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# ADVANCES IN MATERIALS TECHNOLOGY MONITOR

United Nations  
Industrial Development Organization

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## ADVANCES IN MATERIALS TECHNOLOGY MONITOR

Vol. 2, No. 4 1995

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**Recycling of Plastics Waste**

*E. Wogrolly*

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#### Publications

UNIDO's *Advances in Materials Monitor* is established as a mechanism of current awareness to monitor developments in the materials sector and to inform governments, industry and academia, primarily in developing countries.

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### TO OUR READERS

Plastics have now become indispensable materials, not only in industrial countries, but also in developing countries where the proportion of plastics applications in the industrial field is continually increasing. For demanding engineering applications, an annual world-wide growth of 8 - 10 per cent is calculated for the coming years. In 1993, the total world demand rose to over 100 million tons for the first time. An extrapolation of plastics production beyond 1990 yields a production volume of around 120 to 140 million tons by the year 2000.

The concept that plastics are environmentally unfriendly and a health hazard is already not factually applicable for many developing countries in which about 35 - 40 per cent of the total plastics consumed are recycled. However, at present, no guidelines or codes of practice exist for the collection, sorting and recycling of plastic waste.

The environmental problems associated with the greater use of plastics in developing countries can be adequately taken care of by the development of a strong recycling industry. Various studies have found that plastic materials are more acceptable than traditional materials such as paper, at least in terms of waste generation and the associated energy consumption. It has also been scientifically proven that plastics are eco-friendly materials, particularly when the product's life cycle is considered.

Plastics recycling definitely has some positive benefits: (i) it can generate income; (ii) it requires relatively low levels of investment; (iii) it can yield reasonable or high profits; and (iv) it involves technically relatively uncomplicated production processes to produce a wide variety of products for a broad market.

At present in many developing countries, the recycling of plastics, though creating a considerable amount of employment and business, has also raised some issues which need to be urgently addressed. These relate to more scientific and technological inputs in the reprocessing and identification of the right application for the recycled materials, bearing in mind environmental pollution, hazards and safety considerations. Any future strategy should also include drawing up legislation and a code of practice to regulate the disposal of plastics waste, its reuse and recycling. Optimal practices in this regard need to be disseminated.

This issue of the *Monitor* is fully devoted to plastics recycling issues. Readers will be able to find information on existing recycling technologies and how the associated problems are being solved, both in industrialized and developing countries. We hope that it will prove useful for policy makers and entrepreneurs.

On another note, starting with the 1996 issues, the *Monitors* will be published under a new title, namely, "**Emerging Technologies Series**". We believe that the new title more aptly describes the contents of the publications. We hope that your interest in receiving the publication will continue and welcome any feedback from you.

V. Kojamovitch, Technical Editor

# **ADVANCES IN MATERIALS TECHNOLOGY MONITOR**

**VOLUME 2, NUMBER 4, 1995**



**UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION**

**Vienna, 1995**

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## A. SPECIAL ARTICLE

### RECYCLING OF PLASTICS WASTE

*E. Wogrolly,  
M. Hofstatter and E. Langschwert*

#### **Present situation**

About 4 per cent of the total crude oil production is used for the manufacture of plastic materials. The resins are processed into products suitable for use by means of optimum technical processes which are ecologically and economically advantageous. But even the optimum product has a limited lifetime and the question of disposal arises. In Austria more than 250,000 tons of plastics waste are generated annually of which an amount of 60,000 tons was collected in 1993. More than 80 per cent of household plastics refuse is generated by packaging material, making up to 50 per cent of the total volume of waste.

In the reuse of recycled plastics, contaminants and specifically so-called commingled plastics and their influence on the properties of developed new products, play an important role.

Contaminations caused by the practical utilization of virgin products mostly consist of labels, metal caps and residues of the contents. Caused by the relatively low weight of the plastics packages in comparison to the contents, residue in the range of about 1 per cent of the original charge, makes up a partial amount of between 10 per cent and 35 per cent of the total and, in the worst case, the contaminants can amount to the 10-30-fold of the total weight of the waste packaging. Mixtures of different types of plastics impair the quality of the products to a great extent. It is well known that the big four commodity plastics, which are used for products of daily life, are more or less incompatible with each other.

#### **Requirements for recycling and reuse of plastic materials**

The basic question is the degree of purity of the waste plastics intended for reclamation. When plastics are recycled immediately in the same premises, so-called "internal recycling", they appear in most cases as pure materials of the same type and also their thermal prehistory is well known. The reclamation process becomes more complicated when the plastic materials which have been used are not commingled, i.e. not mixed with other types of plastics there may still arise problems through differing tension upon the particular plastic during its use. Additional problems may be caused by the reuse of plastics through waste collection. It cannot entirely be excluded that, under the separation technique practised, material of a completely different chemical structure or physical behaviour may appear in the mixture of the plastics fraction. The resulting regranulate mostly consists of different types with differing properties.

#### **Pure quality plastics**

Non-damaged plastics: recovered by "internal recycling". Sufficiently stabilized material will not be degraded or at least only to a very slight extent even by manifold processing. By the adding of recycled material to the virgin material, in an amount of about 20 per cent, no deterioration of properties will occur.

Damaged plastics: material which has been damaged by thermal processing procedures.

Attempts are being made, by the addition of virgin material, to improve the properties of the plastic, thus enabling reutilization. Through such measures it is inevitable that some mechanical properties will be extensively degraded. Such a regranulate can be reprocessed into products which command strongly reduced requirements.

#### **Waste plastics**

Contaminated plastics: Very often the recycled plastics are no longer of one type. Reasons for this, among others, are contaminants which cannot completely be removed by reprocessing procedures or are caused by materials which have contaminated the plastics by migration. The mechanical properties decrease almost linearly with the increasing degree of contamination. For this reason it is necessary to carefully clean and purify the plastics during the recycling processes.

Commingled plastics: During the recycling processes it is very often difficult to avoid joining, blending, remelting and coextrusion of different types of plastics which cannot be separated by the separation process.

#### **Compatibility of plastics**

Specifically polyolefines, which are widely used in the field of packaging, are known to be slightly compatible. For example, PE and PP cannot be separated practically by the common swim and sink processes, through which differences of specific gravity are separated.

Another important parameter is the processing temperature. If this falls below the processing level the plastification will be insufficient, but if it exceeds the range of processability, the material might decompose. Thus, in the case of mixtures, the ranges of processability may be limited.

Through the addition of compatibilizers, however, mixtures can be provided which—although not compatible with each other—can be melted into a practical system of useful combinations of properties. Such compatibilizers, however, are not yet available for all combinations of waste plastics. Recycled plastics materials can be reprocessed more or less without problems if they are clean and free from contamination. Mechanical properties can be made significantly impure by small amounts of impurities. Compatibilizers can significantly improve the properties of recycled plastics. From the economic point of view, the recycling of plastics has not come to a break-through yet.

#### **Characterization of plastics fractions by analytical methods**

##### **Requirements for identification**

There are two main systems in existence. The first is used for the separation of plastic packaging materials. In this case, only a limited number of six packaging plastics need to be identified. But, in this case, velocity plays an important role.

The second system is suitable for the separation of products made from engineering plastics. An example would be the dismantling of used vehicles. Such a system needs to be able to distinguish between approximately 30 different plastics, resins and blends. Velocity is of minor importance.

#### **Suitable spectroscopic processes**

Two different types of spectroscopic processes are available. The first analyses the polymer without changing its structure or appearance, and avoids any kind of damage or change of appearance. The second type is a process which, through rapid pyrolysis, shatters the polymer into fragments. Figure 1 shows a collection of suitable processes.

#### **Technical methods suitable for separation and recycling of bottles and containers from municipal solid waste.**

In the following paragraphs, some technically suitable and available processes for the identification and separation of plastics bottles and containers are described.

#### **Important factors that influence the choice of method**

- Complexity of the mixture (number and concentration of different components);
- Shape (size and figure);
- Quality and possible markets (properties of the recycled material);
- Contaminations by non-plastic materials;
- Costs and expenditure.

#### **Process for identification and separation of containers**

##### *Manual sorting*

This is currently the most commonly practised method. The efficiency of such systems lies between 50 and 200 kg/h. Sorting accuracy lies between 80 and 95 per cent, mainly influenced by human error. Additional problems may arise through the application of different types of plastics for the same shape and type of bottle. Some problems caused by manual sorting concerning the velocity and accuracy have led to the development of automatic sorting systems.

##### *Semi-automatic bottle sorting*

These are auxiliary techniques for manual sorting where the worker starts with visual sorting and subsequently the bottles are sorted out by means of an automatic mechanism (see figure 2).

##### *Automatic bottle sorting*

The first automatic systems for this type of bottle sorting—which are based on the detection of chlorine in PVC, and subsequently by a series of mechanical mechanisms, sort out the PVC bottles—work on the basis of X-ray-small angle scattering (XRA). The bottles pass side-by-side on a conveyor belt, through a detector. The detector recognizes the PVC bottle and determines its size. Subsequently a certain number of air nozzles are opened separating the PVC bottles from the others. The systematic sequence is given in figure 3.

##### *Bottle recycling system of technical scale*

A typical large-scale system is best described by the "BottleSort System" from the Siemens Company. Plastic bottles from separated waste collection are pressed into big

bales and delivered to the plastics processing industry for recycling. The system is designed for a differentiation of plastic bottles according to type, colour and shape (see figure 4).

#### *Sensory*

An identification unit is built with a number of different sensors, able to carry out up to 6,000 tests per bottle. Fast electronics with suitable software evaluate the data and check within approximately five minutes which types of plastics are involved. At this point disturbances such as stickers, contents residues etc. are recognized by the electronic system and taken into consideration in the identification of the resin.

#### **System of functioning**

Mixed plastic bottles, which are pressed into bales are automatically opened and divided into single bottles. The bottles are individually moved to the sensor in sequence. After the identification of the resin type, its colour and shape, the bottles are moved on the conveyor belt. The separating stations are placed at right angles to the transport direction. By means of a dosing mechanism, the identified plastic bottles are pushed by compressed air into the collecting bins.

#### **Processing**

The processing of plastic residues and wastes is only possible if suitable preparation technology exists. Through this technology, the waste is altered in respect to its structure and composition in such a way that it can be further processed by suitable techniques. Also, a number of chemical and energy recovery processes have certain requirements which the waste must fulfil.

The most important steps are:

- Disintegration;
- Classification;
- Sorting;
- Washing and drying; and
- Agglomeration and regranulation.

#### **Size reduction**

For the reuse of the plastics, it is advantageous to have a particle size which is similar to that of the primary virgin material. In most cases every recycling process will start with size reduction. After having brought the waste plastics into the desired particle size and shape, the recycling process can continue. For the dry grinding of plastics, cutting mills are the most suitable technique.

These cutting mills have to meet the following requirements:

- Stable mechanics;
- Rapid blade changes;
- Easy cleaning; and
- High output and performance.

Modern cutting mills have the following characteristics:

- Welded steel construction;
- Outlying bearing separated from the mill's housing;
- Openable casing with lines of separation in the shaft area;
- Screen easily exchangeable;
- A sloping double cut; and
- Pre-adjustable blade.

Wet-cutting is advantageous because the energy, which is converted up to 99 per cent into friction heat, can be utilized for the intensive cleaning of the waste material. Additionally, wear on the knives is reduced.

### Classification

Classifying, or sizing, means the separation of a mixture of particles by means of differences of size and shape—the so-called “bed properties”. This classification influences the particle size distribution and perhaps also the shape of the particles of the material. This separation into different beds, which may also be termed as fractions or classes, can be carried out according to functional principles, namely screen and stream classification.

### Screen classification

Sizing separation takes place by means of a semi-permeable sorting plate, i.e. a perforated bottom provided with almost identical geometrical holes. This method can be applied to devices having fixed or moveable perforated bottoms.

### Stream classification

In this method the velocity and, respectively, the flow pattern of particles in a fluid (under the influence of moving and inert forces), depending on the size and shape of the grains, can be utilized.

### Cleaning and drying

Cleaning means the removal and separation of solid as well as liquid contaminants from the cut plastics. Cleaning can be carried out in three steps:

- Soaking and dissolving (short detaching time requires thorough circulation);
- Detaching of contaminants: through intensive stirring and shearing of the fluid, relatively high velocities between the grain and the washing solvent are produced, resulting in a separation of the plastics particles and the contaminants;
- Separation of contaminants by sedimentation of the washing solution.

Through drying, the moisture content of the plastics material is reduced. A distinction between mechanical and thermal drying is made.

Through mechanical drying, the moisture of the dressing material is separated by field or inert forces. At the same time, some fine particles of dirt, dispersed in the fluid, are also eliminated.

For the thermal drying of granulated plastics convectional heat transfer is mainly used. By convectional heat transfer from the hot-air stream on the one hand, the plastic particles are considerably warmed up on all sides and without overheating; on the other hand, the steam moisture can be directly removed.

### **Production of high quality recycled materials by elimination of printing inks and other ingredients (NOREC method)**

The recyclability of the polyolefines PE-LD, PE-LLD, PE-HD and PP, is deteriorated by applied blends and additives, which are connected with the application technique.

The most important difficulties and interferences with the preparation of plastic films are:

- Accidental discolouration of reggranulated material by pigments from printing inks;
- Greying of transparent recycled material by degraded sheeting components of plastic films;
- Intensive odour of film, caused by oxidizing decomposition of polymers, components and residues of additives and extenders. Additives of unknown quantity and type having non-recognizable effects on the processing and durability of packaging;

- Indefinable film components, liable to migration, with the hazard of contamination of the goods to be packaged;
- Film specks and flaws having negative effects on optics, quality of compression strength and application.

### Cleaning

The cleaning procedure starts with plastic film being reduced into small pieces, i.e., chips the size of a penny. According to the pollution of the primary (virgin) material these chips are pre-cleaned pneumatically, mechanically or wet (with water) and conveyed to the NOREC process. A thorough cleaning by means of a single organic solvent then follows.

Different selection criteria for the adequate solvent are listed below, which were at the same time a basis for processing development:

- CFC-free;
- Non-toxic;
- Does not dissolve the polymer;
- Good ability to detach printing inks and remove sheeting components;
- Density lower than that of polyolefines;
- Chemically stable with manifold ability to be regenerated;
- Convenient price.

The NOREC method is carried out continuously in several partial procedure steps, as described below (see figure 5).

- Feeding of film chips (E)
  - Compression of chips;
  - Displacement and compensation of air by inert gas;
  - Volume-dosed (batched) channelling of the airless stream of chips.
- Cleaning phase R 1
  - Suspension of chips in a solvent warmed up to 60-65° C;
  - Rapid detachment of printing inks by friction;
  - Total removal of the remaining mineral and greasy contaminants;
  - Starting extraction of sub-surface, slightly migrating film additives.
- Cleaning phase R 2
  - Separation of the polluted solvent at the transition point to R 2;
  - By cleaning of the surface, printing ink residues are removed, i.e. rinsing by means of the extraction solvent already used;
  - Extraction of the sub-surface ingredients continues;
  - Separation of the solvent.
- Cleaning phase R 3
  - Supply of clean and warm solvent at 60-65° C in a “counterflow”;
  - Extraction of waxy depolymerized polymers, low-molecular weight particles and additives, liable to migration, as well as their oxidizing products from within the chips;
  - Separation of the solvent.
- Cleaning phase R 4
  - Rinsing of the wet chip surface with hot water at approximately 60-70° C and ejection of the solvent from the inner chip;
  - Discharge of the chips moist with water from the capsulated NOREC plant and transition from the “Ex-sphere” to the normal atmosphere.



- Drying of film chips (T)
  - Mechanical drying;
  - Thermal drying.
- Chips output
  - Transport of dry chips to a buffer silo for further preparation.

The film chips, cleaned according to the NOREC-method, can be easily regranulated and may be extruded, bonded and welded to new film. In order to avoid yellowing and blemishes, it is useful to add a processing stabilizer to the regranulation to freshen up the used polymers. Strength measurements of such film showed no significant differences in comparison to new film made from raw materials.

**Sorting technique for plastics**

Sorting implies separation of commingled plastics according to their differing properties, such as density, surface structure, ferromagnetism, conductivity, colour etc. In this way sorting accuracy influences the purity of the finished product. Distinction is made between:

- Sorting due to density;
- Sorting due to flotation;
- Electrostatic sorting;
- Thermal separating procedures; and
- Sorting of plastics by the hand-picking method.

**Sorting according to density**

Considering to the important sorting properties, plastics are very similar to each other. The density of most commodity polymers is between 0.9 and about 1.4 g/cm<sup>3</sup> (see table 1).

**Table 1**

Polymer	Density (g/cm <sup>3</sup> )
LDPE	0.92
HPPE	0.96
PP	0.91
PS	1.13
PA	1.05
PMMA	1.18
PVC	1.39
PTFE	2.20

The fundamental idea of this procedure is to separate the various plastics of about the same specific gravity as the separating liquid, which can be varied. This happens by dissolving material with a density lower or higher than water, e.g. alcohols or salts, or by suspension of fine solid particles of a density higher than water, such as "kaolin" or ferromagnetic minerals.

*Swim-sink-separation under the influence of gravity*

In this field steady continuous separators have been successful. They consist of one or several simple, open troughs equipped with feed and output devices; while in the troughs, the particles can rise or dip in the separating agent due to their density (see figure 6).

*Swim-sink-separation in a centrifugal field, e.g. "hydrocyclone"*

The separating agent, loaded with plastics particles, streams, under pressure, into the tangential inlet of the apparatus and is diverted into a rotary motion by the geometry of the unit, circulating like a whirlpool. Through

rotary motion, centrifugal accelerations are generated, due to the Earth's gravity. This acceleration whirls those particles which are heavier than the fluid outwards, whereas the lighter ones are forced to the centre of the vortex, where an air surface exists. In principle the detaching process takes place in the same way as that of the static swim-sink-separator, however, in the whirlpool, it is subjected to multiple gravity, occurring not in a vertical but in a radial direction (see figure 7).

*Sorting according to density in streaming fluids*

In a fluid-grain-suspension, sorting according to density is carried out if the flow velocities are adequately chosen and a suitable preclassification of the waste material in question has been applied. The sorting takes place either within a flow through a channel or in a film flow across an inclined plane.

*Centrifugal technique*

This method deals with a three-phase separation (solid-liquid-solid), in a horizontally located so-called "double cone", fully-coated, screw centrifuge. The centrifuge is partly filled with the separating agent, which forms a fluid ring caused by the rapid rotation. The mixed plastics are put in a suspension, by means of a vertical tube, axially into the centrifuge and meet with the surface of the rapidly rotating fluid ring. Here the particles entering the surface are exposed to very strong shear forces. A strong turbulence takes place which results in an isolation of the plastic particles and at the same time liberating them from particles of dirt.

Particles whose density is higher than that of the fluid are hurled radially to the centrifuge walls, whereas the other components rise towards the interior. The separated partial fractions in this way are conveyed to each of the two conical ends by the screws. They are lifted out of the fluid ring and leave the centrifuge in a dewatered stage.

**Sorting according to flotation**

Flotation is a wet separating method which utilizes the different surface behaviour of the various plastics caused by their different molecular structure. In this way advantage is taken of the flotation with water so that a certain part of the material is equipped with air bubbles because of its hydrophobia, which enables it to rise. The other part of material, however, absorbs water completely because of its hydrophilia and sinks to the bottom (see figure 8).

**Electrostatic sorting**

By means of electrostatic sorting of solid materials, separation into different components may be achieved. For this purpose the components in question have to meet two requirements:

1. They may not be incorporated, e.g. they must appear as free particles side by side.
2. They should distinguish between electric conductivity or tribological charging properties.

Utilizing different electric conductivity as a sorting or separating parameter a so-called "rotor (magnetic) separator" is applied as a separating device. With respect to the different tribological charging properties, i.e. charging by friction, sorting takes place by means of a "falling separator".

**Physical recycling methods**

**Filtering systems for reprocessing procedure**

Recycling means the physical separation of contaminants from the melt through suitable filter materials.

Polymer contaminants are either solid foreign particles or hard meltable polymer particles. They can, therefore, be physically separated. In order to detect all contaminants, as far as possible, the separation takes place in the melt between the extruder and extrusion mould. Many kinds of melting contaminants are due to waste processing.

Table 2 shows the usual polymer enclosures, arranged according to the filtering purpose, suitable filtering system, necessary mesh size, recommended filter area, ensuing filter loading and the most relevant final product.

The enclosures result in different effects depending on the extrusion process used. Coarse contaminants must be

filtered out in order to protect the extruder screw, gear pump, extrusion mould and roll surface. Mesh size and filtering area, as well as the arrangement of the filter material (media), are adjusted for each application.

Filtering systems are machine aggregates which are able to take up the various kinds of filters in simple or multiple arrangement between plates, respectively, in pressure-proof, heatable casings and enable their exchanging as required. Additive agglomerates and gel particles can be separated from the melt by means of fine-pored filter media in large-face filters and retained.

