430985

E-Mail: [hoe@mail.datanet.hu](mailto:hoe@mail.datanet.hu)

## IRELAND

Metal Merchants Association of Ireland

Nathan House, Christchurch Square

EIR - DUBLIN 8

IRELAND

Tel: 353 1 45 44 333 / Fax: 353 1 45 44 690

## ITALY

ASSOFERMET

Corso Venezia 47-49

I - 20121 MILANO

ITALY

Tel: 39 02 760 08807 / Fax: 39 02 781 027

E-Mail: [marcemas@tin.it](mailto:marcemas@tin.it)Website: <http://www.assofermet.it/>

## NETHERLANDS

METAAL RECYCLING FEDERATIE

P.O. Box 85645

NL - 2508 CH DEN HAAG

NETHERLANDS

Tel: 31 70 362 46 10 / Fax: 31 70 363 63 48

E-Mail: [mail@mrf.nl](mailto:mail@mrf.nl)Website: <http://www.mrf.nl/>

<p><b>PORTUGAL</b></p> <p>ANAREPRE Associação Nacional Dos Recuperadores De Produtos Reciclavers  Praca das Industrias  P-Lisboa 1300  <b>PORTUGAL</b>  Tel: 351 21 360 1109 / Fax: 351 21 364 1301  E-Mail: <a href="mailto:aip@aip.pt">aip@aip.pt</a></p>
<p><b>ROMANIA</b></p> <p>FEDERATION PATRONALE RECOMAT  Cal. Victoriei N° 152,  Et. II, Cam 213, Sector 1  <b>RO - BUCHAREST</b>  <b>RUMANIA</b>  Tel: 40 1 3151085 / 6505216  Fax: 40 1 6597797</p>
<p><b>SWITZERLAND</b></p> <p>VERBAND STAHL-UND- METALL-REC. SCHWEIZ (V.S.M.R.)  Konradstrasse 9  PO Box 7190  <b>CH - 8023 ZÜRICH</b>  <b>SWITZERLAND</b>  Tel: 41 1 271 90 90 / Fax: 41 1 271 92 92  E-Mail: <a href="mailto:gerster@jpg.ch">gerster@jpg.ch</a>  Website: <a href="http://www.vsmr.ch/">http://www.vsmr.ch/</a></p>
<p><b>UNITED KINGDOM</b></p> <p><b>BRITISH METALS RECYCLING ASSOCIATION</b>  16 High Street  Brampton  Huntingdon  Cambs PE28 4TU  <b>UNITED KINGDOM</b>  Tel: 00 44 1480 455249 / Fax: 00 44 1480 453680  E-Mail: <a href="mailto:admin@britmetrec.org.uk">admin@britmetrec.org.uk</a></p>
<p><b>USA</b></p> <p><b>ISRI</b>  1325 G Street, N.W.  Suite 1000  <b>USA - WASHINGTON, DC 2005-3104</b>  <b>USA</b>  Tel: 1 202 737 1770  Fax: 1 202 626 0900  E-Mail: <a href="mailto:isri@isri.org">isri@isri.org</a>  Website: <a href="http://www.isri.org/">http://www.isri.org/</a></p>
<p>Other National Associations may be found through Regional or International Association Web sites</p>

## Other references:

Recycling Machinery
Alfred A Nijkerk "Handbook of Recycling Techniques" 3rd edition, ISBN 90-802909-1-2 September 1996
F Johannaber "Kunststoff Maschinen Führer" 3rd edition, Carl Hanser Verlag München, 1992
Saechtling "Kunststoff Taschenbuch" 25th edition, Carl Hanser Verlag München, 1989

## Appendix 10

### Individual Scrap Grades as defined by ISRI (Institute of Scrap Recycling Industries) and BIR (Bureau International de Recyclage)