Table 3 gives a survey of the filter systems available.

Table 2

Polymer enclosures	Filtering purpose	Filtering system	Mesh size $\mu\text{m}$	Filter area	Filter loading	Application products
Bar fraction screws among others	Machine protection Extruder pump Roll	Perforated plate	Very coarse > 500	0.004-0.04	> 100 000	Granular material All half stuffs
Sand, dust	Machine protection Avoidance of holes without breaks	Alternating plate, gate, cont. filter belt, drum	Rough 500-200	0.004-0.04	> 50 000	Granular material All half stuffs
Fibres, papers	Avoidance of breaks or defects	Tube filter LLF	Medium 200-100	0.1-0.5	700-1 000	Granular material All half stuffs
Additive agglomerates	Colour homogeneity Safety of products	Tube filter LLF	Fine 80-60	0.1-3	500-750	Monofil Films
Crystalline polymer particles	Avoidance of breaks or defects	Large-face filter NSF, LLF	Very fine 40-50	2-46	150-400	Continuous fibres Stretch films for video and X-ray films
Gel-like polymer particles Agglomerates	Quality of products Avoidance of breaks	Large-face filter in two chamber designs NSF, LSF	Extremely fine 15.10,5	1-6	50-150	Microfibres Sound carrier film Condenser film

Table 3

Filtration systems	Arrangement of filter media	Alternating device	Producer
Leaf (disc) filter	Perforated plate	Gate (disc) Cont. gate (disc) Ram (plunger)	Bematec, Beringer, FBM, Gneuß, CHIVA, JPL, Kreyenberg
Tube filter	Cylindrical support	Ram, gate with tubes Pre-assembled insert	Barmag, Werner u. Pfeleiderer
Band filter	Perforated plate with filter band (belt)	Continuous shift	Auto Screen, HITECH, Lenzing
Self-purifying plate filter	A double-disc system rotating disc	Back-washing	Erema, Gneuß, Kleen Screen, Siemens, Reifenhäuser
Auto-purifying drum filter	Drum rhythmically rotating	Back-washing in segments	Berstorff
Drum filter with filtrate outlet	Drum with separate system	Discont. outlet of filtrate	Extrudex
Large-face filter	Two chambers as above with change-over valves	Change of plate when machine is running	ASKA, Barmag, Fluid Dynamics, Fuji Filters, LCJ

Table 4

	PS	SAN	ABS	PA	PC	PMMA	PVC	PP	PE-LD	PE-HD	PET
PS	1										
SAN	6	1									
ABS	6	1	1								
PA	5	6	6	1							
PC	6	2	2	6	1						
PMMA	4	1	1	6	1	1					
PVC	6	2	3	6	5	1	1				
PP	6	6	6	6	6	6	6	1			
PE-LD	6	6	6	6	6	6	6	6	1		
PE-HD	6	6	6	6	6	6	6	6	1	1	
PET	5	6	5	5	6	6	6	6	6	6	1

1 = mixes well, 6 = mixes badly

**Improvement of quality by means of additives (stabilizers)**

All organic materials are exposed to natural ageing, polymer materials included.

To avoid, or at least to decelerate the degradative reaction, plastics are treated with additives, the so-called processing-, thermal- and light stabilizers.

The anti-ageing agents, as stabilizers are called, contribute to the protection of the sources, twofold:

- By the prolongation of life they reduce the needed application of non-renewable raw materials (for example, oil);
- By means of stabilizing, an improvement—in most cases—of the amount of plastic materials to be used more efficiently and economically can be achieved, which leads to thin-walled articles.

**Restabilizing of recycling material**

The damage grade of plastic waste depends on the type of polymer, the way of stress (thermal) and the primary stabilizer. To preserve material at as high a quality as possible some measurements are to be observed (i.e. desirable ideal case):

- Clean, if possible, pure quality used plastics;
- Determination of kind and quantity of additives originating from the primary application;
- Careful definition for new use (restabilizing);
- Testing of processing and long-term stability of the new definition;

The testing of stabilizers of the new plastic material, as well as the recycled one, mostly refers to three fields: processing-, long-term and light stability.

**Compatibilizers of plastics material**

Certain kinds of polymers can be commingled with each other. In this way, the so-called blends arise which display certain defined properties. Not all plastic material is inter-mixable; this applies to the recycled material as well.

Polymers are provided with compatibilizers for improvement. Compatibilizers are substances for making those polymer components which are partially mixable or non-mixable compatible. Adding pre-prepared compatibilizers is one of the most frequent and successfully applied techniques. A relatively new technique is the use of compatibilizers in recyclable plastic material mixtures. In this

way, plastic blends whose properties have thus been modified, can be used for various applications.

Compatibilizers diminish the surface tension, reduce the size of particles, improve the connection between the matrix and the dispersed phase and finally work against coagulation (flocculation) of the dispersed phase. Of note is the fact that homogeneous blends have one glass transition temperature, whereas heterogeneous have two.

Table 4 above shows the miscibility of different plastics materials.

**Chemical recycling methods**

Under this topic, processes are described which use plastic waste as cracking feed. These processes are hydrogenation, gasification, cracking and carbonization (coking). In most cases, the feed material has to meet certain qualitative requirements such as trace metals, halogen content, concentration of heavy metals and fillers, which may vary from waste to waste. In most cases pre-treatment is necessary to convert the waste material into a suitable feed material for the petrochemical industry. The table below shows the composition of plastics packaging in household products.

Table 5

Articles	%	Resins	%
Film	32	PE	54.2
Beakers	12	PVC	8.4
Bottles	14	PP	18.7
Foams	1	PS	13.4
Others	41	Others	5.3

**Petrochemical processes for the recycling of plastic waste**

*Pyrolysis*

Used plastics can be transformed into raw materials through pyrolysis. This involves the production of liquid and gaseous pyrolysis products, such as oils and technical gases, by thermal degradation with the exclusion of air, or

at least a deficiency of oxygen, which are then further conditioned by common technical separation techniques. Pyrolysis, in comparison to combustion yields a volume of crack gases (methane, ethane, ethylene, propylene, butylene and so on), which is 5-20 per cent lower than flue-gases from incineration plants.

Another advantage is that commingled plastics can be used without any need for sorting or classification. Pyrolysis of plastics is specifically advantageous if it is carried out in a fluidized bed reactor. By means of strong heat and material transfer an adequate constant temperature can be produced. Consequently it is possible to maintain a constantly good quality of the products, with up to 50 per cent of the feed material being obtained as liquids.

### Fluidized bed

If fine grain material placed on horizontal, perforated bottoms is percolated, a state is reached under certain conditions which is similar to a boiling fluid. The boiling zone produces bubbles and the particles within this zone are in a permanent fluidizing up and down movement thus remaining in a floating position. Figure 9 shows this schematically; a description follows.

The butt of the plant is a fluidized bed reactor. The plastic waste is fed in by a screw or a sluice and pyrolysed in a fluidized bed of quartz sand at temperatures between 600 and 900° C. As the fluid agent pyrolysis gas pre-heated up to 400° C can be used. The heat is applied indirectly by radiating heat tubes, caused by combustion of the pyrolysis gas; the flue gas is transported from the reactor to a heat exchanger in the stack. The crack gas, which has been formed by pyrolysis, leaves the reactor and is purified in a cyclone and small particles are removed. In a quench cooler it is cooled down to room temperature by circulating the product oil. Consequently, the gas passes through two quenching columns filled with glass beads. During this process oils are formed, which are separated into two distillation columns whereby the fraction with a boiling range from 150 to 170° C is used as the quenching liquid. Furthermore, high boiling tar is obtained which contains toluene and benzene. The gas produced is purified by means of an electric precipitator or filtration system and compressed at 2-3 bar and stored.

### Hydrogenation

Hydrogenation is a suitable process for the reusing of mixed and/or contaminated plastics waste products. By hydrocracking the macromolecules are thermally decomposed into very reactive fragments, which during their generation are saturated with molecular hydrogen. A suitable high pressure of about 200 bar will ensure that enough hydrogen is present to keep the hydrogenation process working (see figure 10).

The process is carried out in a bottom phase reactor and based on living organisms (bacteria, fungi, yeasts, algae). In this special case it is a double column reactor. The temperatures in the reactor vary from 440 to 480° C; the pressure lies between 150 and 250 bars.

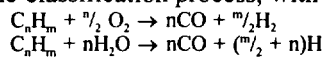
Furthermore there is a process based on the old "leuna-technique", which depolymerizes the plastic waste. The mixed plastic waste is heated to 260° C and 420° C together with heavy oils. The plastics are degraded into small molecular fragments showing a significantly lower viscosity. Simultaneously hydrochloric acid is formed from the PVC present in the mixture, as well as low boiling hydrocarbons which can be condensed and recovered separately.

### Classification of used plastics

At temperatures of 1,600° C and pressures up to 150 bar, the product is a gas which, due to its composition, calorific value and range of application, may be defined as:

- Poor gas and water-gas 4,600-12,500 kJ/Nm<sup>3</sup>
- Synthesis gas and reducing gas 12,500 kJ/Nm<sup>3</sup>
- Town gas and rich gas 16,700-20,000 kJ/Nm<sup>3</sup>
- Rich gas and synthetic natural gas 25,000-37,000 kJ/Nm<sup>3</sup>

The classification process, with the equation:



can be divided into three parts:

1. Heating and cracking: Hydrocarbons are cracked down to carbon, methane and hydrocarbon radicals.
2. Oxidation and classification: The hydrocarbons partly react with oxygen forming CO<sub>2</sub> and H<sub>2</sub>O. Oxygen is consumed during this process. Simultaneously some of the oxidized hydrocarbons react with the generated CO<sub>2</sub>.
3. Consecutive reactions: The formation of methane and soot in the hot departments of the reactor is influenced by pressure, temperature and the amount of steam (see figure 11).

### Reduction in a blast furnace

The blast furnace is a reactor for the transformation of ore into iron. For this transformation reaction high temperatures are necessary which are generated by the burning of fuels such as heavy oils or coke. Plastics, mainly the so-called commodities (PE, PP, PS, PVC), consist of carbon and hydrocarbons, like coal and heavy oils, and are therefore suitable for the reduction process in a blast furnace if the concentration of chlorine is not higher than 2 per cent.

One has to consider that the process may be influenced by certain components of the plastic waste originating from collection, such as metallic packages (e.g. aluminium caps, etc.).

Interferences to the blast furnace process may originate from:

- Titanium oxide (TiO<sub>2</sub>) From the white pigment none. If the concentrations are too high, will be removed with the slag.
- Sodium, potassium None. If in the common order of magnitude, removed with the slag.
- Copper None. The small amounts will be accepted from the pig iron.
- Cadmium, lead From pigments and stabilizers. Will be present in the blast-furnace dust.
- Chalk, talcum, glass fibres From filler and reinforcing additives. Are removed together with blast-furnace dust and slag.
- Sulphur None. Plastics contain very low quantities of sulphur in comparison to heavy oils which have a sulphur content of up to 2.5 per cent.

The advantage of plastics as energy producers in the blast-furnace process lies mainly in the replacement of coke, coal and heavy oil, thus saving the natural resources. In contrast to heavy oil, plastic waste contains almost no sulphur.

#### **Depolymerization of PMMA**

Polymethyl methacrylate (acrylic glass) is a high-quality material which is almost entirely processed into long-life goods for optical purposes, motor vehicle industry, building industry and light advertising leaflets. One-way articles of PMMA only arise from medical applications. A regular and continuously packaged component of household refuse may be excluded. Total PMMA consumption in Western Europe in 1993 was about 200,000 tons.

Recycling processes are almost exclusively concentrated on production and processing wastes. It is a requirement of quality-controlled recycling that mixing with other types of plastics is definitely avoided.

PMMA belongs to that low number of plastics which, under the influence of heat, can be transformed into the original monomer. Temperatures must be significantly higher than 300° C to ensure that the PMMA is quantitatively depolymerized.

Processing of PMMA wastes: The wastes can be seen as pure by type and kind of resin. Smaller quantities of foreign matter do not play any significant role because they will not be depolymerized or decomposed under the conditions in practice.

Depolymerization is continuous; at a certain temperature, the purification only lasts a few minutes. Temperature and purification have a great influence on the quality of the monomer produced.

The monomer formed by the depolymerization of PMMA waste is regularly contaminated with small amounts of low and high boiling substances, as well as with water and for this reason it successively needs further processing. From practical experience it has been proven that almost all products made of virgin methyl methacrylate (MMA)-monomer can also be manufactured from recycled MMA-monomer. The products have shown nearly the same properties as products made of virgin material, so a closed material circle could be realized in the case of PMMA.

In such processes it is very often difficult to avoid a joint grinding, remelting and coextrusion of different types of plastics which cannot be separated by the separation process.

#### **Factors affecting the economic viability of recycling**

Recycled plastics must compete on price and quality with virgin polymers if these are to be used to manufacture the same products. The costs of reprocessing plastic wastes are essentially fixed, so that any change in the price of virgin polymers directly affects the price of recycled plastics which is in turn reflected in the price paid for recyclable plastics.

Recycled plastics may have to be sold at a lower price than virgin equivalents, in order to compensate for any increase in production costs arising from the use of recycled plastic, for example as a result of slower machine running speeds or thicker product wall sections.

The low bulk density of plastic wastes causes the collection and transport costs for plastic wastes to be high relative to other recyclable materials. This fact, together with the high costs of processing and reprocessing, can make plastic waste recycling unviable unless the costs of

disposing of the plastic wastes by landfill or incineration are equally high.

The economic viability of mixed plastic recycling to produce wood-substitute materials is marginal, since the manufactured products compete with relatively low-cost alternatives such as wood. The main advantage that such material offers in comparison with wood is its claimed long-term durability. However, it has yet to be proven that the anticipated longer life justifies the higher initial cost.

The markets for recyclable plastics are limited by the available reprocessing capacity and by the required quality of the recycled polymer. Recycled plastics cannot compete in all virgin polymer applications, for example for hygiene reasons recycled plastics are not used in food-contact applications (unless they are enclosed within a virgin polymer coating), except in a few specific cases such as the recent introduction by a soft drinks manufacturer of recycled PET bottles in Belgium. The reuse of plastic food packaging and the use of recycled plastics for food contact applications is a subject of debate and is currently being studied.

New production techniques have been developed to make more use of recycled plastic, for example multi-layer bottle blowing, which encloses the recycled plastic within an inner and outer layer of virgin polymer. Existing production equipment may also need to be adjusted or even modified in order to use recycled plastics.

Unless recyclable plastic material is colour sorted prior to reprocessing, the resulting recycled plastic can have an unattractive colour, such as grey or green. Some reproducers do colour sort bottles prior to reprocessing and can then produce a range of colours of recycled material. The colour of the recycled plastic can limit the markets for its use, for example, much recycled plastic is used in grey or black coloured applications, such as street furniture or piping. This colour limitation can result in recycled plastics being used primarily in lower grade and hence, lower value applications.

The only legislation which has affected the recycling of post-use plastics is that of national legislation relating to packaging recovery. Such legislation, which has been independently introduced by a number of States, notably Austria, Germany, France, Denmark and Belgium (with similar voluntary agreements in the Netherlands and Italy), has set targets for the levels of plastic recycling, which in all cases has led to an increase in plastic recycling. The draft EC Directive on Packaging and Packaging Waste will have a similar effect.

#### **Possible environmental problems caused by recycling**

The two primary environmental impacts of plastics recycling are those resulting from, and increased use of, transport compared with localized disposal, and water-borne effluent from the washing stages of the reprocessing operations.

Plastics have a low bulk density, so that the transportation of a given weight of plastic will have a greater environmental impact than for other recyclable materials. Given the automated nature of plastics reprocessing plants, there is a minimum economic capacity for such plants, which is estimated to be in the range 10,000-15,000 tons per annum. The collection of such a tonnage of plastic recyclable material will have to take place over a considerable catchment area, with the resultant transport implications.

The impact of the effluent arising from the washing of recyclable plastic material during reprocessing, is dependent

firstly on the original contents of the plastic containers and secondly on the quality of the effluent treatment plant. With regard to the first issue, some reprocessing plants do not add detergents during the washing process, since there are often sufficient detergent residues in the material being reprocessed (this is primarily the case with plastic bottles). The collection of plastic containers which have been used for product categories such as pesticides or other hazardous household products are discouraged in some collection schemes, in order to minimize the contamination of the washing effluent and since there is concern that the recycled plastic could contain traces of the original product.

**The development of appropriate standards and specifications and the need for harmonization**

The standards and specifications for recycled plastics are set by the reprocessors in order to compete with virgin alternatives. The reprocessors therefore also set the standards for recyclable material in order that they can achieve the required recycled plastic standards. Since the collection and reprocessing of post-use plastics is a relatively local activity (the long-distance transport of recyclable plastics is unusual due to the costs involved), there seems to be no need for harmonized standards yet. The one international standard which has already been referred to is the standard on plastics identification.

**Table 6**

**Plastic consumption for the EC in 1992, by polymer**

Polymer	Consumption (thousand tons)	Per cent
LDPE/LLDPE	5 063	22
HDPE	2 812	12
PP	3 012	13
PVC	4 763	21
PS/EPS	2 160	10
PET	536	2
Other thermoplastics	1 603	7
PU	1 265	6
Other thermosets	1 397	6
<b>Total</b>	<b>22 612</b>	<b>100</b>

**Table 7**

**Age analysis of post-user plastic wastes generated in Western Europe in 1992 (percentage of all plastic waste arising)**

Polymer	Less than 2 years	2-10 years	10-20 years
LDPE/LLDPE	25.9	5.7	1.3
HDPE	9.1	3.8	1.3
PP	6.9	3.9	0.8
PVC	5.8	2.7	2.5
PS/EPS	5.8	3.5	1.0
PET	3.3	0.3	0.0
PU	1.0	3.9	0.8
Other	2.2	6.0	2.4
<b>Total</b>	<b>60.2</b>	<b>29.7</b>	<b>10.1</b>

Table 8

Packaging and non-packaging consumption and waste arising in the EU in 1992

	Consumption (thousand tons)	Waste arising (thousand tons)	Waste arising as a percentage of consumption
Packaging	9 010	8 156	91
Non-packaging	13 602	5 610	41
<b>Total</b>	<b>22 612</b>	<b>13 766</b>	<b>61</b>

Table 9

External EC trade in plastics waste, 1992

Category	Imports		Exports	
	Tons	Thousand ECU	Tons	Thousand ECU
Polymers of vinyl chloride	10 422	2 101	56 031	8 782
Polymers of ethylene	18 487	6 141	54 870	8 685
Polymers of propylene	6 090	1 762	5 038	1 963
Polymers of styrene	4 015	1 301	1 808	581
Acrylic polymers	618	410	9 336	3 015
Additional polymerization products	5 831	3 290	18 934	11 035
Epoxide resins	211	148	409	1 187
Other plastics	27 791	13 547	39 255	20 168
<b>Total</b>	<b>73 465</b>	<b>28 700</b>	<b>185 681</b>	<b>55 416</b>

Table 10

Estimate of mechanical recycling of post-user plastic waste by polymer for Western Europe (1992)

Polymer	Percentage of total tonnage recycled	Range of estimates of percentage of tonnage recycled
LDPE/LLDPE	59.0	30-75
HDPE	8.4	2-3
PP	13.6	3-25
PVC	5.0	6-14
PS	4.2	5-7
PET	1.0	1-25
PA	1.3	
Others	7.5	3-11
<b>Total</b>	<b>100.0</b>	

**Table 11**

Plastic	Non-plastic products			Plastic products		Total consumption (In thousand tons/year)
	Applicability	(In %)	(In thousand tons)	(In %)	(In thousand tons)	
PE-LD				100	5 548	5 548
PE-HD	Fibres	2	64	98	3 285	3 349
PP	Fibres	26	1 120	74	3 183	4 303
PVC				100	5 095	5 095
PS/EPS				100	2 235	2 235
PET	Fibres	59	995	41	696	1 691
ABS/SAN				100	487	487
PMMA				100	234	234
Azetal				100	97	97
PC				100	184	184
PA	Fibres	61	560	39	353	913
Polyacrylonitrile		98	399	2	10	409
Others				100	272	272
<b>Total</b>		<b>13</b>	<b>3 138</b>	<b>87</b>	<b>21 679</b>	<b>24 817</b>
Alkyd resin	Coating	100	340			340
Amino resin	Wood binding agent	57	980	43	725	1 705
Phenolic resin	Coating Adhesive	57	278	43	209	487
Epoxy resin	Coating	76	185	24	60	245
Polyester resin	Coating	17	83	83	412	495
Polyurethane		24	400	76	1 275	1 675
<b>Total</b>		<b>46</b>	<b>2 266</b>	<b>54</b>	<b>2 681</b>	<b>4 947</b>
<b>Total</b>		<b>18</b>	<b>5 404</b>	<b>82</b>	<b>24 360</b>	<b>29 764</b>

**Consumption according to field of application**

	Percentage
Packaging	41
Electrical engineering/electronics	12
Agriculture	4
Motor vehicle industry	7
Construction industry	20
Others	16

**Consumption of plastic packaging according to products  
respective processing technology**

	Percentage
Injection-moulded packaging	11.3
Blow moulded packages	21.2
Thermoformed packages	11.2
Films	49.0
Extruded coatings	3.9
Others	1.8
Foamed packages	1.6



**Table 12**

**Plastic component in total flow of waste**

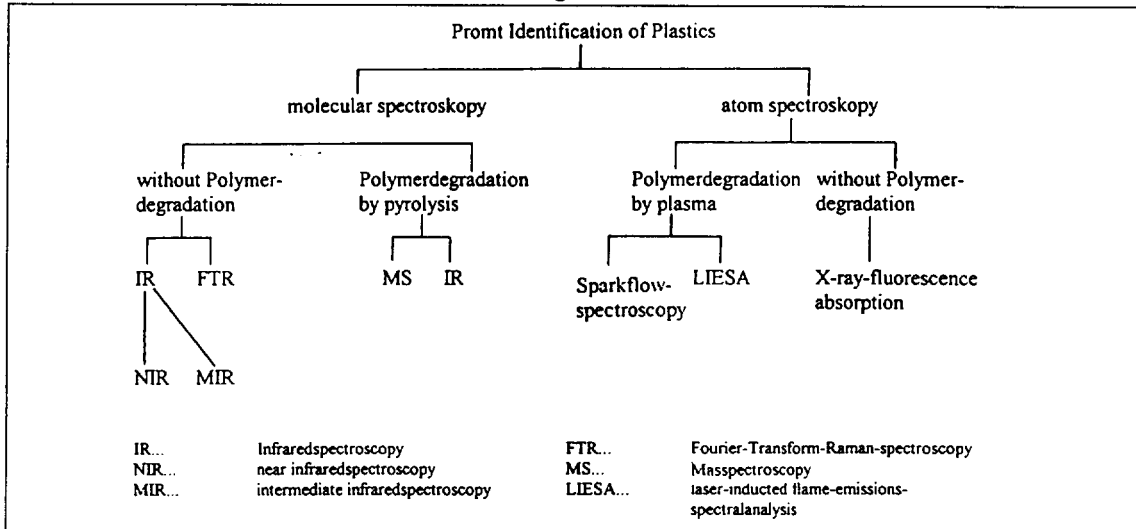
	Origin of waste						
	Agriculture	Construction industry	Origin of domestic waste	Trade, industry	Motor vehicle industry	Electronics	Others
Total amount of waste (thousand tons)	560 000	230 000	138 556	290 000	12 030	4 090	1 565 324
Percentage share	20	8.2	4.9	10.4	0.4	0.2	55.9
Total amount of plastic waste (in thousand tons)	636	753	10 928	2 636	842	518	0

**Table 13**

**Reuse of plastic waste according to recycling processes**

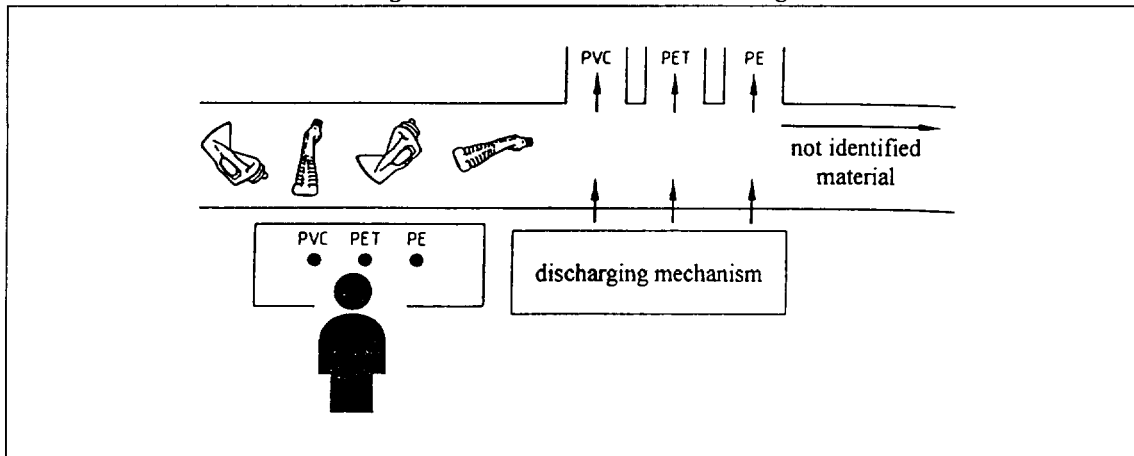
		1989	1990	1991	1992	1993
Amount of waste	(in thousand tons)	11 433	13 594	14 637	15 230	16 211
Material recycling	(in thousand tons)	846	958	1 080	1 043	915
	(in percentage)	7.4	7.0	7.4	6.8	5.6
Energy recycling	(in thousand tons)	1 675	2 108	2 138	2 422	2 425
	(in percentage)	14.7	15.5	14.6	15.9	15.0
Total recycled amount of waste	(in thousand tons)	2 521	3 066	3 218	3 465	3 340
	(in percentage)	21.1	22.5	22.0	22.7	20.6

Figure 1



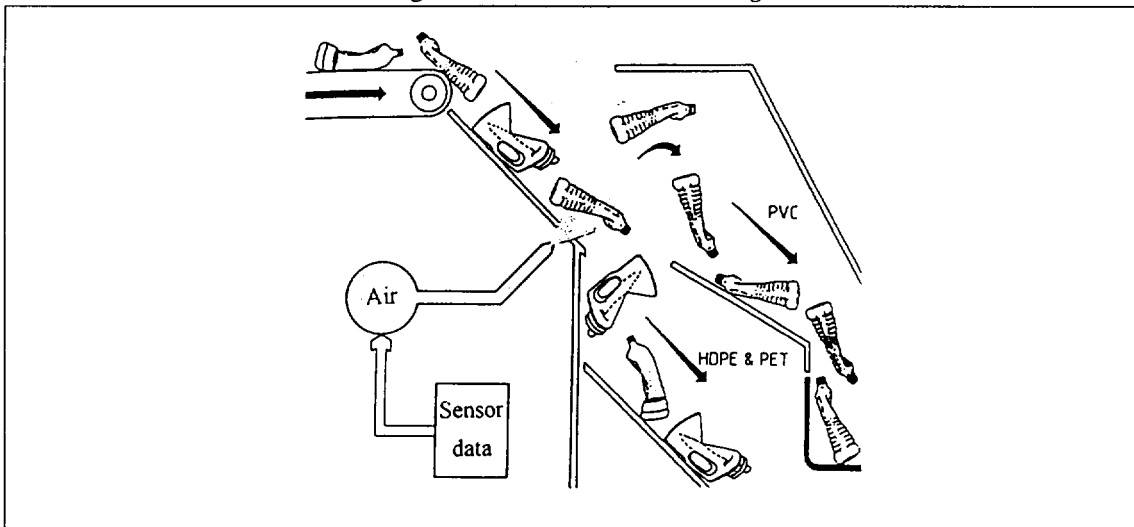
Source: Keith Engstrom "Die Wiederverwertung von Kunststoffen" [1]

Figure 2. Semiautomatic bottle sorting



Source: Keith Engstrom "Die Wiederverwertung von Kunststoffen" [1]

Figure 3. Automatic bottle sorting



Source: Keith Engstrom "Die Wiederverwertung von Kunststoffen" [1]

Figure 4. Schematic presentation of the BottleSort sequence of operation

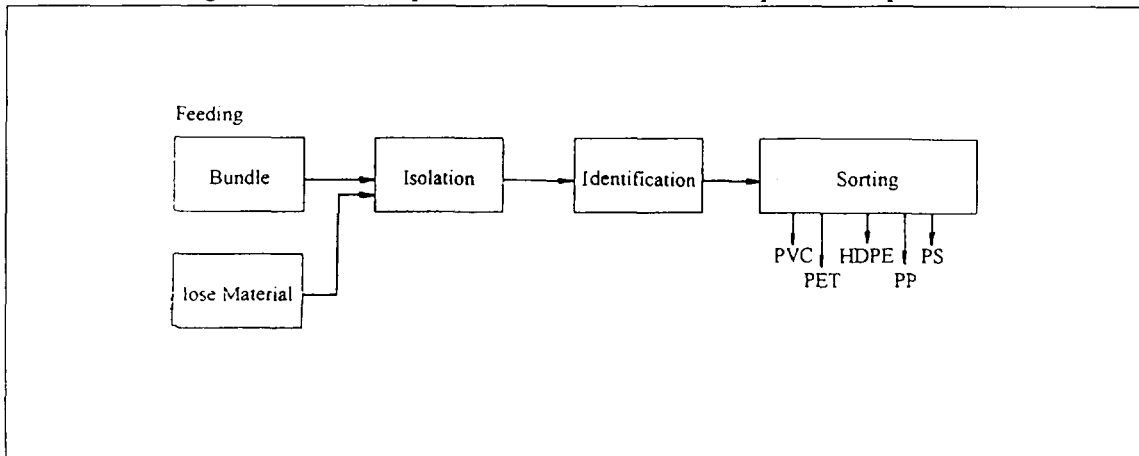
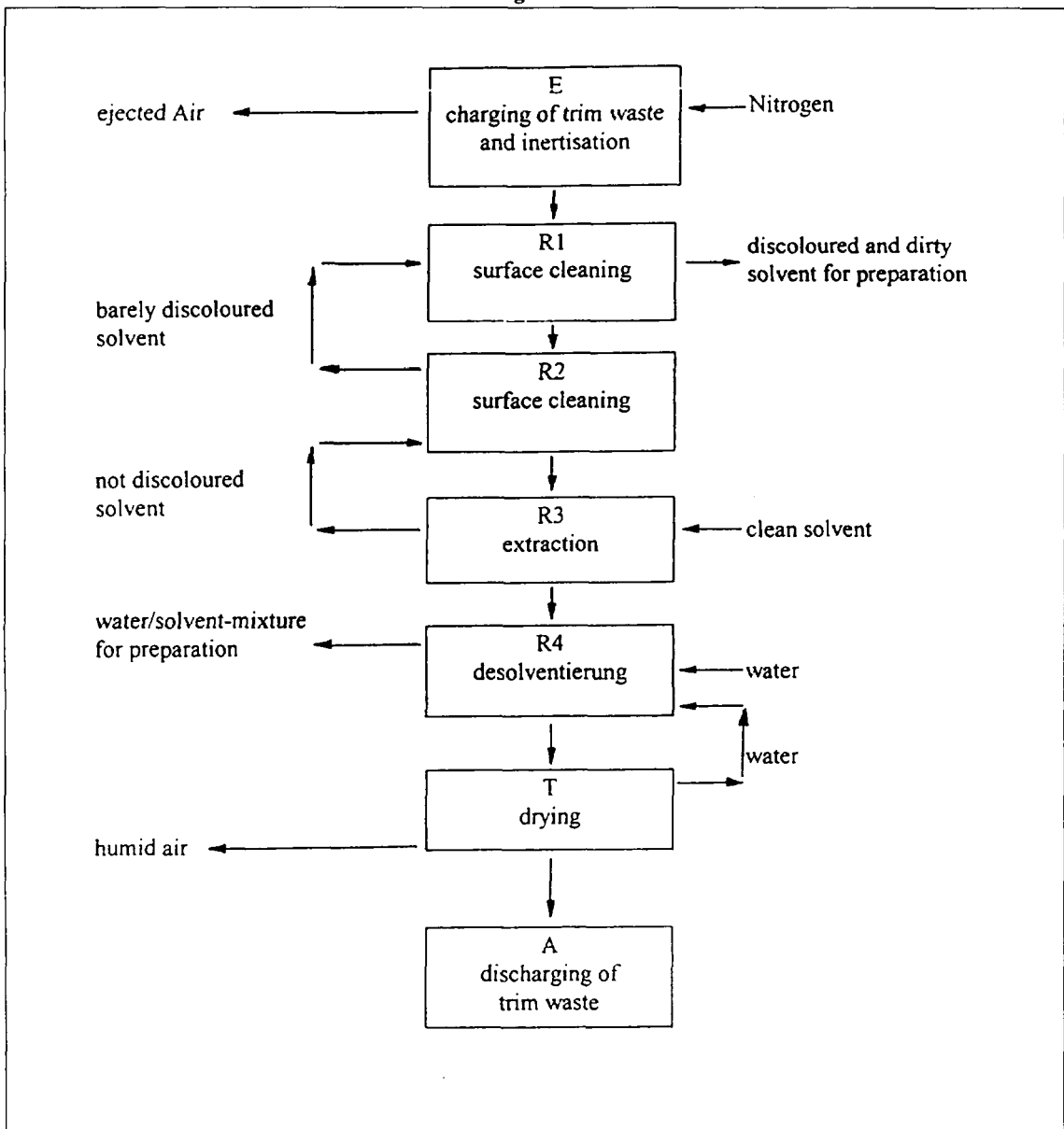


Figure 5



Source: H. P. Walter "Die Wiederverwertung von Kunststoffen" [1]

Figure 6. Heavy-liquid separation [3]

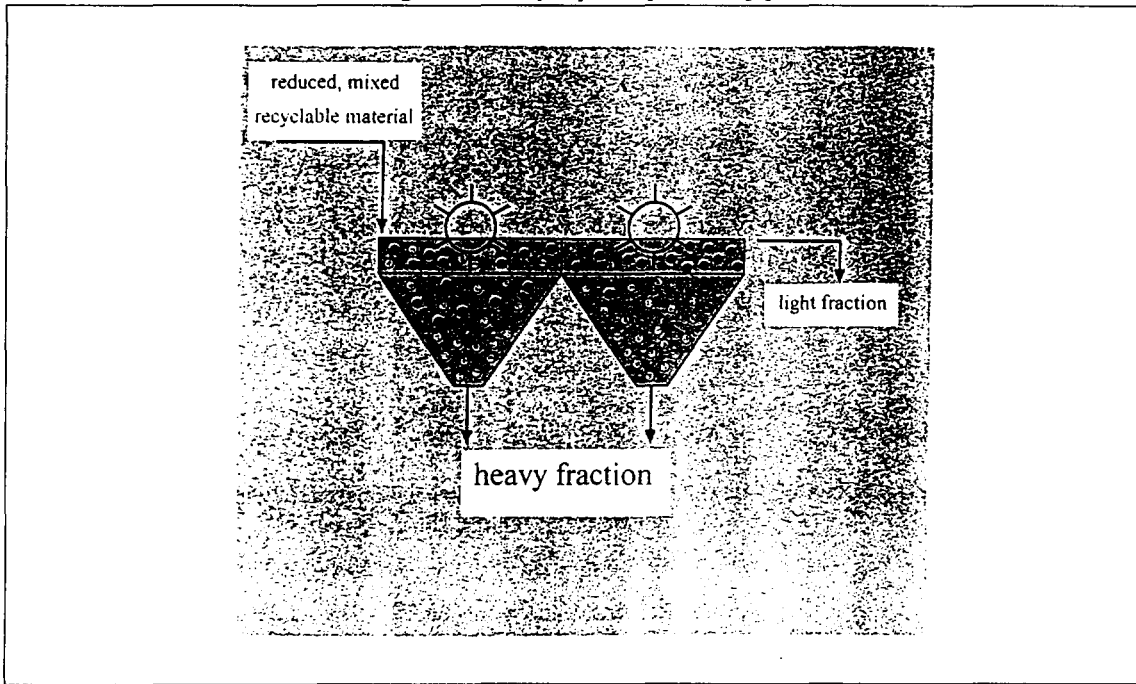


Figure 7. Hydrocone [3]

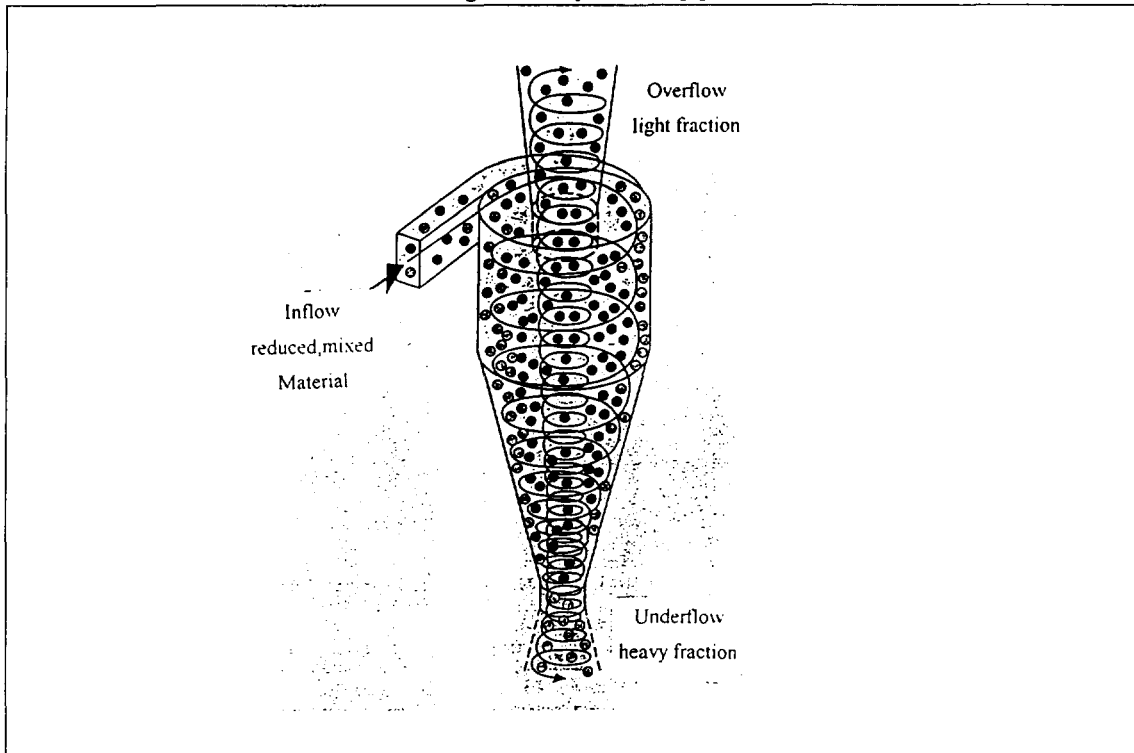
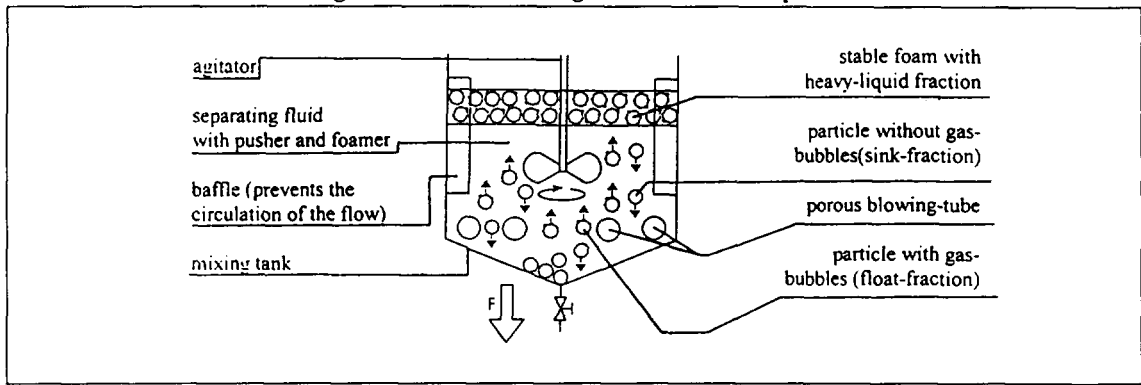


Figure 8. Schematic diagram of a flotation plant



Source: W. Michaeli, M. Bittner "Die Wiederverwertung von Kunststoffen" [1]

Figure 9. Fluid bed pyrolysis [3]

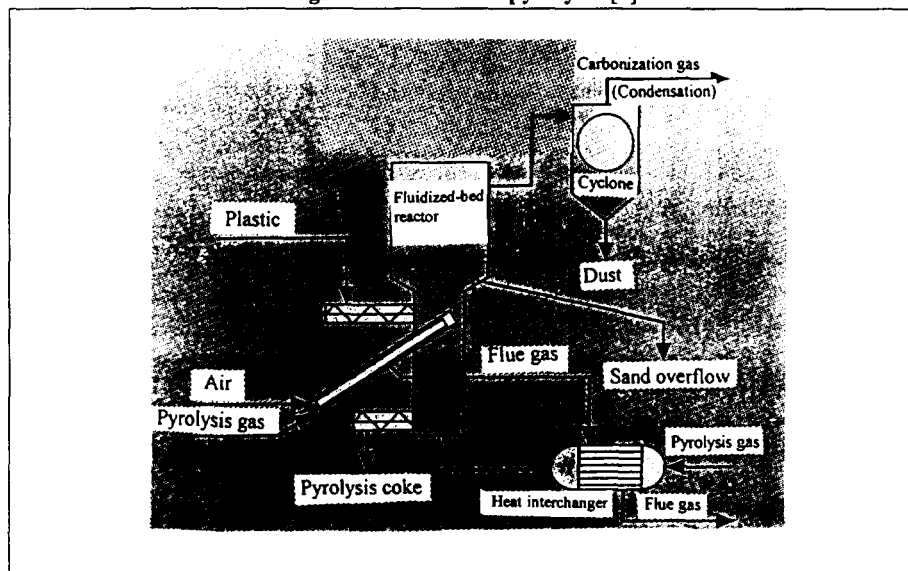


Figure 10. Polymer hydrogenation [3]