Copies of current plastic scrap classifications may be obtained or found through or on the websites of [www.bvse.de](http://www.bvse.de) under the publications section entitled "bvse u. BIR - Qualitäten-verzeichnis für Altkunststoffe" (single copies are free) other brochures on plastic recycling may be found on the bvse web site. On the web site <http://www.isri.org/specs/index.htm> each of the following chapters of the ISRI Scrap Specifications Circular 2001 are obtainable:

#### Chapters

- [Introduction](#)
- [Nonferrous Scrap](#)
- [Ferrous Scrap](#)
- [Glass Cullet](#)
- [Paper Stock/Domestic Transactions](#)
- [Paper Stock/Export Transactions](#)
- [Plastic Scrap](#)
- [Metals Transactions](#)



Appendix 11

FLWSHEET ON THE SEPARATION OF FOUR PLASTICS

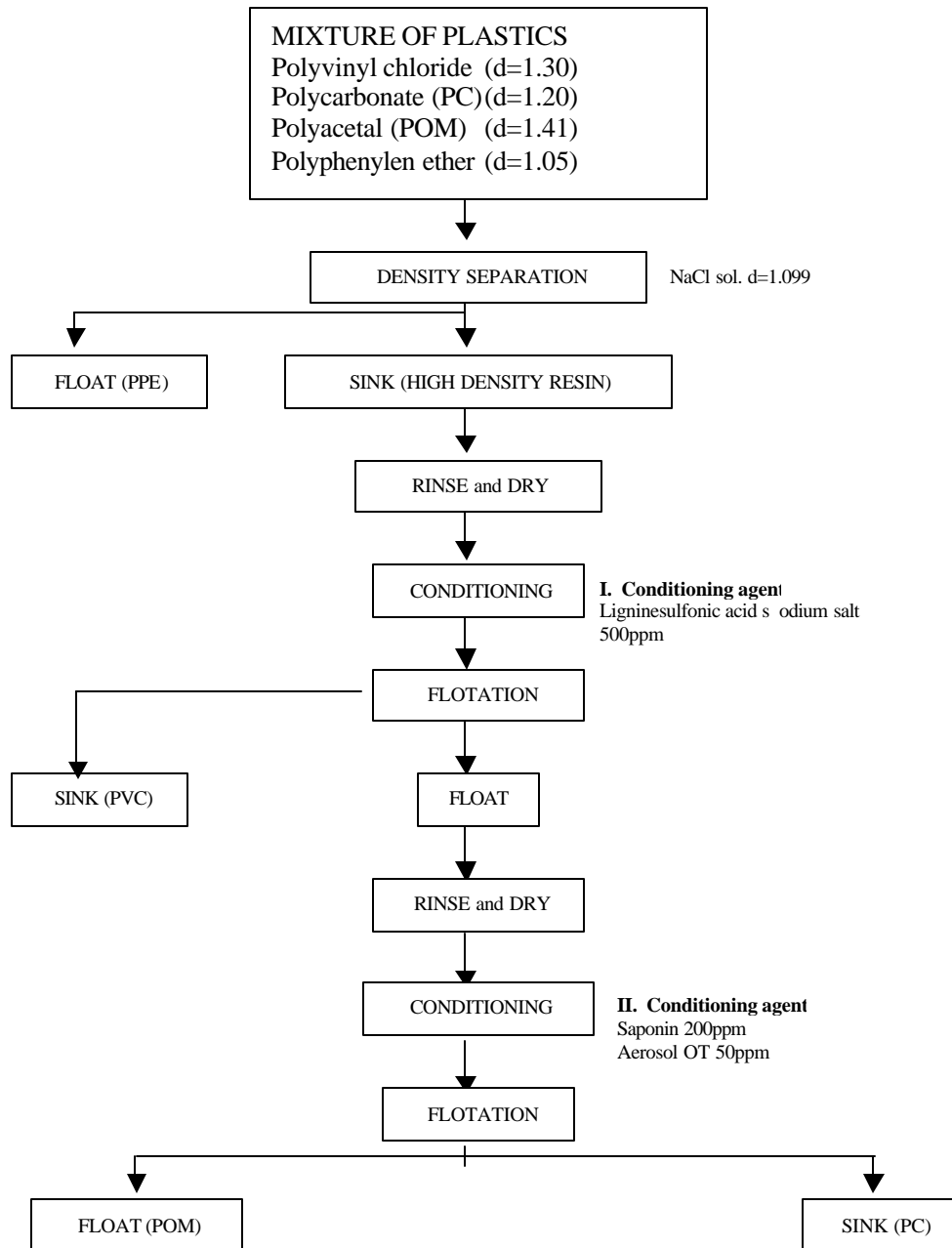


Figure 4 Flowsheet of separation of four plastics materials by density separation and flotation

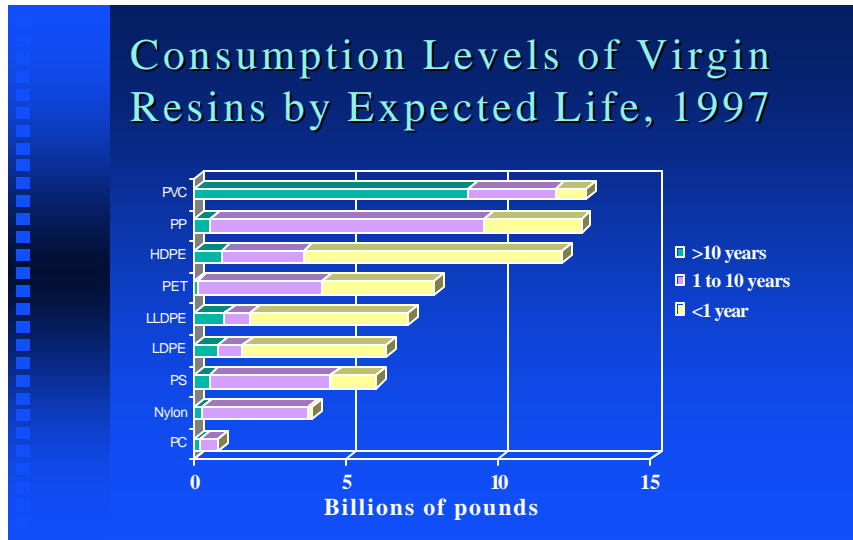
Appendix 12**Type and quantity of plastic waste for various processing methods**

<b>Origin/waste-generating activity</b>	<b>Type and quantity of waste</b>
Dry blending Banbury mixer	Powder agglomerates, removed by screening drippings, aborted runs.
Extrusion compounding	Chunks and strands from extruder purging. Wastes generated during faulty operation (overheating, impure feed). Custom compounding: 1-2% of throughput. In line compounding: 0.2% of throughput.