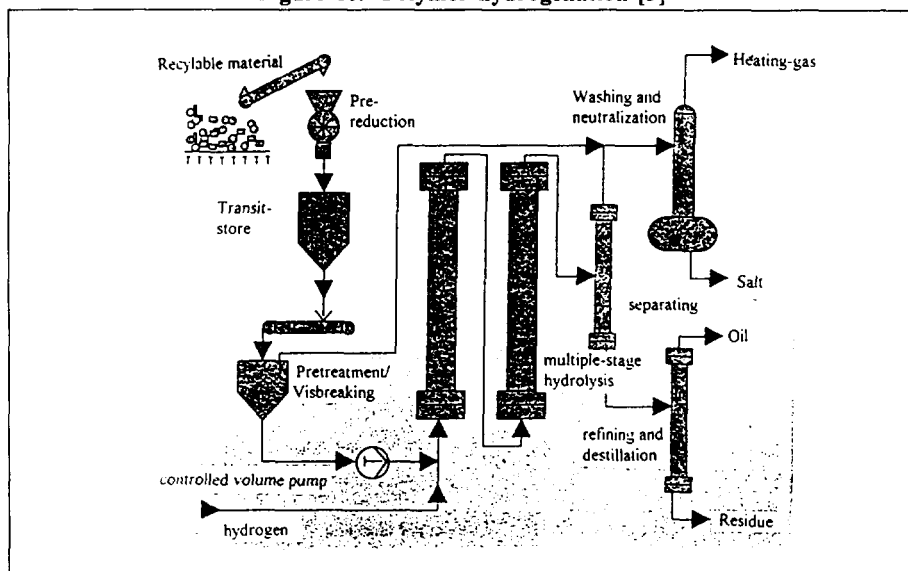
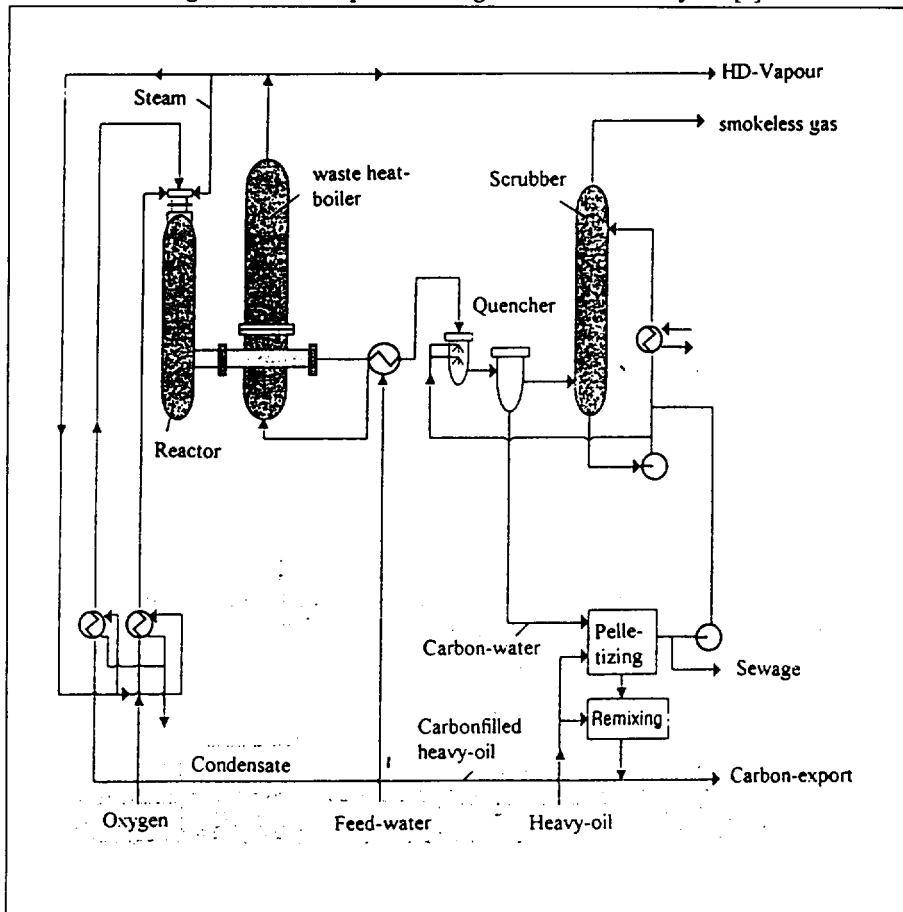


Figure 11. Shell-process for gasification of heavy oil [3]



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## B. NATIONAL PROGRAMMES AND PROJECTS

### **Production and consumption of plastics in Asian countries**

#### *World Production and Consumption.*

Against a background of a world production of around 100,000 tons/year of "Classical" thermosets and derivatives of natural materials, the development of plastics into bulk scale materials started around 1930 with the introduction of standard thermoplastics based on styrene, vinyl chloride, ethylene, and later also propylene polymers, and with the transition from coal-based to petroleum-based chemicals and new condensation and addition polymers since the 1950s, and lasted for four decades with a doubling of production every five years. In 1973, at the peak of this growth to over 40 million tons/year, the industrial countries of Western Europe, the USA and Japan had about a 90 per cent share. After the subsequent slump in the market in the years of recession, the world volume of plastics production has practically doubled again with a total of approximately 77 million tons/year. During this period, considerable changes have taken place.

Western Europe and North America, with a share of approximately a third of production and consumption, are still the chief plastic producers and consumers. Western Europe's share of production, however, is in recognizable decline and the growth of North America's depends largely on the powerful growth in capacity in Canada (1986: > 2 million tons). Asia has been able to considerably increase its production share. With a production of scarcely 10

million tons/year in Japan, this growth depends primarily on an increase in production in China, Taiwan and Republic of Korea. Taking into account the recently developed production capacities in the Near East, Asia will, in the future, claim an even higher share of overall production volumes. The capacities being developed in developing countries, including Latin America, are for the most part production plants for thermoplastic standard polymers for domestic consumption and export. In this area, a decline in the share of Western Europe, USA, and Japan together, from approximately 67 per cent of world sales in 1985, to hardly 55 per cent by 1995 is expected.

Plastics have now become indispensable materials not only in the industrial countries but also in developing countries, where the proportion of plastics applications in the industrial field is also continually increasing. For demanding engineering applications, an annual world-wide growth of 8-10 per cent is calculated for the coming years.

For consumer applications, an increase in consumption in industrial countries must be in the order of magnitude of an increase in the gross national product. But there still exists a considerable need for the Asian and Latin American countries to catch up in this sector.

In 1993, the total world demand rose to over 100 million tons for the first time. An extrapolation of plastics production beyond 1990, yields a production volume of around 120 to 140 million tons in the year 2000.

Figure 1

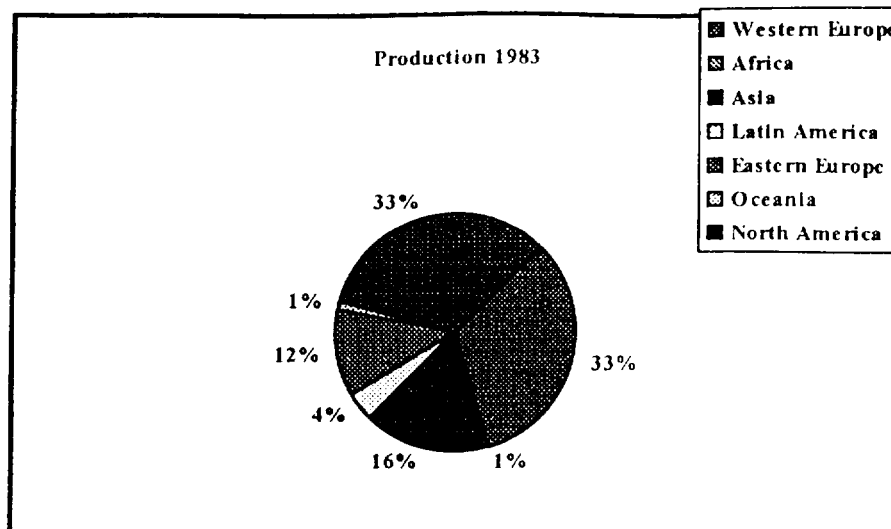


Figure 2

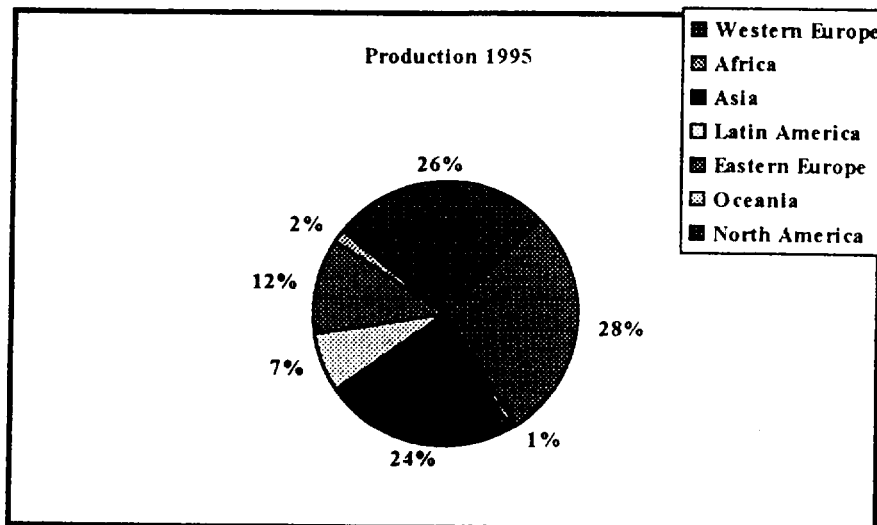


Figure 3

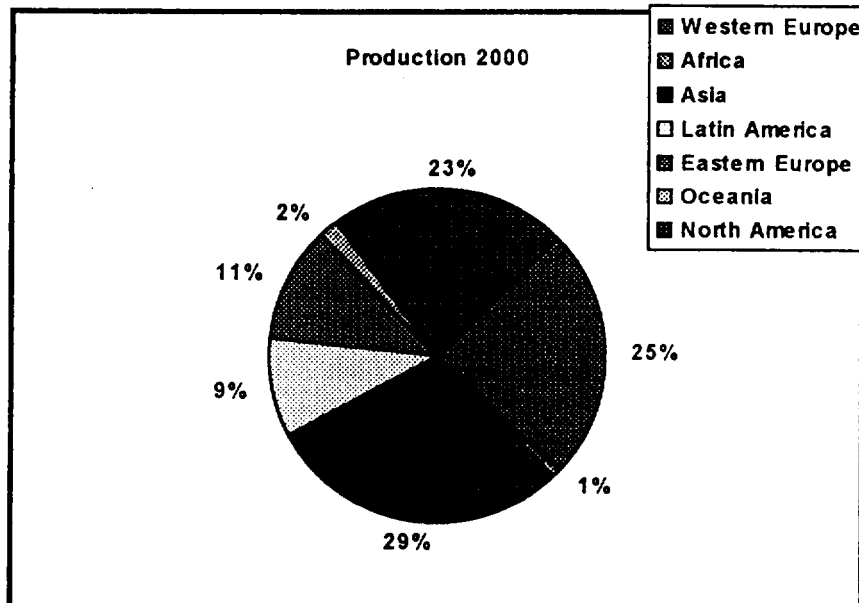




Figure 4

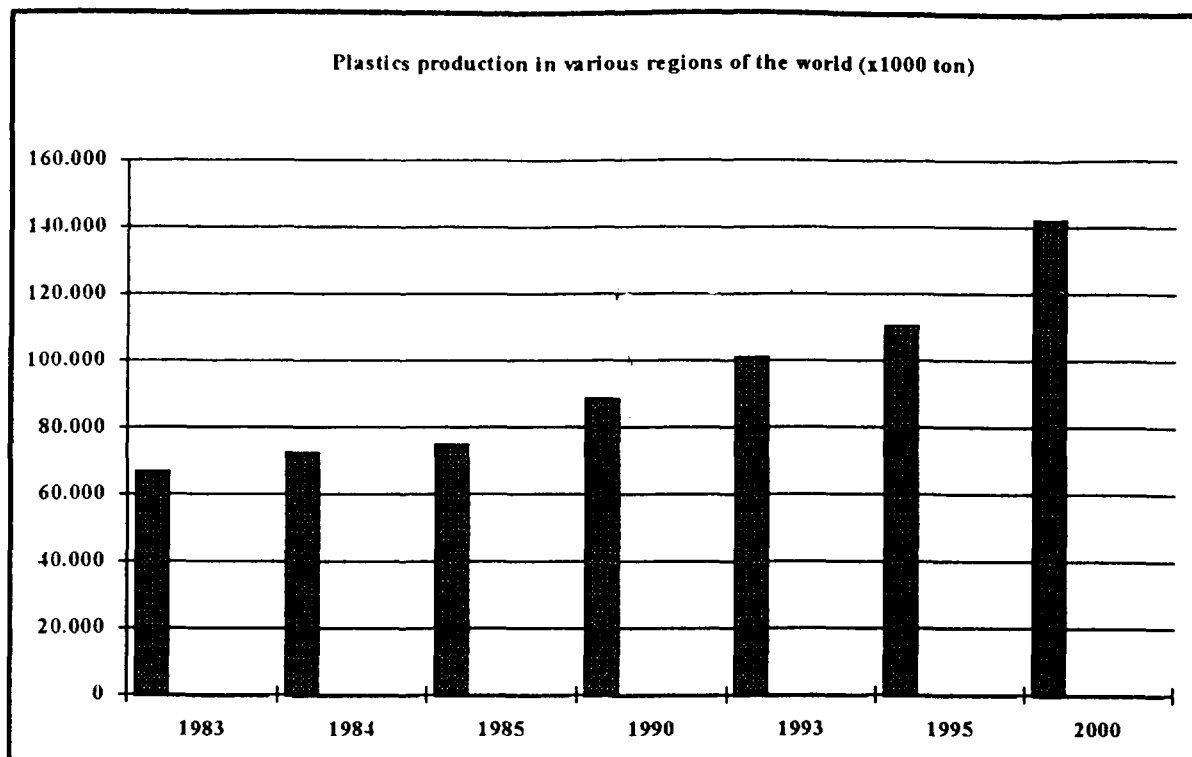


Table 1. Plastics production (estimation) in thousand tons

Plastics Production in various regions of the world

Region	Production (in 1000 tons)						Change (in %) 1983/1990	Share (in %)		
	1983	1984	1985	1990	1995	2000		1983	1990	1995
Western Europe	23,010	23,910	24,210	28,600	31,577	34,864	3.47	34.42	28.56	24.54
North America	20,808	22,602	23,590	26,500	29,258	32,303	3.91	31.13	26.47	22.74
Asia	11,328	12,966	13,742	16,200	26,090	42,019	6.14	16.95	23.60	29.58
Eastern Europe	8,099	8,797	9,140	10,489	12,897	15,858	4.22	12.12	11.67	11.16
Latin America	2,565	2,943	3,088	5,018	8,156	13,256	13.66	3.84	7.38	9.33
Oceania	686	700	800	1,192	1,776	2,646	10.54	1.03	1.61	1.86
Africa	350	385	400	565	198	1,127	8.78	0.52	0.72	0.79
<b>Total</b>	<b>66,846</b>	<b>72,303</b>	<b>74,970</b>	<b>88,564</b>	<b>110,552</b>	<b>142,071</b>	<b>4.64</b>	<b>100.00</b>	<b>100.00</b>	<b>100.00</b>

Source: *International Plastics Handbook*

### Definitions of recycling

As a result of the rush of legislation in recent years, recycling has become the main answer to the environmental challenges facing plastics producers, processors and end-users. Recycling has several meanings and any one of the following four routes can legitimately be described as a form of recycling:

*Primary recycling* is the processing of scrap plastic into the same or similar types of products from which it has been generated, using standard plastics processing methods.

*Secondary recycling* (or mechanical recycling) is the reprocessing of scrap plastic into plastic products with a lower quality level.

*Tertiary recycling* (chemical recycling, depolymerization, feedstock recycling, polymer cracking) returns plastics to their constituent monomers or to their basic hydrocarbon feed stock. The resulting raw materials are then reprocessed into plastics materials or other products of the oil refining process. Commercial chemical recycling of PET has started, but development work is needed before chemical recycling is possible on a significant commercial scale.

*Quaternary recycling* is the recovery of the latent energy content of plastic materials via incineration. Unpopular with the public in many instances and not included as part of the recycling chain by many legislators, incineration with energy recovery nevertheless has an important recycling role, especially when other methods are not appropriate or feasible.

Recycling is generally taken to refer to primary and secondary recycling, and these forms, and the problems associated with them, are discussed in the following.

### Secondary recycling

Mechanical recycling of most plastics materials is technically feasible. Even thermoset resins can now be recycled. It is a matter of economics and organization which raise serious questions about the long term success. Recycling will not take place on a large and continuing scale if it is not economically viable. If it is to be established as the predominant method of dealing with the disposal of used plastic products, as appears to be the wish of many legislators, each of the following conditions must prevail. Recycling schemes will fail if these conditions are not met.

- A reliable and large supply of post-consumer plastic waste needs to be made available to recycling companies at reasonable prices. This entails the establishment of wide-spread and efficient recycling infrastructures.
- There must be sufficient demand and markets for the recycled resin: new applications are constantly emerging for recycled material but they have, initially at least, been for low value products, such as plastic wood.
- Virgin resin prices must not fall too far: virgin resins command a premium over most recycled materials as the latter lose some of their performance upon recycling. On average, recycled resins sell for 60 per cent to 70 per cent of the virgin resin price. Therefore, the cost of collecting and recycling plastic material must be below the 60 per cent to 70 per cent threshold if recycling is to be profitable. If there is a significant fall-off in the performance of the recycled material, the gap between the virgin resin and the recycle price will be bigger. The combination of economic slow-down and large expansions of thermoplastic capacity in the last couple of years have pushed down

virgin resin prices and therefore the prices of recycled resin.

As interest grows, efforts are being made to improve the technology to lower costs. Such improvements include the following:

- Economic separation of the different types of waste plastics. Recycling of mixed plastics is possible, but the resulting recycle is of low value. The purer the resin yielded by the collection process, the higher the eventual value of the recycled product.
- Low cost methods of washing the collected resin, removing labels, adhesives and other contaminants, are also essential for the achievement of high value recycle.

### The scope of recycling in industrial countries

The additional complexities of plastics recycling mean that it lags behind those of other materials in most countries. In comparison with recycling rates for paper of over 50 per cent in the Netherlands and typically over 20 per cent in other OECD countries; for glass of over 90 per cent in Finland, 50 per cent in Japan, 60 per cent in Belgium; and up to 83 per cent in Sweden for aluminium cans—plastic recycling rates look less impressive. The comparable rates are no more than 1 per cent in the US, 7-8 per cent in Western Europe and 12 per cent (mostly post-industrial rather than post-consumer waste) in Japan.

Processing of industrial plastic scrap has taken place for many years, but the recycling of post-consumer plastics waste, which is where the main efforts are directed, was virtually non-existent 10 years ago. This has, however, not prevented legislators establishing highly ambitious targets, to be achieved within extremely tight, if not impossible, time-frames.

In the US, 1989 and 1990, plastics recycling rates were less than 1 per cent. These aggregate figures conceal the 10 per cent PET recycling rates and HDPE recycling rates of almost 2 per cent. Recycling rates for other major thermoplastics and specialized resins were all much less than 1 per cent.

Forecasts of plastics recycling growth rates in the US to the year 2000, vary between 20 per cent and 30 per cent p.a.—five to seven times above the expected demand growth of virgin resins. These apparently high growth rates are taking place from an extremely low base. According to forecasts from the Society of the Plastics Industry (SPI, the US representative body) the quantity of plastics recycled in 2000 will be equivalent to about 8 per cent of virgin resin demand, compared with about 2 per cent in 1993.

PET and HDPE will continue to be the most recycled products: in 1992, 26 per cent of US PET bottles and containers were already recycled, and 15 per cent of all plastics bottles and containers. In the years ahead, a greater proportion of other resins, particularly PVC, LDPE and PP, will be included. Packaging will continue to be the most active area in recycling but activity will increasingly be directed at other sectors.