Injection moulding	Sprues and runners. Normally reground and reprocessed in amounts ranging from 1-15% of total feed. About 1% dirty grindings, floor sweepings, chunk for Purging and contaminated moulding.
Extrusion of pipe, rod, tubing and profiles	2-3% scrap for common extrusion processes. Up to 40-50 % scrap for items machined from rod stock.
Film blowing	Start up, tail and reject film. Extruder purging.
Sheet extrusion	Scrap generation: 15% PE, 25% PVC, 40% PP-film
Extrusion coating	6% loss in extrusion coating on paperboard 5-6% in wire and cable coatings.
Coextrusion	9-10% scrap (sometimes 20%) generally sold to convertors
Injection blow moulding	Practically no scrap
Extrusion blow moulding	Amount of pinch-off, depending upon excess length of parison. Minimized by good design.
Rotational moulding	Removal of open sections, small amounts of trim flash
Dip and slush moulding	No cut-off arises, since the material forms a solid solution on the mould. There is, however, a great potential for contamination of the plastisol or the fluidized solids-bath, resulting in rejected parts
Casting	3-5% loss
Calendering	Drippings from mixer and calender rolls (<1%) Trim, front and strip and tails (6-7%)
Thermoforming	Trimings arise in significant quantities 8% in high pressure lamination Side trimmings or scrap cuttings when forming labels, bags etc. from laminates.
Spreader coating	6-10% scrap, little of which can be recycled
Cellular plastics	5-10% in expanded PS
Compression/transfer moulding	2-5% flash (excess material).

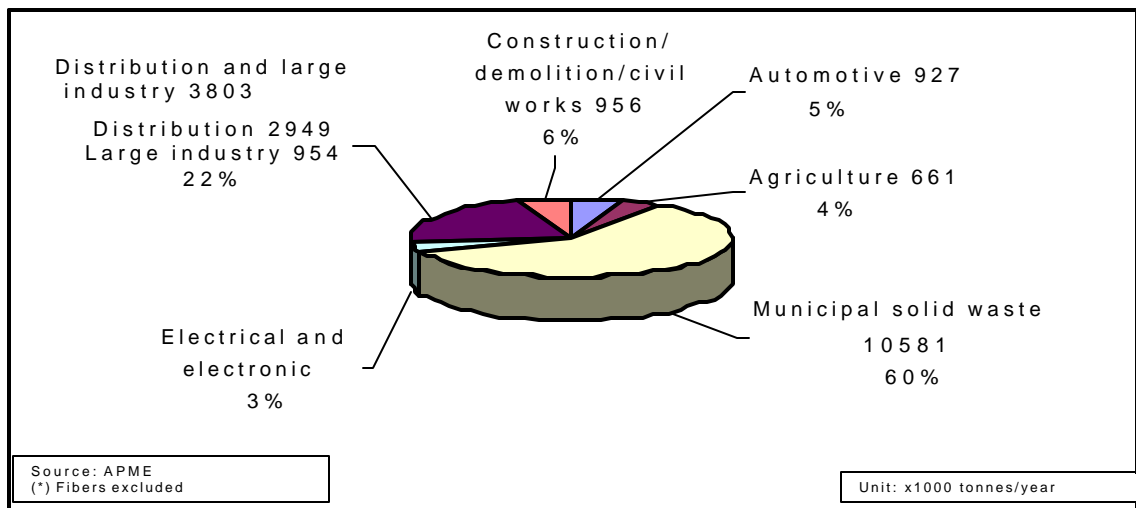
**Source :** M.Sittig, Pollution Control in the Plastics and Rubber Industry , pp 134-163  
(Noyes Data Corp., Park Ridge, N.J. 1975)

Appendix 13

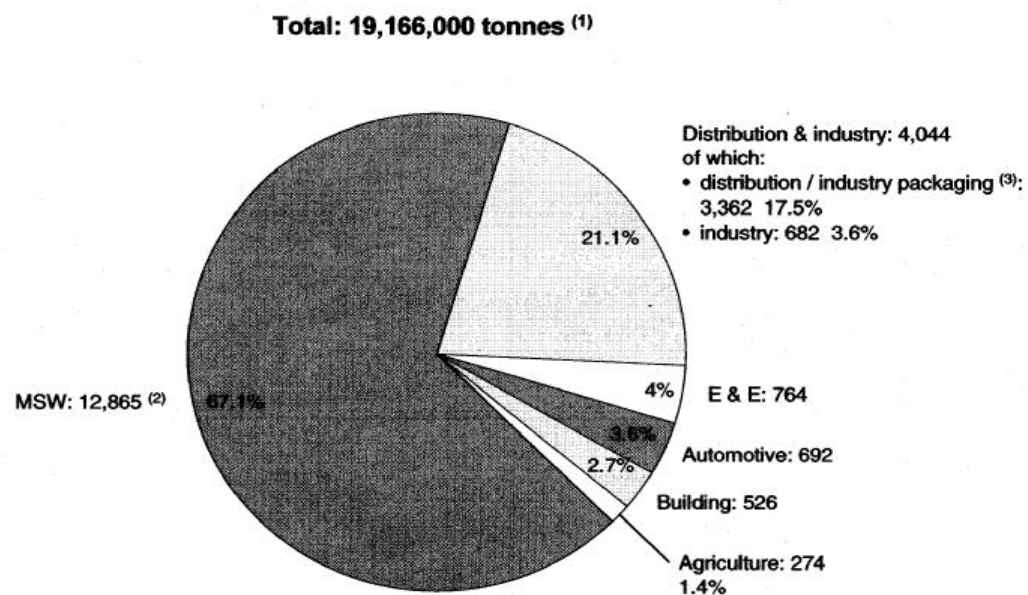
Consumption Levels of Virgin Resins by Expected Life, 1997