West European rates of about 8 per cent of plastic waste stream (i.e. almost 1 million tons) are much higher than US rates. Recycling rates vary tremendously, not only between resins, but between countries. Switzerland is the most successful Western European recycler to date, leading the way with 13 per cent of post-consumer plastics. Italy manages about 15 per cent of its PE film. The UK, on the other hand has low rates, recycling 2,000 tons out of a plastic bottle waste stream of 180,000 tons a year. Total

UK plastic waste accounts for about 1.4 million tons of MSW.

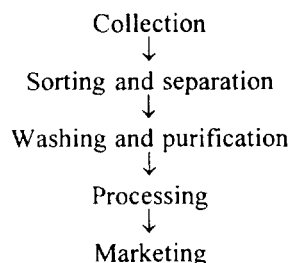
Japan has a highly successful infrastructure for recycling industrial plastic waste: roughly 5 per cent of Japanese plastics production is recycled, and about 12 per cent of the Japanese plastic waste stream. Recycling of post-consumer waste, however, is insignificant. Household and commercial waste is sorted and segregated according to whether material is combustible, not according to the material type, which is the pre-requisite for a recycling programme.

Recycling of household plastic waste was more popular in Japan in the early 1980s than now. Japan's Plastic Waste Management Institute (PWMI) has reported that in 1982, 25 municipal governments had plastics segregation and recycling programmes. Ten years later only one municipal authority, Kusatsu, a city of 90,000 people, collects post-consumer plastic waste. This waste is then recycled into flower pots, stakes and plates.

The PWMI attributes the paucity of post-consumer recycling efforts in Japan to poor economics: recycling costs are almost eight times higher than average waste disposal costs (i.e. costs of ¥ 190,000 per ton for recycled plastics compared with an average waste disposal cost of ¥ 24,000). Recent legislation requiring the recycling of household appliances, cars and polystyrene packaging foam has, however, increased interest in post-consumer recycling in Japan.

### Recycling process

Although a gross oversimplification of reality, the following scheme represents the main essential steps in the process:



The process used for different polymers and products are adapted to particular requirements. For example, there are two broad approaches towards PET recycling: the first involves the crushing of collected PET bottles before shipping to a processing facility, where they are ground into small pieces and separated at high speed into PET, HDPE, aluminium, paper and a residue mostly composed of adhesives. In the second method, complete bottles are sent to the processor who separates the base cup, label, cap and any other additions in a mechanical process. The PET share is then washed and ground separately. The latter approach has the benefit of yielding a purer, and therefore higher value, form of PET. However, the first method can operate more easily on a larger scale and involves lower transport costs because of the shipping of crushed rather than complete bottles.

### Collection and sorting of plastic waste by origin

One of the keys to successful recycling is the guaranteed availability of sufficient quantities of good quality waste. In order to achieve this, an effective collection system must be set up. This can be done more efficiently and effectively in areas of high population

density. Several options are available, each with their own advantages and disadvantages.

A number of different collection and sorting systems have been suggested, developed and tested, and in some circumstances actually employed, to collect plastics from the various waste streams. The collection and separation methods are considered as the better system. However, the costs of collection are high in terms of equipment, manpower, time and energy.

### Collection of municipal solid waste

Municipal waste can be treated as a potential source of raw materials. Plastics constitute only a small portion of municipal solid waste (about 7 wt per cent for ECE), the actual quantity, especially when it comes to volume units, is enormous. Existing methods of collecting household waste throughout Europe are efficient and well accepted by householders.

### Kerbside collection

Kerbside collection involves the collection of recyclable materials as a segregated part of the normal MSW collection process. From the householder's point of view, kerbside collection removes the need to transport the waste to dedicated collection points, but it can create problems of storage, especially if the householder is expected to segregate a number of materials in a relatively small living area. MSW collection costs also rise with kerbside collection schemes.

One of the major advantages is that participation rates are consistently higher than with other collection methods. This bears out the view that individuals will save and collect material for recycling when it is made as easy as possible for them to do so; schemes which require householders to separate more than three or four materials are likely to be less successful. From the point of view of plastics, this probably allows for nil separation by resin after the waste has been separated into paper, glass, aluminium and plastic.

Kerbside collection schemes are gaining in popularity in the US: in 1991, there were about 2,300 programmes in operation. By 1994, the number is anticipated to have increased to over 4,000. Not all of these schemes cover plastics, but an increasing proportion of them do. Kerbside collection is not so popular in Western Europe.

Experience has shown that kerbside collection/recycling programmes are well supported by the public, particularly as they require little knowledge and effort by the householders to separate recyclable items at the source.

The three systems of kerbside collection systems offered world-wide, with their main characteristics, are:

- *Kerbside, roadside sorting: "blue box"*
  - Blue bins: low cost
  - Compartmentalized vehicles: high cost
  - Collection costs rise due to the slow collection rate
  - Intensive labour
- *Kerbside, sorting at a central facility: "green bin"*
  - Green wheeled bins: medium cost
  - Standard collection vehicles
  - Material recovering facility
  - Labour to sort
- *Kerbside, sorting at a central facility: "multi-compartment bins"*
  - Multi-compartment bins: high cost

- Material recovering facility
- Labour to sort

The best investment, taking into account the money which is available for recycling programmes is the "green bin system" for industrialized countries. It offers the most practical economical solution to provide a sustained supply of quantified plastics waste for recycling. The use of a material recovery facility is a necessary part of a "green bin" collection system as a means to sort collected mixed recyclables into individual streams.

The kerbside collection system is the preferred option for collecting plastics waste because of the high recovery rate achieved. But this success depends strongly on several factors such as the population density, the motivation of the householders, the separation level, the organization and the infrastructure. Kerbside collection can be very productive and intensive in areas with a high population density, but is also very expensive, and the effectiveness varies strongly from project to project.

#### **Bring systems (drop-off systems)**

In bring systems the consumers are asked to bring back their plastics waste, mainly bottles, to container-parks, where under the supervision of a watchman, the plastic bottles are segregated in three types of resin: PVC, PET, and HDPE. The advantage of such a system is that the pre-sorting is very good, but operating this system is fairly expensive and the response is very low (20 per cent ECE region).

The best results can be obtained under the following conditions:

- A small distance to the collection point
- The assistance of people with authority
- A good information channel

#### **Door to door collection**

The door to door collection permits to collect several municipal waste fractions, and especially bottles only, pre-sorted in PVC, PET, and HDPE.

#### **Bring-and-get-money system, SRRUC-Shanghai, People's Republic of China**

Shanghai City, People's Republic of China, has a collection system of particular interest.

The SRRUC collection network composes about 270 settled selective collecting stations spread all over the Shanghai town (purchasing stations). These stations supply 12 recycling shops, acting as sorting wholesalers, where the wastes are sorted and prepared for transport to the recycling factories:

- Sorting
- Washing
- Drying
- Compacting

These 12 recycling shops are also supplied by the plastics transformation industries, which bring their industrial waste there.

This plastic waste collection system is remarkable and unique in the world. Shanghai seems to be the leader and pilot with this system for the People's Republic of China. It is however difficult to estimate the exact cost in the energy and manpower involved in this collection work. The People's Republic of China, and in particular Shanghai can be considered as the leaders in the recycling of plastics coming from urban rubbish. This result has been obtained because the population:

- Gives importance to plastics waste, taking the economical and molecular value of it into account.
- Possesses a real will to collect the secondary raw material contained in the plastics waste.
- Has a knowledge about the rheology and thermodynamical problems involved by the recycling of plastics waste.

#### **Container deposit legislation collection**

Consumers pay a deposit upon purchase of goods, usually bottles, and the deposit is returned when the recyclable object is brought back to the store. These schemes require the consumer to transport the item to the central collection point, but participation rates tend to be higher than for reverse vending machines and voluntary buy-back schemes. However, they only cater for relatively small, albeit a high-value, element of the waste stream.

#### **Reverse vending machines collection**

Consumers place the recyclable material in a machine and, in return, receive a cash payment or tokens which can be redeemed for goods. Many of these machines contain a compactor or shredder so as to minimize storage requirements. Reverse vending machines suffer from similar disadvantages to those of the buy-back programmes.

#### **Collection and sorting of industrial plastic waste**

Industrial solid waste is sorted and the products sold to small recycling companies or disposed of as urban waste. The production scrap is homogeneous, and clean. The scrap which is not utilized as a part of the production process is mostly sold to trade recyclers who reprocess by either granulation or agglomeration, to produce finished products which are similar in size and shape to prime materials.

#### **Sorting and separation**

Successful sorting and separation of objects by resin content, and also by colour in some cases, is crucial to an economically viable plastics recycling chain. The more homogeneous and pure the resin recovered, the more suitable it will be for higher value-added applications. The presence of impure and contaminated resins can impair the process and significantly reduce the performance of the final product. Mixed resin recyclates can rarely replace virgin resins.

The most cost-effective way of collection a large volume of plastic waste is to compact the material at the point of collection, thereby reducing the transport costs of such high volume/low density products. Density separation of PET and HDPE from shredded bottle waste is possible, but no techniques are as yet commercially available for a wider range of commingled material: sorting therefore usually takes place at a recovery facility or at the recycling company itself, and is followed by compacting and shredding. Technical developments, or the emergence of a uniform labelling system may solve this particular problem.

In view of the limited quantities of resin which have been recycled so far, sorting and separation has been carried out manually until relatively recently. This was easier when collection schemes were limited to relatively few items such as HDPE milk bottles and PET beverage bottles; but as recycling has caught the imagination of the public and legislators alike, the number of collection programmes and the variety of materials have increased. The expansion of plastics recycling has highlighted the

following drawbacks of manual sorting methods:

- High labour costs;
- Slow throughput;
- Difficulty in distinguishing between some commonly used resins by sight, particularly clear PET and PVC.
- The resulting separated streams do not always have sufficient levels of purity to avoid chemical degradation of PET.

In anticipation of a higher throughput arising from the avalanche of recycling legislation, considerable research and investment has gone into the development of automatic sorting and separation equipment which is now increasingly appearing in recycling facilities. A number of technologies are being used, including infra-red sensitivity and electromagnetic detection. Automated methods now offer the following advantages over manual sorting:

- Purity levels of 99 per cent and above for separated resin;
- Lower costs in the long run;
- Increased productivity levels, resulting from processing times up to 16 times faster than manual sorting.

During the last few years, major efforts have gone into the development of separation systems for plastic bottles—the high-value end of the plastic packaging waste stream. The first commercial automated sorting equipment was developed by Tecoplast-Govoni and launched in 1988.

The first generation of automated sorters concentrated on the separation of PVC and PET bottles. Both materials are highly recyclable on their own, but incompatible processing characteristics result in a severe loss of performance if attempts are made to reprocess commingled PVC and PET resins. Techniques used to separate the two include X-ray fluorescence sensitivity and electromagnetic screening: typically, a sensor detects the presence of chlorine in the PVC and a diversion device, either compressed air or mechanical means, is used to eject either the PVC or PET from the waste.

As recycling demands increase, and the range of resins collected widens, greater efforts have been made to sort and separate multi-resin waste. The first generation of automatic sorters required the bottles to pass in single file past the sensors. Technology is emerging which can effectively sort and separate bottles, and other containers, in batches, resulting in up to three times the speed in sorting.

Automated sorting machines require a substantial initial investment—anything from tens of thousands to almost a million dollars for multi-resin, colour identification multi-line systems.

However, if large-scale plastic recycling is to take place, future development of this technology is crucial. The following developments would facilitate the sorting process:

- Increased separation of commingled resins;
- A commercial system which can separate already crushed material, leading to significant savings at the collection stage of the recycling chain;
- The automatic removal of lids and all other closures;
- Rejection of bottles with hazardous or reactive residues.

Effective automated sorting machines will pay for themselves relatively quickly, providing the economics of the rest of the recycling chain are favourable. Furthermore, the greater purity of waste streams emerging from automated, as compared to manual sorting, could further stimulate recycling.

### Mixed plastics recycling

High levels of sorting are not always possible, and certain products like laminates, blends and co-extrusion are not so easy to separate. Commingled plastics can be recycled, but the end uses are of a lower value than the purer recyclates. The processes involved in mixed plastics recycling are similar to those for individual polymers, except that the melt is not pelletized, but is moulded or extruded immediately in order to omit an intermediate stage and thus reduce costs.

Markets for recycled mixed plastics include fence posts, park benches and other substitute timber applications. Such plastic items are durable, relatively cheap, weather resistant and do not need painting, thereby saving on maintenance costs.

### Country experiences: Republic of Korea

Although waste management has a long history, the history of systematic waste management in the Republic of Korea is relatively short. The Waste Management Law was promulgated in 1986. There have been a lot of changes since then in the aspects of waste generation and the demand for proper waste management, especially for hazardous and solid wastes. Many problems in dealing with wastes have occurred and the major problems are:

- Lack of treatment/disposal technologies, specially in waste incineration technology;
- Improper collection and transport systems for separating wastes, which makes it difficult to handle, recycle and re-utilize waste;
- Reduced willingness to reduce and recycle waste;
- Insufficient support for the waste recycling industry;
- Insufficient landfill sites available.

In order to solve these problems the Waste Management Law was amended in March 1991, and enacted on 9 September 1991.

The Korean Plastics Industry has become indispensable and is regarded as one of the priority industries which contributes its share to the country's economic growth and development, both in potential foreign exchange earnings and as a good source of employment. It has earned a position of importance in several industries as it provides essential inputs to practically all other industrial and agricultural sectors.

The plastics industry is mainly that sector involved in the transformation of polymer resins and some other compounds, such as plasticizers, fillers, stabilizers into various plastic products, finished and semi-finished, both for consumer and industrial applications. The plastics industry has already had considerable impact on several areas of the country's economic activity. But many opportunities still exist in the plastics industry, both in the domestic and export markets, due to the increasing participation of plastics in several industries, such as packaging, automotive, housing, construction, health, agricultural, electronics, leisure and others.

### Production and use of plastics in the Republic of Korea

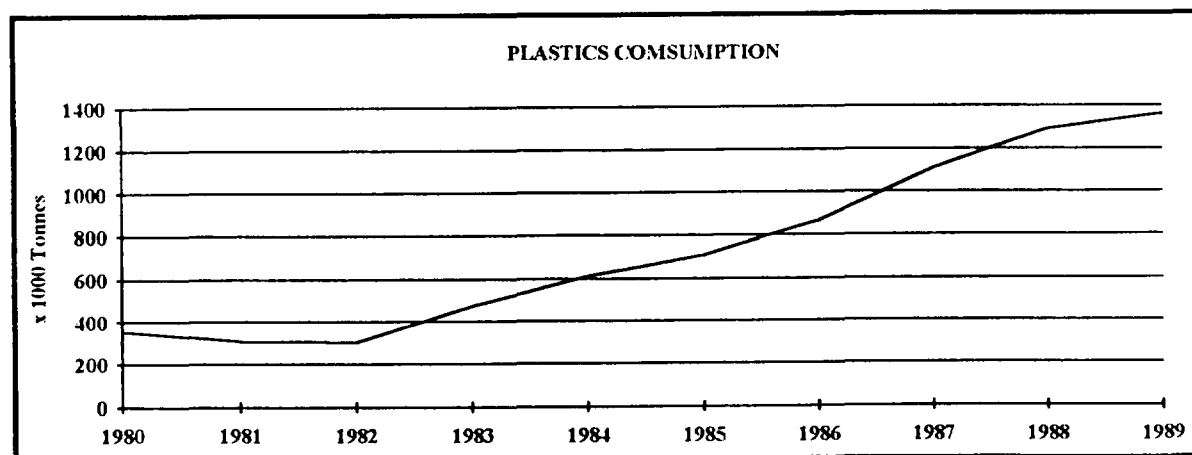
#### Volume of plastic production

In 1989, 1,360,000 tons of plastics were consumed in Korea, compared with 350,000 in 1980. The consumption of plastics is rapidly increasing, as shown in table 2, of various kinds of plastics. On the other hand, the per capita consumption of plastics was 16.8 kg in 1980, and it increased to 41.7 kg in 1987, showing an annual increasing rate of 14.5 per cent on average.

Table 2. Consumption of plastics (tons)

Year	LDPE	HDPE	PP	PVC	PS	ABS	Total
1980	87,836	26,519	81,143	127,223	25,022	6,955	354,698
1981	74,319	25,374	75,707	92,655	31,077	9,866	308,998
1982	68,764	41,934	65,430	80,129	35,443	11,296	302,996
1983	106,782	56,017	110,518	119,419	60,817	18,376	471,929
1984	140,553	73,196	134,133	119,167	80,116	23,685	610,850
1985	159,580	117,972	154,959	173,331	81,613	21,245	708,700
1986	180,577	153,971	213,649	187,659	105,286	25,853	866,995
1987	228,711	179,230	259,275	248,154	151,595	41,844	1,108,809
1988	264,455	231,638	341,241	227,554	164,087	64,583	1,293,558
1989	231,571	233,617	352,877	306,791	175,813	60,141	1,360,810
Annual increasing rate	11.4%	27.3%	17.7%	10.2%	24.2%	27.2%	16.1%

Source: Industrial waste management, Ministry of Environment.



#### Main areas of end-uses for plastics

Data on the product consumption pattern are scarce and dispersed. Due to their adaptability and low manufacturing cost, plastics are used in the Republic of Korea in practically all basic applications. Plastics products manufactured locally are classified as finished or semi-finished products. The major plastics produced for the domestic market include film bags, calendar products, woven plastic sacks, bottles, packaging containers, housewares, and industrial products such as pipes and fittings, using the following processes.

*Extrusion process:* film bags, netting, ropes, pelletized/recycled plastic products, pipes, profiles, sheets, wire and cables, woven sacks.

*Moulding process:* (injection, blow, compression): housewares, industrial parts/products (e.g. crates), packaging containers (e.g. bottles), personal care products, toys and novelties, wearables.

*Specialty process:* adhesive tapes, calendar products, casting, dip-coated products, laminated/coated/metallized products, office and school supplies, printed plastic products, vacuum formed products.

The local plastic processing industry refers to that sector which undertakes the transformation of the major

thermoplastic resins currently in use in the world (e.g. polyethylene, polypropylene, polyvinyl chloride and polystyrene) into various plastic products for both consumer and industrial applications.

#### Sources of plastic waste

##### Generation of plastic waste

In 1989, 770,000 tons of plastic wastes were generated and the increasing rate of plastic waste generation was much higher than that of overall waste generation.

The increasing use of plastic products in an expanding range of applications is posing problems in the disposal of these plastic articles when their useful life is finished. The Republic of Korea faces problems on solid waste disposal, of which plastic waste is one of those contributing to the dilemma. As a result of increased industrialization and commercial growth and development, the continuous influx of people into the region remains unabated. Infrastructure development has not been able to keep pace with the population growth, and this has imposed an enormous strain on an already overburdened infrastructure. This has been one of the primary causes of the environmental degradation and the deterioration in the quality of life throughout the region.

**Table 3. Trend in plastic wastes generation (tons)**

Year	LDPE	HDPE	PP	PVC	PS	ABS	Total
1985	103,249 32.4%	35,846 11.3%	75,057 23.5%	78,173 24.5%	20,969 6.6%	5,548 1.7%	318,845 100%
1986	127,242 31.8%	51,144 12.8%	95,172 23.8%	93,620 23.4%	24,914 6.2%	7,849 2.0%	399,961 100%
1987	147,228 30.3%	71,303 14.7%	122,481 25.2%	104,406 21.5%	29,567 6.1%	10,931 2.2%	485,916 100%
1988	175,795 26.5%	90,462 13.6%	144,789 21.8%	176,013 26.5%	64,051 9.7%	12,653 1.9%	663,762 100%
1989	210,715 27.2%	115,811 14.9%	177,617 22.9%	191,473 24.7%	64,303 8.3%	15,028 2.0%	774,947 100%
Annual increasing rate	19.5%	34.1%	24.0%	25.1%	32.4%	28.3%	24.8%

Source: Industrial waste management, Ministry of Environment.

**Collection and sorting of plastic waste in the Republic of Korea**

*Collection and sorting of industrial waste*

Plastic waste is generated in industries, households and farm areas. Plastic waste generated from industries was 248,940 tons in 1989. Approximately one third was recycled, half was incinerated, 8 per cent was stocked and the remainder disposed of by landfill.

**Table 4. Distribution of the industrial plastic wastes**

Industrial plastic wastes	
Recycled	33 per cent
Stocked	8 per cent
Incinerated	50 per cent
Landfill	9 per cent

Source: Industrial Waste Management Division, Ministry of Environment.

*Collection of post-consumer plastic waste*

Most plastic waste from households is collected by the municipalities and disposed of at landfill sites. Some waste films from farmland are collected by the Korea Resources and Reutilization Corporation (KORECO), and those wastes collected are reutilized in an appropriate manner. As shown in table 5, the amount collected in 1989 was 44,952 tons and was 11.6 per cent more than that in 1988.

**Collection system**

*Background of foundation*

Korea Resources Recovery and Re-utilization Corporation (KORECO)

There are two reasons for the foundation of KORECO.

- The consumption of synthetic resin (plastic) drastically increased since 1970 and the amount of plastic waste increased, especially waste from farmlands. Some of these were discharged carelessly in fields, streams and mountains, causing environmental pollution problems.
- After the energy crisis in the 1970s, prices of petrochemical products soared and the Korean Government tried to find methods to cope with the situation.

As a consequence, to reduce environmental pollution, and to try to limit plastic wastes, the Synthetic Resin Waste Disposal Law was promulgated which established KORECO in 1979.

*Functions and organization*

The main functions of KORECO are to collect and transport waste systematically in order to protect the environment and to reutilize as much waste as possible so as to reduce wastes which need treatment or disposal. KORECO collects plastic wastes, waste paper, scrap iron and empty biocide bottles.

*Achievements*

There are 60 branch offices in KORECO across the nation as the front-line operation centres of the corporation, each of which takes charge of on average two provinces and two cities with 8-10 staff and three collection vehicles. Each branch office collects plastics waste, empty biocide bottles, etc. by collection vehicles according to the collecting round schedule.

**Table 5. Plastic wastes treatment by KORECO  
(in tons)**

Year	Amount of collection	Amount of treated disposal			Cumul. stockpiled	
		Total	Sold for recycling	Incineration		Others
1981	19,748	13,029	12,830	155	44	7,794
1982	20,572	21,472	19,877	1,330	265	6,894
1983	23,804	24,124	21,772	1,681	671	6,574
1984	29,008	25,892	23,251	1,618	1,023	9,690
1985	29,650	25,703	22,167	3,177	359	13,637
1986	34,764	26,801	23,612	2,923	266	21,600
1987	31,237	25,051	21,340	2,601	1,110	27,876
1988	36,280	31,513	29,328	1,851	334	32,553
1989	44,952	37,108	36,070	788	250	42,794

Source: Industrial Waste Management Division, Ministry of Environment.

**Table 6. Statistics of collected amounts by KORECO, in tons**

	Plastic waste	Paper waste	Scrap iron	Empty bottles for agricultural chemicals
1981	20,823	-	-	-
1982	28,366	11,708	104,847	-
1983	30,698	29,070	119,929	-
1984	35,582	12,228	140,325	-
1985	39,340	1,350	116,176	-
1986	48,401	3,818	122,880	-
1987	52,337	58,174	117,681	10,393
1988	64,066	50,064	115,550	11,893
1989	44,952	12,517	116,680	13,477
1990	47,380	-	133,039	14,799

Source: Industrial Waste Management Division, Ministry of Environment

#### Financial resources

In accordance with the Synthetic Resin Waste Disposal Law, KORECO was founded as a special corporation, without capital but is supported for the collection and disposal of plastic waste, and charges less than 1 per cent of the sales prices of manufacturers and importers of plastic

products made of PE, PP, PVC, PS, ABS, AS, EVA, PDVC, acrylic resin and PMMA. The Government subsidizes operation at cost and also facilities and equipment for the collection and disposal of empty biocide bottles.

Detailed statistics related with charging are shown below.



Table 7. Statistics of collected amounts by KORECO.

Classification		1985	1986	1987	1988	1989	1990
The rate of charging (per cent)		0.53	0.54	0.54	0.6	0.6	0.7
The amount of income (million won)		3,401	3,811	4,814	7,124	7,603	9,855
No. of manufacturers and importers	Importers	239	270	293	311	408	493
	Manufacturer	8	8	8	11	15	16
	<b>Total</b>	<b>247</b>	<b>278</b>	<b>301</b>	<b>322</b>	<b>423</b>	<b>509</b>

Source: Industrial Waste Management Division, Ministry of Environment.

### Recycling of plastic waste in the Republic of Korea

#### *Recycling of industrial waste*

- Industrial plastic waste material originating from the plastics processing is recycled in two ways:
  - Recycled by plastic transformers in the same installation as the virgin material. This is economically viable in local conditions. Some plastic transformers are importing plastic waste to meet demands for reasonable prices of their products;
  - Sold to plastic recyclers.

#### *Recycling of post-consumer waste*

Of the collected waste, waste paper is sold to paper manufacturers, while scrap iron and empty biocide bottles are sold to steel iron plants and glass manufacturers respectively. Sorting is done by branch offices before being sent to private waste recycling plants. HDPE waste, which cannot be reutilized for economic reasons, is recycled by the corporation. To recycle HDPE waste, the corporation built a facility of 4,000 tons/year in 1989 and is constructing another facility of 4,000 tons/year. Plastic waste which can not be sorted or which is too contaminated is burned in incinerators.

#### *Future perspectives*

Recycling and reutilization of waste should be understood as an important task for the preservation and protection of the environment. Efforts will need to be intensified in the future. To promote proper collection for recycling, the development of techniques and subsidies for construction facilities are needed. A new collection system for separating wastes has been enforced; everyone who emits waste has to separate it into three parts: recyclable wastes, combustibles, and non-combustibles. It is not under consideration to introduce an identification mark for plastic products as to their composition.

A law passed in December 1992 prohibits the use of PS in toys and packaging for gift sets. The law also calls for a general reduction in PS packaging for electrical appliances and further requires that all PS packaging for electrical appliances dispatched directly to the customer must be recovered. Six Korean expanded polystyrene producers have formed the Korean Foam Styrene Recycling Association to help compliance with the law.

### Disposal of plastic waste

There are three methods used to treat plastic waste: landfill, incineration and reutilization. Landfill is the old

method for municipal solid waste disposal. However, this method creates a problem with plastic waste disposal. Because plastic waste cannot be easily biologically decomposed, the waste remains in the ground.

The second method for treatment is incineration. This method is frequently adopted when plastic waste cannot be recycled or reutilized. Plastic waste could be mixed with other materials and therefore be contaminated. In this case plastic waste must be disposed of and the incineration method is used. Although some opportunities exist to recover waste heat generated through incineration, air pollution problems arise.

The recycling method of plastic waste may be divided into two: the first is energy recovery through materials conversion, and the second is recycling as a raw material instead of synthetic resin. In order to recover energy from plastics waste, the pyrolysis method can be used. This may need high technologies and a high capital cost for construction. To promote the recycling of plastic waste, many efforts must be concentrated in the fields of collection, segregation, and the development of re-utilization technologies, etc.

### Economics of recycling and disposal of plastics waste

Disposal of waste, and especially of useful plastic waste, is a loss of expensive and non-renewable natural resources. Therefore, recycling is not only an environment protection programme, but also has an important economic and social impact on the performance of the national economy. Obviously, recycled materials will always have secondary applications, or will be used in combination with virgin materials (multi-layer products). However, recycling will increase the potential for use of plastic materials in general, as many countries import the majority of their virgin material. In many countries, producers of virgin materials, having an influence on standardization rules, have introduced limitations on the use of recycled materials.

This discrimination is no longer acceptable and the use of recycled materials should be allowed, according to the application and the development of new applications, especially for mixed plastics and should thus be supported by the Government.

### Legislation

The highlights of new Waste Management Law are as follows:

The main purpose of this amendment is to change the waste classification system into general and specified waste. General waste will be handled by local governments and specified waste by the central government. All hazardous waste will be categorized into specified waste. This requires:

- Setting-up of basic plans for waste management by the Ministry of Environment, or local governments.
- Standardization of collection/transport vessels and the enlargement of waste collection zones.
- Support from central government for the waste minimization and re-utilization effort.
- Introduction of a deposit system for the proper treatment of hazardous wastes such as waste oil, scrap tyres, mercury-containing batteries, and plastics.
- Building-up of a waste management fund for waste recycling and its proper treatment.

The main administrative responsibilities for the above waste management activities are handled by the Waste Management Bureau of the Ministry of Environment and programmes have been developed by the National Institute of Environmental Research. Public facilities for hazardous waste treatment have been managed by the Environmental Management Corporation. The Korea Resources Recovery and Utilization Corporation is responsible for waste re-utilization, treatment and technology development.

It is expected that waste can be managed more systematically and recycling and re-utilization of wastes can be promoted by the enactment of the amended Waste Management Act. (Source: *Survey on Management of Plastic Waste in Asian Countries*, author: Vincent Sciascia. Prepared for UNIDO, December 1994)

### **Plastics recycling in developing countries**

In developing countries, and particularly in Asia, the recycling of plastics derived from waste materials is thriving, based on their research on solid waste recycling options. Plastics recycling can generate income and employment.

The plastic recycling boom is due to a combination of factors:

- High unemployment and low labour costs mean that the labour-intensive manual processes involved in the reprocessing of waste plastics, such as collecting, washing and sorting waste, are economically feasible.
- Because of the large numbers of low-income consumers, the level of market acceptance of cheaper, poorer-quality products is high.
- The use of plastic waste instead of raw materials such as crude oil or virgin plastic pellets means that production costs are reduced considerably.
- There are few or no regulations or quality standards for recycled products.

In contrast with the industrialized countries, most plastics in developing countries are reprocessed in small enterprises that depend almost exclusively on recovered materials. For many people, working in the informal waste sector is the last resort in their daily struggle for survival.

Nevertheless, a large number of traders and re-processors have managed to set up businesses that generate reasonable, or even high profits. The technologies they use are in principle the same as those used in the (formal) large industries, although most machinery is outdated or has been upgraded with locally available spare parts.

Given their small size and the large proportion of scrap they use, these enterprises are highly dependent on a

network of dealers and reprocessors for supplies of raw materials that meet their specifications.

The four types of plastics that are most commonly reprocessed are polyethylene (PE), polypropylene (PP), polystyrene (PS) and polyvinyl chloride (PVC).

### **Chain of activities**

Plastics recycling consists of a chain of activities. The initial stages of collecting, cleaning and sorting are labour-intensive and require low capital investments and little or no specific technical skills.

The collected waste materials can be reduced in size by cutting with scissors, or using techniques such as shredding or agglomerating. Size reduction reduces the bulk of the material, thus reducing transport costs, and facilitating feeding the plastics into machines for further processing.

These further reprocessing stages consist of mixing, extrusion, pelletizing and product manufacturing. An extruder produces spaghetti-like strings that are cut into pellets suitable for continuous feeding into manufacturing machines. Product manufacturing processes are for example extrusion, injection moulding, blow moulding and film blowing. These processes are based on extrusion techniques, in which either the form of the dies or the blowing technique determines the shape of the end product.

### **Collecting and sorting**

The initial stages of collecting and sorting the waste materials are performed by waste pickers and scrap-dealers. In the later stages of size reduction, mechanical washing and drying, pelletizing and product manufacturing, small industries become involved.

Small manufacturing workshops may also be involved in the initial stages, such as the selection of materials according to the type of polymer, or colour, in addition to the preselection by waste pickers and dealers. The different stages in plastics recovery are closely interlinked, and extensive networks exist between the various entrepreneurs involved. Waste reprocessing enterprises also provide work for a number of craftsmen, electricians and fitters, who carry out critical tasks in maintaining the production process.

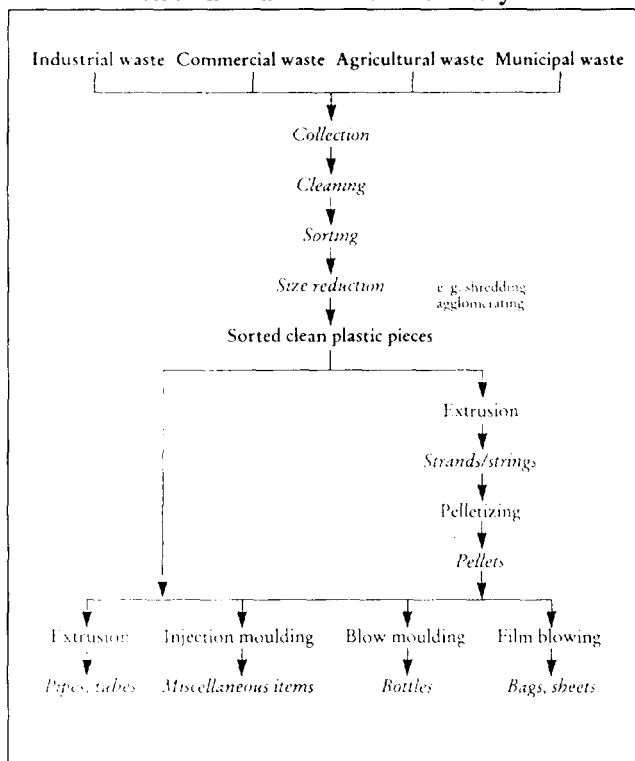
The initial stages of collecting and sorting waste generate most employment. In metro Manila, for example, it has been estimated that as many as 7,000 individuals are economically fully dependent on plastics recovery activities such as sorting, cleaning and drying (CAPS, 1992). In some cities a large number of small reprocessing workshops exist.

In Manila, the plastics industry comprises more than 450 companies, the majority of which are small to medium-scale manufacturers who use reprocessed plastics in their production processes (CAPS, 1992).

Different markets demand goods of different quality. First, there is the demand for regular or good quality products from high-income consumers and more specialized markets: such products incorporate only small proportions of recycled waste plastics (5-20 per cent). Second, there is a high demand for lower-quality products made from recovered materials, which are sold at lower prices.

This difference in demand is clearly demonstrated in Turkey for example, where both regular water pipes and a low-quality version are manufactured. The regular, high-quality version is manufactured from virgin polyethylene and is pale blue in colour. This version is destined for use in the formal market in the construction of new apartments,

Flow chart of a typical waste plastics reprocessing stream in a low-income country



shops and office buildings. The lower-quality version made of reprocessed polyethylene is black, due to the mixture of differently coloured waste plastics; such pipes often vary in thickness, with thin patches that may be porous. These pipes are sold for example in rural villages in Anatolia, in the east of the country, for use in housing and as irrigation pipes (Konings, 1989).

The viability of a waste plastics recycling plant will depend upon a number of important technical factors, and socio-economic and political circumstances. Macro-economic factors such as international prices and trading policies, government policies (including import restrictions), and municipal policies related to solid waste management will all determine the level of recycling that is feasible. Also, a well-developed indigenous plastics processing industry is crucial for the feasibility of plastics reprocessing enterprises. The informal plastics recycling sector often flourishes alongside formal industries. Some small-scale entrepreneurs receive their training within the formal sector, and the availability of second-hand machines and locally manufactured equipment means that huge savings on capital investments can be made.

The quality of the final products derived from waste plastics will be improved considerable if all contaminants (non-plastics, dirt, etc.) are removed prior to reprocessing, and if the degree of moisture is reduced to a minimum. It is also important that the different types of plastics are separated as carefully as possible and as close to the source of generation as possible (e.g. collecting plastic waste from houses, offices and industries instead of from landfills). Thus the waste plastics should be sorted, washed and dried, preferably before size reduction. Also, working conditions will be improved considerably if the waste plastics are washed and dried before they are sorted.

In many economically less developed countries the prospects of the plastics reprocessing industry are good, mainly because the demand for plastic products is growing, and so are the amounts of plastic waste being generated as a result. The amounts of plastic waste have increased considerably in developing countries and have reached levels, for example in South-East Asia and the Indian subcontinent, similar to those in Western Europe and the United States. In 1982, in Metro Manila in the Philippines, plastics accounted for 7.5 per cent of the weight of solid waste generated. By 1990, this proportion had increased to 12.4 per cent. These figures do not include the waste generated by the plastics industry itself, since this is sold directly to recyclers (CAPS, 1992). According to data from the Association of Plastics Manufacturers in Europe (APME), in 1990 plastics accounted for 7.3 per cent (by weight) of the municipal waste generated in Western Europe.

Also, possibilities exist for setting up new enterprises. If there is no local tradition in small-scale manufacturing of consumer goods, short-term successes may be easier to achieve by initiating activities such as collecting, washing and sorting plastic waste materials rather than product manufacturing.

In setting up and maintaining small enterprises, it is essential to establish business links with formal large-scale industries. First, they could be interested in buying semi-processed products, such as clean and sorted shredded plastic materials or pellets. Second, these industries are becoming more interested in contributing to employment generation on the one hand, and recycling on the other to build up a social and "green image". Small enterprises may be able to benefit from these tendencies and to take advantage of the expertise available within these industries.

The best way to prevent environmental and health problems caused by waste would be simply to avoid the generation of waste in the first place. Prevention should always be an important first measure. This is especially true for high-income countries where, for example, the packaging industry uses plastics unnecessarily and where literally hundreds of types of plastic materials are available commercially. But it also applies to developing countries. In economically less developed countries, fewer types of plastics tend to be used than in industrialized countries. In Calcutta, for example, approximately 17 major types of plastics are used for general applications, and there are more than 50 minor types, called grades (Ptr Services, 1992). The larger the number of plastic types, the more difficult it is to sort and the lower the quality of the products. Restricting the number of plastic types is therefore an important measure. But plastics continue to be produced and recycling is an interesting option for handling this waste.

#### Positive benefits

Plastics recycling definitely has some positive benefits; it can generate income, it requires relatively low levels of investment, it can yield reasonable or high profits, and involve relatively technically uncomplicated production processes to produce a wide variety of products for a broad market. Also, local governments benefit from recycling activities, because less waste has to be collected and disposed of. Local governments could play an active role in stimulating the growth and improving the performance of these enterprises by:

- Recognizing and integrating existing informal recycling networks within municipal solid waste management systems;
- Stimulating the development and implementation of appropriate technologies for plastics recovery;
- Formulating policies to protect and encourage the horizontal growth of small-scale resource recovery initiatives;
- Creating legal frameworks and control mechanisms that will both improve safety in the workplace, and protect the environment; and
- Disseminating information both to the general population and to enterprises on the benefits of recycling and the prevention of waste generation.

(Source: Gate 3/95)

### **Plastics waste management: India**

(Paper presented at the National Seminar on "Emerging Trends in Plastic Recycling Technologies and Waste Management" held at Goa, India on 27th and 28th May, 1995)

#### **Abstract**

The consumption of thermoplastics in India during 1993-1994 was around 1.36 million tons. The likely demand by the year 2000 would be about 2.86 million tons with an investment of US\$ 5 billion by that time.

The Indian plastics processing industry is predominantly in the small scale sector. There are about 20,000 units with an investment of about US\$ 250 million. This number is expected to increase to 30,000 processing units by the year 2000.

The major source of plastics waste generation is from the domestic sector, and the industrial and agricultural applications of thermoplastics. Plastics waste forms only a small fraction (1 per cent by weight) of the total municipal solid waste.

India has a well organized system of collection of plastic waste from houses, garbage heaps and industrial and agricultural sectors. This system is heavily dependent on the use of manual labour. Plastics waste generation is planned to be reduced in India by a three-fold strategy, viz. source reduction and reuse, repair and recycling. Source reduction can be through use of better manufacturing practices, improved process engineering and technology and product design by the processors. Reuse of plastic products ensures extended life and reduced waste generation. Repairing is the extension of the reuse concept which ensures longer product life. Recycling is the best way of disposal of the waste and the three basic approaches to it would be (1) mechanical (2) mixed waste and (3) feedstock recycling.

There are many policy issues relating to management of plastics waste, such as improvement in collection and sorting techniques, improving the technologies for recycling and identification of the right end use applications.

There is a need for a nodal agency within the country to take the lead and play a coordinating role. A system of exchange of expertise and technological information among various countries also needs to be established.

#### **Overview of the Indian economy**

India has a total area of around 3.3 million sq.km with a population of about 915 million. There are about 250 million people with adequate disposable income and this figure is expected to go up to 400 million by the turn of the century. The country has the third largest technical

manpower and it is available at a comparatively reasonable cost. The monthly labour cost is around US\$ 60 (US\$ 1 = IRS 31.00).

The Indian economy has emerged stronger following recent restructuring and the launching of an array of long overdue reforms. The measures taken during the past two years have brought down the soaring inflation, ensured a systematic overhaul of foreign trade and exchange rate policies, largely dismantled the cumbersome system of industrial licensing, launched a more liberal policy towards foreign investments and ushered in far reaching changes in the governance of the capital market. Policy changes have also been introduced to impart greater flexibility to monetary operations. GDP grew at 3.8 per cent in 1993-1994, with agriculture growing at 2.3 per cent, manufacturing at 2.5 per cent and the growth of utilities and other services sectors ranging from 3.8 to 8.1 per cent.

The investment climate and expectations in the industrial sector have shown a remarkable improvement over the years. A number of policy initiatives have been taken in the infrastructure sectors to promote efficiency and raise resources for their development and expansion.

Petrochemicals, particularly plastics and fibres, contribute revenue to the national exchequer to the tune of US\$ 1.7 billion. The exports from this sector currently stand at US\$ 1 billion. This works out to about 5 per cent of India's total export of about US\$ 18 billion. Consumption of major petrochemicals in India was about 3.4 million tons in 1993-1994 (table 1).