Total post-user plastic waste, by source of waste (\*)  
 Western-Europe, 1994  
 (Post-user plastic waste: 17,505,000 tons)



**B3 - COLLECTABLE POST-USER PLASTIC WASTE**  
**B.3.1. Breakdown by end-use sector (Western Europe, 1999)**



Source: TN SOFRES Consulting, Ministries of environment, waste management organisations

(1) Collectable available waste

(2) Households: 80/90% / Assimilated: 10/20% (small shops and offices are also included). Distribution / industrial waste is not included

(3) Supermarkets, industries

Unit: x 1 000 tonnes / year

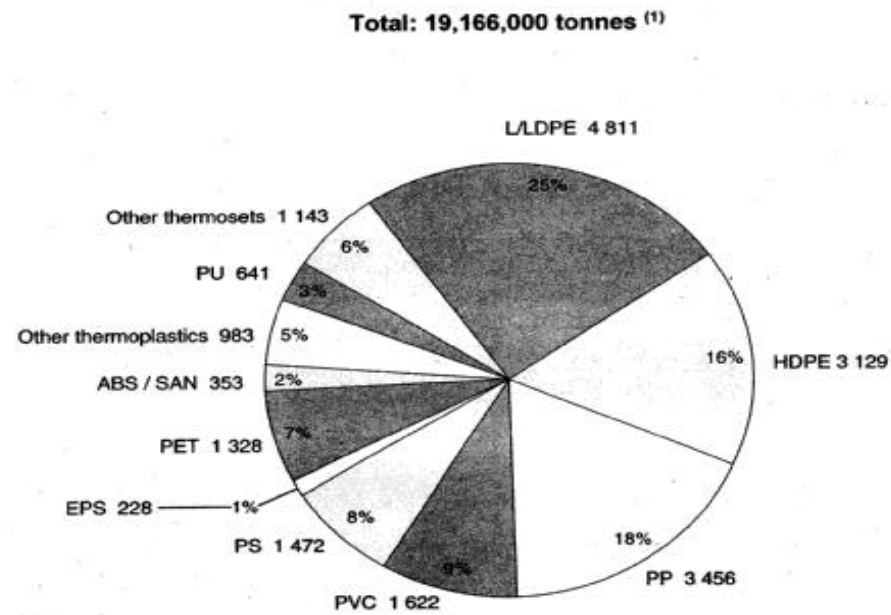
TAYLOR NELSON SOFRES - Consulting

Information system on plastic waste management in Western Europe - European overview - 1999 Data (January 2001)

A	C
D	F

51

**B3 - COLLECTABLE POST-USER PLASTIC WASTE**  
**B.3.3. Breakdown by polymer (Western Europe, 1999)**



Source: TN SOFRES Consulting  
 (1) Collectable available waste

Unit: x 1 000 tonnes / year

TAYLOR NELSON SOFRES - Consulting  
 Information system on plastic waste management in Western Europe - European overview - 1999 Data (January 2001)

A	B	C
D	E	F