#### **Growth of plastics industry in India**

The petrochemical industry is a hi-tech industry, wherein production and processing into end-products are going through constant upgradation of technology. The industry has come a long way since the first naphtha cracker unit was set up by Indian Petrochemicals Corporation Limited (IPCL) in Baroda in the 1970s. There are about 40 major raw material manufacturing industries. In India, the total production of plastics in the year 1993-1994 was around 0.9 million tons, while the consumption was of the order of 1.36 million tons. About 30-35 per cent of India's total consumption of plastics is met through imports. The total demand for plastics in 1994-1995 has been estimated at about 1.48 million tons. The capacity, production and consumption of the major commodity plastics during 1993-1994 are given in table 2. The demand is likely to be around 2.86 million tons by the year 2000. Nearly 80 per cent of the total requirements of plastics is only for commodity plastics. The expansion of the existing petrochemical complexes and new gas and naphtha based crackers in Nagothane and Thane (Maharashtra), Gandhar, Hazira and Jamnagar (Gujarat), Upper Assam (Assam), Auraiya (UP) and Haldia (West Bengal) would make available still larger volumes of existing products and also new generation polymers.

India's per capita consumption is of the order of 1.4 kg, against the world average of 18 kg. The consumption of plastics is expected to grow at a healthy rate of 13.6 per cent per annum compounded during this decade and is expected to reach a per capita consumption level of 2.5 kg by the year 2000. The Indian plastics industry, which has investments in the order of US\$ 1.7 billion, is poised to become a US\$ 5 billion industry in terms of investment by the turn of the century.

The Indian plastic processing industry is characterized by a predominance of units in the small scale sector. There are about 20,000 primary processing units, converting more

Table 1. Consumption of major petrochemicals

(Unit '000MT)

	1993-1994			1992-1993		
	Production	Imports	Consumption	Production	Imports	Consumption
Polymers	902	460	1,362	638	511	1,149
Fibres	635	53	688	537	14	551
Intermediates	652	85	737	574	74	686
Synthetic rubber	44	36	80	52	15	67
LAB	211	31	242	206	0	206
PX	201	55	256	178	72	250
<b>Total</b>	<b>2,644</b>	<b>720</b>	<b>3,364</b>	<b>2,185</b>	<b>686</b>	<b>2,871</b>
Increase over 1992-1993	21%	5%	1.7%			
		<b>Consumption</b>	<b>% Increase over 1992-1993</b>			
		Polymers	18.5			
		Fibres	24.8			
		Intermediates	13.7			
		Synthetic rubber	19.4			
		LAB	17.5			
		PX	2.4			
		<b>Overall</b>	<b>17.2</b>			
<i>Items included:</i>						
Polymers	- LDPE, LLDPE, HDPE, PP, PVC, ABS					
Synthetic fibres	- AF, PSF, PFY, NFY, NIY					
Intermediates	- DMT, PTA, ACN, CAPRO, MEG					
Synthetic rubber	- SBR/PBR					
Others	- LAB, PX					

Table 2. Capacity consumption and demand estimates for polymers

(Unit thousand tons)

Polymer	Capacity as on 1.4.94	Consumption 1993-1994	Demand 1999-2000 +	
			High	Low
LDPE/LLDPE	193	280	425	404
HDPE	345*	330	640	551
PP	115	257	766	645
PVC	550	413	865	755
PS	81	67	169	142
ABS	27	15	not considered	
<b>Total</b>	<b>1,311</b>	<b>1,362</b>	<b>2,865</b>	<b>2,497</b>
+ High/Low demand reflect price elasticity of demand				
* Combined capacity of HDPE/LLDPE.				

Source: Report of the Export Group on Petrochemicals, Department of Chemicals and Petrochemicals, Ministry of Chemicals and Fertilizers - 1993.

than 1 million tons per annum of raw materials and deploying over 40,000 primary processing machines at present. This will be increased to 30,000 primary processing units with over 120,000 processing machines with a processing capacity of 4.5 million tons of raw materials in the year 2000. Investment in the processing industry has increased from US\$ 25 million at the end of 1970 to about US\$ 250 million today. Nearly 75 per cent of the total units presently existing in this industry are in the small scale sector.

The plastic processing units contribute substantially to employment generation, currently estimated at about 2.5 million, and thereby serve a vital need of the country's economy. They also have a very good scope of entrepreneurial development. The employment potential (both direct and indirect) in plastic processing units is growing in a cascading manner.

#### **Associations/organisations dealing with plastics in India**

The Department of Chemicals and Petrochemicals, in the Ministry of Chemicals & Fertilizers, is the nodal authority in the Government of India for petrochemicals, including plastics. There are two prominent associations of polymer producers, namely Chemicals & Petrochemicals Manufacturers Association and PVC Manufacturers Association. The main associations and organizations, which look after the interests and growth of plastics processing and conversion industries in the country on an all-India level are: All India Plastics Manufacturers' Association (AIPMA), Organization of Plastics Processors of India (OPPI), PLASTINDIA FOUNDATION, All India Federation of Plastics Industries (AIFPI), Indian Plastics Federation (IPF), The Plastics Woven Sacks Manufacturers' Association (PLASMA) and All India Flat Tape Manufacturers Association (AIFTMA). There are many regional level associations also, which contribute towards the growth of plastics industries. Institutions like the Central Institute of Plastics Engineering and Technology (CIPET) and the Indian Plastics Institute (IPI) have a special focus on development of manpower for the plastics industries. CIPET plays a catalytic role in promotion of plastics conversion industries by providing not only trained manpower, but also the necessary technical back-up services. Organizations like the Society of Plastics Engineers (SPE) are also actively involved in promotion of plastic technology and trade. Other associations like the Waste Dealers' Association, and All India Plastic Waste Recycling Industries Association contribute to the growth of plastic recycling industries in the country.

#### **Export of plastics goods**

India has been exporting plastic goods to various countries in the world, the bulk of which are woven sacks and bags. This is closely followed by plastic moulded and extruded goods, valued at US\$ 62 million. The total exports during the year 1993-1994 were of the order of US\$ 255 million.

#### **Major applications of commodity and engineering plastics**

Initially, the use of commodity plastics in the late 1960s was in films for packaging. The late 1970s witnessed an increase in the use of plastics in packaging, agriculture, water management and the replacement of wood. However, in the last few years, commodity plastics have started to be used in significant quantities in applications such as films, woven sacks, pipes, bottles, flexible

packagings, medical items, household goods, toys, stationery, novelties, etc.

#### **Plastics waste and management systems**

##### *Plastics waste and social need*

The main sources of plastics waste are: (i) industry; (ii) agricultural; and (iii) household. Industrial plastics waste is non-consumer plastic and includes waste from moulders, plastic manufacturers, etc. This can be processed on traditional equipment after some cleaning and size reduction. The advantages of industrial waste are: (i) clean, (ii) segregated, and (iii) available in bulk.

Agricultural films and woven sacks are easy to collect in large quantities from a few fixed sources. These are generally soiled, but can be easily cleaned and recycled.

Household waste can be any plastic that has been used by the consumer and discarded. It includes plastics bottles, packaging material; milk pouches, PVC footwear, disposable cups and plates, shopping bags, etc. the problems with the household waste are: (i) it is dirty, (ii) difficult to separate, and (iii) smaller volume per collection site.

India has a well organized system of collection of plastic waste from houses, garbage and junk heaps. Plastics waste is collected from these sources by rag pickers and sold to scrap dealers. The scrap is segregated by rag pickers, based on quality and the grade of the material. The well separated plastics waste material is sold to reproducers. The scheme of plastics waste collection, transfer and recycling is illustrated in table 3. However, with the increase in uses of plastic and higher generation of plastics waste, such manual collection systems, involving a very large manforce, need to be improved.

The trend of collection, separation and recycling of plastics and paper wastes in India, presents an interesting, and socially and technologically different picture than that in the developed countries. In those countries, campaigns are organized by government departments, the plastics industry and municipalities for the collection and separation of plastics wastes by offering incentives and subsidies, while in India, these activities are self-organized through a chain of self-employed individuals or groups of dealers and agents for whom this work is a source of income.

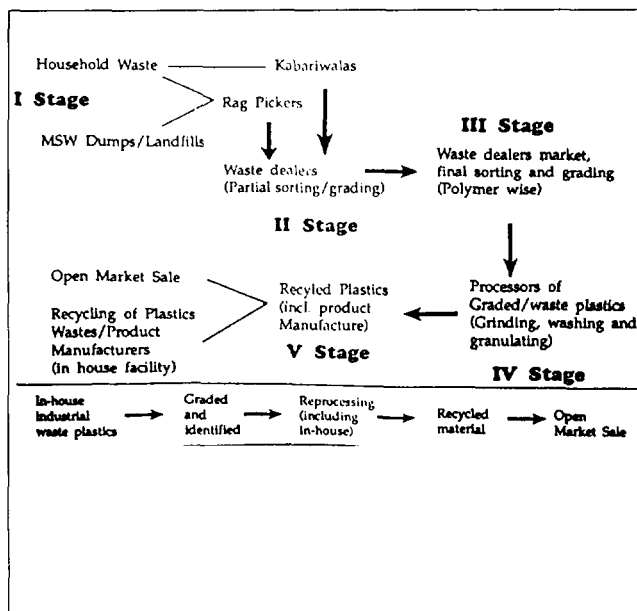
A study conducted showed that a rag picker in India during one day, collects about three to five kilograms of plastics waste, earning about Rs. 30 to Rs. 50/- (US\$ 1 to 1.5) per day. This waste is then washed, cleaned and recycled and these processes cost about Rs. 7,000/- and Rs. 8,000 - per mt. The reprocessed raw material is then sold in the range of Rs. 18,000 - 20,000 - per mt. a price of less than 50 per cent of the virgin raw material. From the reprocessed material, many finished products are made. Sometimes the reprocessed material is mixed with virgin material, when the finished product does not demand high quality norms. The total number of rag pickers in the country is estimated to be about 1 million.

At present, the annual generation of solid waste per capita is half kg., which is likely to increase to one kg. by the turn of the century. This highlights the need to focus urgent attention on the cost-effective management of solid waste in the country. Visualizing the acute problems of Municipal Solid Waste (MSW) Management, the Ministry of Environment and Forests of the Government of India has initiated studies in sixteen selected cities with a view to evolving strategies to reduce the generation of municipal solid waste and minimizing its conventional disposal as a land fill. The present quantity of plastics waste in MSW is about 1 per cent by weight.

**Sorting**

After collection, the waste plastics are separated into different categories based on the type of resin, grade and colour. This is the most critical stage of recycling. In India, most of the sorting is done manually because of the low costs. Sorting of plastic waste by mechanical means and by using devices, such as a hydro-cyclone, is not widely practised in the country. The clean and separated waste is shredded into small pieces by means of a grinding machine. In some cases, the clean scrap and ground pieces mixed together are also converted into granules by extrusion to take advantage of the combined properties of mixed plastics for certain end products. The granules of single plastics are then sold to processing industries which convert them into finished products through extrusion, blown film, blow moulding and injection moulding processes. Some of the units directly process the materials without making granules. Coloured master batches are also added to make coloured products.

**Table 3. Pattern of waste plastics collection, transfer and recycling in India**



**Waste management strategy**

In India, a three-fold waste management strategy is being considered for adoption namely (1) source reduction and reuse, (2) repair and (3) recycling.

**Source reduction and reuse:** Source reduction and reuse can be considered as a first step towards reduction in waste generation. Source reduction of plastics waste is important to converters and manufacturers and will include areas of better manufacturing process technology and product design. Reuse of plastics ensures an extended product life. Many household products and products in the industrial sector have good reuse potential. The product becomes available for reprocessing to a lesser extent only after the purpose of reuse has been served. Typical products reused in the household are edible oil containers, carrier bags, etc. Heavy duty plastics sacks find extensive reuse among farmers and industrial users. HDPE drums and carboys are also reused in the industrial sector for packaging purposes.

**Recycling:** The recycling technology following the traditional method—grinder, washing, mixer and extruder—

as practised in India, has matured over the years. The technology continues to be improved, updated and refined with local skills and machines. The plastics waste recycling industry in India is spread throughout the country in the form of small units, based mostly on the waste available in their vicinity. In fact, this industry, which is following the locally developed recycling systems and techniques, can be termed as the most “organized unorganized” set-up, operating parallel to the virgin processing industry. Entrepreneurs have been exploring the new possibilities of using various types of mixed thermoplastic wastes for recycling and conversion into volume applications. This has been necessitated by the compulsions for clearance of plastics waste arising out of increased utilization of plastics, more particularly in packaging and disposables.

**Recycling technologies**

There are basically three approaches for recycling: (i) mechanical recycling; (ii) mixed waste recycling; and (iii) feed stock recycling.

Mechanical recycling is practical, if the waste materials are largely unmixed, clean and available in economically viable quantities. This recycling process has already been practised in India, with large quantities of in-house production waste. These are generally reprocessed into pellets which can be used in many non-critical applications. Mechanical recycling undergoes four typical stages: size reduction, washing, separation at chip level and melt processing. Mechanical recycling lines have been developed for nearly all major thermoplastics.

Mixed waste or co-mingled plastics waste processing involves the use of mixed plastics as feed stock. This technology has applications for buildings and the construction industry as a substitute for wood and concrete products.

In the process of feed stock recycling, the macromolecular structure is broken down to the basic monomer/chemical and this can then be used for manufacture of plastics. Developed countries adopt techniques such as pyrolysis, hydrogenation and chemolysis. In India these techniques have been restricted to materials such as PETE, PMMA and polyamides. All these plastic materials are depolymerized to their respective monomers which are again used in the manufacture of plastics. There have been no attempts so far to recover energy from plastics waste through incineration.

**Size of market and scale of operations**

Out of the reprocessed plastics waste material, which is mainly converted into consumer items, PVC accounts for a share of 45 per cent, LDPE and HDPE at 25 per cent and 20 per cent, Polypropylene 7.6 per cent and other polymers like Polystyrene at 24 per cent. Recycling of plastics is carried out sometimes four times. Four grades of recycled material are available, with each recycling the characteristics of the particular recycled material undergo a change.

It is estimated that over 1,000 tons of plastics waste is received for sale to reprocessors everyday in plastic waste collection centres in various parts of the country. Delhi is the nucleus market for plastic waste in northern India. Delhi’s plastics waste market is Asia’s largest, with about 5,000 dealers, and at least 200 reprocessing units spread in and around this market. Other important centres are Bombay, Calcutta, Madras, Bangalore, Ahmedabad and Kanpur. It is estimated that the small recycling units in the country may be of the order of 20,000.

**Environmental policies, legislation and codes of practice**

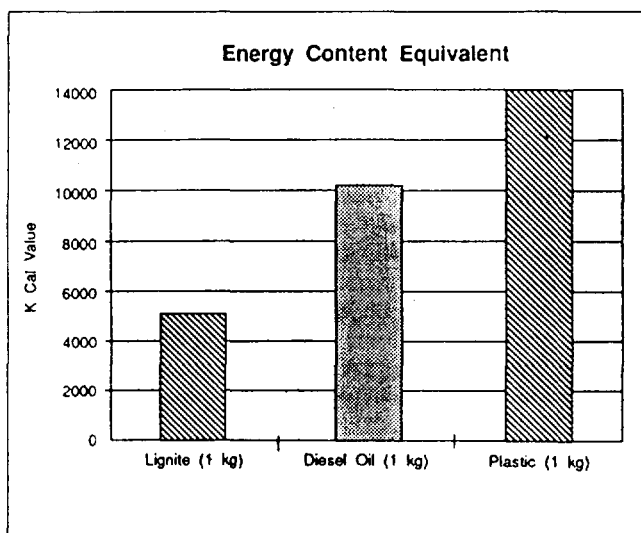
The National Waste Management Council of Ministry of Environment and Forests periodically discusses plastic waste management practices as part of MSW to arrive at future strategies. The Ministry of Environment and Forests has issued criteria for labelling plastic products as "environmental friendly" under its "Ecomark" Scheme, in association with Bureau of Indian Standards. One of the requirements for plastic products, is that the material used for packaging shall be recyclable or biodegradable. The end uses for recycled plastic products have been listed. However, the results and usefulness of this scheme have yet to appear, as the scheme is not mandatory.

At present, there are no guidelines or codes of practices for the collection, sorting and recycling of plastics waste. Conventional practices are adopted and accepted, although a need has been voiced to upgrade these, both by the authorities and NGOs. However, while formulating Indian Standards specifications for various plastic products used for critical applications like plastic piping systems, water-storage tanks, packaging for food, a clause is included which reads "no recycled plastics waste shall be used". An exercise has also been recently carried out by the Ministry of Environment and Forests, in association with the Bureau of Indian Standards, for the inclusion in Indian Standards, the use of recycled plastic waste, wherever appropriate, in the manufacture of plastic products.

**Environment consciousness**

The plastics industry is facing criticism in many developed countries as being the source of non-degradable solid waste. The concept that plastics are environmentally unfriendly, and a health hazard, is not factually applicable for a developing country like India. About 35-40 per cent of the total plastics consumed in India are recycled. However, eco-balance studies show that for many types of plastics, combustion to create energy is more environmentally beneficial than recycling. It is further established that plastics are a vital component in helping burning municipal solid waste (MSW). In fact, without plastics in MSW, we would need to use valuable fossil fuels, as brought out by the calorific value of MSW without plastics in table 4.

**Table 4**



The environmental problems associated with the greater use of plastics in developing countries can be adequately taken care of by the development of a strong recycling industry. It has been found by various studies that plastic materials are more acceptable than traditional materials like paper, in terms of waste generation and associated energy consumption. It has been scientifically proved that plastics are eco-friendly materials, particularly when the product's life cycle approach, i.e., cradle to grave analysis, is considered. Recycling in India, though relegated to the unorganized sector, is so well planned that not much is left in disposal dumps to create such an environment problem as it is made to appear.

**Environmental education and awareness programme**

The trade and professional associations/institutes, of late have been concerned about the growth of plastics waste. Out of necessity and economic considerations, plastics waste continues to be collected, disposed and recycled, thereby supplementing the raw materials supply and also providing business and employment to rag-pickers/traders and reprocessors. However, not all plastics waste is recycled, the accumulation of plastics waste in dumps and landfills in and around residential and industrial localities in cities and towns is becoming a nuisance, and environment and eco-campaigns are launched by the public and NGOs in this connection. These campaigns very often question the usefulness of plastics. There is, therefore, a pressing need to make the various Government and municipal authorities, as well as the public, aware of the correct position about the usage of plastics and handling of its waste.

The Ministry of Environment and Forests, through its National Waste Management Council, and meetings and workshops on Solid Waste Management, have been focusing attention on this matter. The Building Materials and Technology Promotion Council (BMTPC) of the Ministry of Urban Development, New Delhi, has been involved in promoting plastics waste utilization in the development of volume applications for the building and construction industry in India. The Indian Plastics Institute, in association with the Federation of Indian Chamber of Commerce and Industry (New Delhi), organized an all-India Conference on "Plastics and the Environment" during September 1994 at New Delhi.

There are a number of NGOs in the country, which are very active in this direction. One NGO, based in Bangalore, has involved itself in promoting Solid Waste Management, and encouraging awareness programmes for recycling of plastics and other wastes, through schools, TV/poster/leaflets presenting information for the benefit of consumers and producers. Another NGO, based in Delhi, is involved in the welfare of rag-pickers responsible for collecting recyclables including plastics in the city. There has been a growing public appreciation of the need for regular "awareness" programmes to promote organized collection of plastics waste.

Environmentalists and regulatory authorities often hold plastic waste responsible for creating pollution, fire and health hazards in congested areas where the waste dumps/collection centres/dealers markets/reprocessing units are located in cities and towns. It is important to locate such activities in non-congested areas. Because of the size of the country and the scale of operations of plastics waste management at various levels, there is a pressing need for



an institutional setup to organize and promote plastics waste management, environmentally and technically, keeping in view the future growth of plastics industry in the country.

#### **Application of recycled plastics materials**

Unlike developed countries, recycled plastics in India find a wide range of applications. At present, the major uses are in manufacturing domestic/consumer products. This is due to the low cost of recycled materials, which coupled with low labour costs, keeps the costs of products low. The highest grade scrap is used for making good quality articles of both household and industrial use, such as buckets, mugs, pens, jerry cans, water pots known as "kodam", twines, footwear. Better quality scrap granules are also used by processors for blending with virgin material in order to reduce production costs without any appreciable change in the quality of finished products. Low quality scrap is generally converted into shopping bags, inexpensive moulded toys, pipes and bottles, containers and some household items. Recycled plastics have also begun to replace traditional packaging and natural materials, such as paper, cloth, jute, and leather, particularly for shopping bags and footwear. Many novel applications can be promoted with mixed plastics waste, like boat docks, outdoor furniture, car stoppers, farm structures, pallets, etc. Structural polystyrene in the form of synthetic wood substitute is commercially available. The applications are endless.

#### **Plastics recycling: Issues and future strategies**

The recycling of plastics, as is practised in India, though creating a considerable amount of employment and business, has raised some issues which need to be addressed urgently. These relate to improving the working conditions of the waste collectors, more scientific and technological inputs in reprocessing and identification of the right application for the recycled materials. The future strategy could include drawing up legislation to regulate the disposal of plastics waste, its reuse and recycling. The strategy would also include drawing up a code of practice relating to the use of recycled material.

The upgradation of the quality of the plastic processing industry should include providing new product designs and processes to optimize material consumption and to minimize material waste. Technology inputs also need to cover upgradation of recycled plastics by blending suitable other materials to form alloys, etc.

The upgraded technology for recycling of plastic waste also needs to keep in view environmental pollution, hazards and safety considerations. Optimal practices in this regard need to be disseminated.

Training institutions need to provide courses on quality recycling and waste management and other related issues. non-government organizations (NGOs) and other bodies could help in launching awareness programmes at various levels in the country.

Plastic waste by itself is neither polluting nor poses any health hazard. The problem that waste recycling comes across is regarding the contents packed in the plastic containers which have to be washed to obtain clean material for recycling. It is these contents and washings which pose environmental and other problems. Keeping this aspect in view, it is best to encourage the indigenous collection of waste and recycling. Cross-border movements

of plastics waste may pose problems due to the aforementioned environmental reasons and is therefore not desirable. In fact, voluntary restraints on cross border movement of plastics containing remnants of harmful material like pesticides, chemicals and other products is called for. (Source: *Popular Plastics & Packaging*, September 1995)

#### **Country experience: People's Republic of China**

The plastics industry in the People's Republic of China began to rise in 1958, with an average annual growth rate of 27 per cent. The output of synthetic resins was 1,905,000 tons while the annual production of plastics products reached 3,541,000 tons in 1988, and 5,368,210 tons in 1992. It was predicted that the production of plastic products would reach 8,000,000 tons by the year 2000.

With the rapid development of the plastics industry and the increasing expansion of its fields of applications, an ever-increasing discharge of plastics is realized. The recycling and utilization of plastics are, therefore, increasingly important.

Work has been done on the reclamation and re-use of plastics waste since the 1960s in China and considerable success has been achieved. In recent years great attention has been paid to recycling and utilization of plastics waste in China because of three factors as follows:

- (a) A short supply of domestic synthetic resins. In China, the total production of six synthetic resins (LDPE, HDPE, PP, PVC, PS and ABS) was 1,332,110 tons in 1987; 1,654,100 tons in 1988, and 2,243,500 tons in 1990,
- (b) Rise in the prices of synthetic resins and ingredients on a large scale,
- (c) Serious environmental pollution cause by waste recycling.

In 1984, the first monograph concerning recycling and utilization of waste plastics was published in China. In addition, there were a few reviews on waste plastics recycling. The technical reports and Chinese patents concerning the treatment and utilization of waste plastics have been gradually increased since 1987. Many experts in China have already made suggestions to the Government on strengthening of the development of "treatment techniques of plastics wastes" in the 8th Five-year Plan during 1991-1995. It is expected that the proportion of plastics waste recycling and re-utilization in China will be greatly increased, and treatment techniques will be considerably advanced, environmental pollution will be controlled effectively in the last decade of this century. Information concerning plastics waste is not readily available as yet due to lack of a functioning information system.

#### **Production and use of plastics in China**

##### *Volume of plastics production, importation*

Plastic can be used for several and different types of applications. In 1990 around 2,243,500 tons of plastics material were produced in China. A comparison with the plastics production and the consumption in China shows that the balance is negative; the difference comes from importation and the recovery of waste plastics (1,424,331 tons).

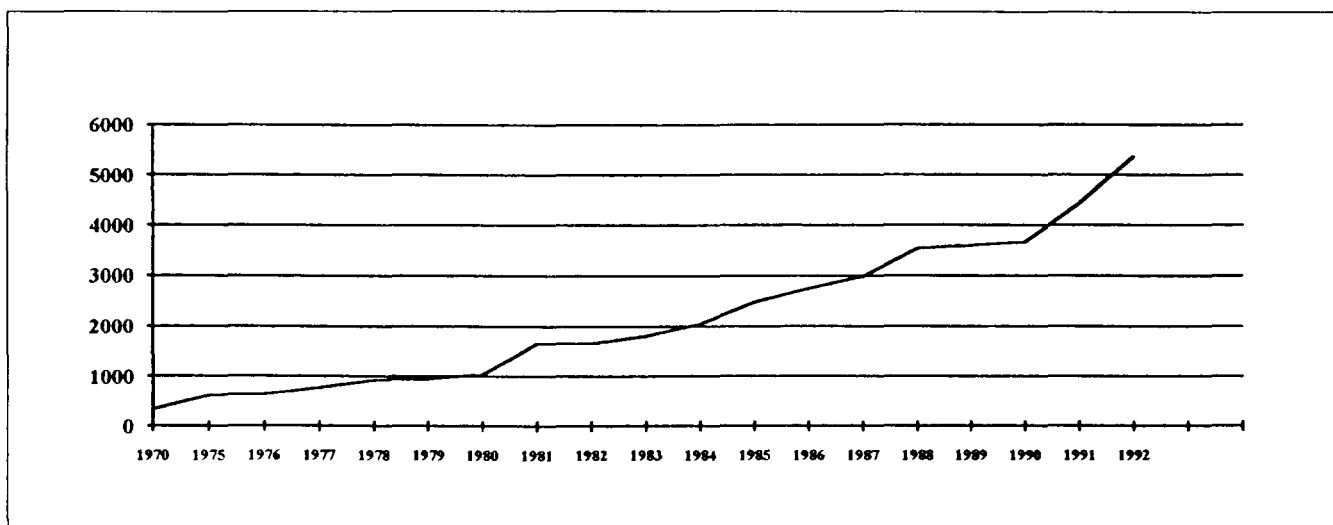
As shown in table 2, of all synthetic resins in China, PVC and PP will increase sharply. As a result, the amount of their recovery and utilization will undoubtedly rise greatly.

**Table 1. Plastics production and consumption in China.**

Years	Production tons	Importation tons	Consumption tons
1970	-	-	328,000
1975	332,000	275,000	607,000
1976	357,000	283,000	640,000
1977	527,000	242,000	769,000
1978	679,000	241,000	920,000
1979	793,000	155,000	948,000
1980	893,000	144,000	1,037,000
1981	915,000	745,000	1,660,000
1982	1,008,000	652,000	1,660,000
1983	1,120,000	690,000	1,810,000
1984	1,160,000	890,000	2,050,000
1985	1,230,000	1,250,000	2,480,000
1986	1,310,000	1,435,000	2,745,000
1987	1,527,000	1,451,000	2,978,000
1988	1,905,000	1,636,000	3,541,000
1989	-	-	-
1990	2,243,500	1,424,331	3,667,831
1991	-	-	4,434,751
1992	-	-	5,368,210

Source: The Technical Information Centre on Waste Material (December 1982)  
 Yang Chunbai, Zou Liying: Synthetic Resin and Plastic, No. 1,2 (1990)  
 Own assessment based on local interviews.

**Plastic Consumption x 000 tons**



**Main areas of end-uses for plastics**

Data on the product consumption patterns are scarce and dispersed. Due to their adaptability and their low manufacturing cost, plastics are used in China practically in all basic domains of applications (table 3). The main sectors for plastic consumption in China are: packaging, building and construction, electrical and electronics, automotive, other transportation, furniture, agriculture, toys, leisure, households, clothing, mechanical engineering, medical, and others.

The pattern of average consumption of plastics products in China is shown in table 3. A rapid development has been made in packaging materials and agricultural films and ground films in recent years. The consumption of packaging material constituted 17 per cent in 1980 and 26 per cent in 1988, which approached the level of developed countries. The total production of agricultural films from 1980 to 1988 was 2,500,000 tons, 700,000 tons of which are the production of ground films. The output of plastic shoes reached 600-700 million pairs. They all constitute a potential resource of recycled plastics.

The largest consumer of plastic is packaging. For the recycling of post-consumer plastics, short-lived plastics are primarily used. Mainly plastics in the fields of packaging and agriculture are considered as short-lived.

Different production techniques are used to produce these items. The main production techniques used in China are listed below:

*Extrusion process:* film bags netting, ropes, pelletized/recycled plastic products, pipes, profiles, sheets, wire and cables, woven sacks

*Moulding process:* (injection, blow, compression): household goods, industrial parts/products (e.g. crates), packaging containers (e.g. bottles), personal care products, toys and novelties.

*Specialty process:* adhesive tapes, calendar products, casting, dip coated products, laminated/coated/metallized products, office and school supplies, printed plastic products, vacuum formed products.

The local plastic processing industry is that sector which undertakes the transformation of the major thermo-plastic resins currently in use in the world (e.g. polyethylene, polypropylene, polyvinyl chloride and polystyrene) into various plastic products for both consumer and industrial applications. The plastic processing sector comprises over several thousands companies ranging from relatively large to small. The plastic waste which they produce is either recycled in line, or sold to recyclers. For some fabrication methods they use a percentage of recycled material from 10 per cent to 100 per cent depending on the product.

It should be pointed out that the recycling equipment and the quality of the recycled material cannot always meet the requirements of the processors. Indeed the equipment these processors use is generally out of date. Almost all machines have been manufactured by Chinese factories and the majority of the tools which are used have also been produced in China.

**Table 2. Production of main synthetic resins in China (tons)**

**Plastics resins produced**

Resins	PVC	PE	PP	PS	ABS	Total	Gross resin production
1981	371,500 40.6%	304,800 33.3%	100,700 11%	20,200 2.2%	11,000 1.2%	808,200 88.3%	915,000
1982	424,500 42.2%	307,100 30.5%	116,000 11.5%	24,500 2.4%	3,100 0.31%	875,200 86.8%	1,008,000
1983	481,600 43%	335,400 29.9%	119,700 10.7%	21,900 1.96%	2,400 0.21%	961,000 85.8%	1,120,000
1984	503,900 43.9%	337,000 29.1%	119,900 10.3%	25,800 2.21%	5,500 0.47%	992,100 85.5%	1,160,000
1985	507,800 41.3%	334,000 27.2%	132,200 10.7%	31,500 2.56%	11,300 0.92%	1,016,600 82.6%	1,230,000
1987	579,800 38.1%	515,300 33.7%	177,500 11.6%	34,200 2.24%	14,300 0.94%	1,321,100 86.5%	1,527,000
1988	638,400 33.5%	692,500 36.4%	267,800 14.1%	38,100 2%	17,300 0.91%	1,654,100 86.8%	1,905,000

*Note:* Numbers in this table do not include the import amounts of synthetic resins.

*Source:* Yang Chunbai, Zou Liying: Synthetic Resin and Plastic, No. 1,2 (1990).  
Li Huaxing, Plastics Sciences and Technology, No.5, 50 (1987)

Table 3. Pattern of average consumption of plastics products in China from 1987 to 1988

## Type of Product

	%	Typical products
Packaging	26	Films, womens bags, hollow containers, boxes, etc.
Agricultural	18	Agricultural and ground films, pipings, etc.
Household	28	Shoes, artificial leathers, etc.
Construction	4	Doors, windows, etc.
Industrial	17	Wires and cable, household electric appliances, electronic devices, etc.
Others	7	

Source: Cheng Haoming: Synthetic Resins and Plastics, No. 1,7 (1990)

Table 4. Classification of life spans and waste percentage of plastics products

	Production MT	Group 1 %	Group 2 %	Group 3 %	Group 4 %
LDPE	484,271	85	7	3	5
HDPE	618,160	30	42	25	3
LLDPE	321,900	88	10	2	0
PP	319,000	38	20	34	8
PVC	775,000	35	15	30	30
PS	33,500	40	25	35	0
ABS	87,200	2	13	65	20
Other thermo- plastic	592,800	2	30	60	8
Thermosets	436,000	10	15	50	25
Total	3,667,831				
Average per cent		36.63%	20.96%	31.59%	10.83%

Group 1: (1 to 2 years) disposable packaging materials, agricultural films and ground films, etc.

Group 2: (3 to 5 years) household goods, toys, etc.

Group 3: (6 to 9 years) turnaround boxes, automotive and electric appliances, etc.

Group 4: (over 10 years) piping, wire and cable, construction and furniture, etc.

Source: Xie Zhonglin: Paper, International Conference on Plastics Waste Recycling Technology, 1991

Statistical data concerning the applications, as well as a production profile of the plastic processing industry are not available. However, the data given below (table 5) are accurate, within an error margin of 20 per cent, and are only produced to assess the amount of waste recycled

material from the supply side.

The number of plastics processing enterprises in China are not easy to identify, because many enterprises are private businesses which only employ less than 3 employees.

Table 5. Split of the processed plastics

Plastic	Film	Fibre	Rigid	Other
LDPE	95	-	-	5
HDPE	10	-	80	10
PP	20	30	40	10
PS	10	-	60	30
PVC	10	-	50	40*

\* Flooring materials

Source: Own assessment based on local interviews.

### Economy of recycling and disposal of plastics waste in China

Disposal of waste and especially of useful plastic waste is a waste of expensive and non-renewable natural resources. Therefore, recycling is not only an environment protection programme, but also has an important economic and social impact on the performance of the national economy. Obviously, recycled materials will always have secondary applications, or will be used in combination with virgin materials (multi-layer products). However, recycling will increase the potential for the use of plastic materials in general as many countries are importing the majority of their virgin material. In many countries, producers of virgin materials which have an influence on standardization rules, have introduced limitations on the use of recycled materials. This discrimination is no longer acceptable and the use of recycled materials should be allowed according to the application and the development of new applications, especially for mixed plastics and should thus be supported by the Government.

### Cost elements of the plastics recycling

Recycling is an economically viable operation if the cost of the whole system operation is lower than the purchase of virgin material having adequate properties. The following operational costs are included in the final recycled material price:

- Collection, sorting, grinding, washing/cleaning,
- Drying, blending;
- Re-granulation.

Collection and sorting are independent operations; the remainder are included in a recycling installation, operated continuously, or semi-continuously.

The costs of collection and sorting depend on the individual plastics material, which is relevant to the local prices of the virgin material. It has been noted that, in general, prices of recycled granulate sold to the plastics processor are 60 per cent - 75 per cent of the virgin material local price. The operation of recycling of plastics must be economically viable because statistics show an import of scrap material from industrialized countries. Prices of the imported scrap differ, but it may be competitive to local recycling costs. This is due to the legislative and taxation measures taken by the Governments of industrialized countries; e.g. in Japan plastic scrap is available free of charge. The buyer has to bear the bailing and transportation costs. Recycling costs are highly

dependent on the origin of material (sorted, non-sorted) and the technology applied by recyclers.

The investment cost is much lower than in industrialized countries. The buildings as a rule, are old structures adapted from other applications. There is no heating or air conditioning system, electrical wiring is simple as well as the water circulation system. The grinding/washing equipment is second hand. Only the extruders are new, however these are simple machines produced in China, their price is 3-4 times lower than the respective European machines. The major deficiencies of these machines is their higher energy consumption, and low automation, which does not allow the reproduction of optimal processing parameters. (Source: *Survey on Management of Plastic Waste in Asian Countries*; Author: Vincent Sciascia, prepared for UNIDO, December 1994)

### Country experience: Malaysia

There are about 600 plastics processing factories in Malaysia involved with various types of production techniques such as injection moulding, blow moulding, film extrusion, lamination, thermoforming, pipe and profile extrusion, calendaring, rotational moulding and glass-reinforced plastics. The plastics and products are mainly used in the areas of engineering, building and construction, packaging electrical/electronics, automobiles, furniture, agriculture, toys, household goods, footwear, adhesives and coating.

The major type of plastics raw materials consumed are PVC, PE, PP, PS and polyester resins. Other plastics resins used are the whole range of general purpose and engineering grades of thermoplastics and thermosets. The total consumption of plastics raw materials was estimated to be 150,000 tons in 1988.

Polymerization plants are available in Malaysia for the production of PS, PVC, polyester and phenol formaldehyde (PF) resins, other plastics raw materials are all imported. Per capita consumption of plastics is estimated to be about 9.8 kg, which is low when compared with industrialized countries.

### Solid waste disposals

Disposal of solid waste in Malaysia is the responsibility of the Ministry of Local Government and Housing. In 1988, statistics showed that a total of some 1.2 million tons of solid waste were collected. The constituents of the solid waste were wood, metal, paper, glass, rubber and

leather, ceramics, plastics and a range of other organic waste. There are no official data on the breakdown of the solid waste components, but a sample analysis of some solid waste obtained in the state of Penang is listed in table 1.

The municipal solid waste collected were dumped in some 230 designated open-air dumping sites all over Malaysia. Of late, disposal of solid waste by land-fill method has also been introduced in the state of Selangor.

**Classification of plastics waste in Malaysia**

Plastic waste in Malaysia can generally be classified into five different groups. They are:

- Primary industrial waste
- Mixed consumer waste
- Well defined agricultural and industrial waste
- Long-life building and automotive waste
- Short-life applications waste

*Primary industrial waste*

The sources of raw materials for this plastics waste are:

- Resin production of PS and PVC, mainly reactor sludges and crusts; discarded products contaminated because of container breakages and laboratory testing waste.
- Granulated and primary processing, which supplies plastics raw materials coming from processing machinery cleaning operations, or from certain processing phases (such as resin or colour changes), as well as plastics that cannot be recycled during processing. This happens because the processor does not have any recycling plant, or due to the fact that the product being processed does not permit even the recovery of clean scrap.
- Secondary processing—scraps from mouldings, lamination, thermoforming and trimming processes are generated in this stage mainly from processing factories with no upward integration with a film or sheet extrusion line.

The plastics waste obtained from the above sources has a medium-to-good quality and a relatively homogeneous composition. The recovery of plastics from this category of industrial scrap is regarded as economically viable. There are at present about 10 to 15 companies in Malaysia involved with these recycling activities and the materials concerned are PE, PP and PVC.

*Mixed consumer waste*

These are plastics scrap from old and discarded consumer items such as household goods and appliances, toys, furniture, PVC sheets, diapers, packaging items, shoes, etc. This plastic scrap is always contaminated, and in order to recover and reclaim them, it is necessary to use more complex recycling machines and plants which feature a longer sequence of washing, separation and rinsing phases in combination with drying and granulating operations. These operations are therefore considered to be time-and energy-consuming and non-economical in terms of operation procedures, waste collection and separation problems. In Malaysia, there is no factory involved in this category of plastics waste recycling.

*Well defined industrial and agricultural waste*

Plastics waste in this category composes the following main groups:

*Industry:* sacks and drums from the chemical industry (mainly HDPE, PP, PVC); plastic containers and synthetic fibre scrap from the textile industry (polyamide and polyester), packaging boxes for bottle handling and transport; shrink film from the industrial and food industry; cable insulation sheaths (PVC and PE).

*Agriculture:* mulch film in plantations and farm areas, fertilizer sacks, nets and boxes.

All the above mentioned scrap represents an important resource for recycling. In fact, in Malaysia today, there are no less than 6 companies involved with the recycling of PVC cable insulation sheaths, plastics crates and containers and packaging films for conversion into recycled materials. These materials are then used for the processing of lower value-added products such as shoe soles, sandals, agricul-

**Table 1. Composition ratios of solid waste sample**

Type composition	Domestic waste	Commercial waste	Industrial waste
Paper	25%	28%	36%
Plastics	12%	10%	15%
Rubber/leather	3%	3%	4%
Wood	3%	11%	11%
Metal	2%	9%	2%
Glass	2%	9%	4%
Organic waste	49%	15%	18%
Others	4%	15%	10%

Source: Ministry of Local Government and Housing, Malaysia February 1988

tural, nursery and rubbish bags. However, it is important to note that these sources of plastics waste are sometimes highly polluted and mixed, which therefore requires more complex operations such as washing, cutting, densification, etc, for their appropriate regeneration. Sometimes incorporation of virgin resins and additives during the regranulation phase is necessary in order to obtain a reusable product in a granular form.

#### *Long life building and automotive waste*

Sources of plastics waste from Malaysian buildings are mainly water tanks (glass-reinforced polyester resin) pipes and fitting (PVC), electrical switches (thermo-setting resins), water cisterns (PP, PS) light diffuses (PS) and wall papers (PVC). Hitherto no sizeable reclaimed plastics are obtained from this source of plastics waste, possibly due to the small quantities of materials available at present. Various types of thermoplastics and thermosets are used as automotive components. However, most of these plastics parts are long-life and replaced only once after a period of a few years.

There are about 1.1 million vehicles (passenger cars, trucks, vans, buses, etc.) in Malaysia, assuming the lifetime of an average vehicle to be 10 years, each has approximately 50 kg of plastics-made components, then we can expect about 5,000 tons of plastics waste from the automotive sector per year. Nevertheless, most of this plastics waste is not reclaimed. One noticeable exception is the battery casing which is made from PP. In Malaysia, there are 3 to 5 companies dealing exclusively with the recycling of these battery cases. Statistics show that some 1,500 tons of virgin PP materials are consumed every year for the manufacture of new battery casings for automobiles. Therefore, it can be estimated that possibly about 1,500 to 2,000 tons of PP are recycled from old and used battery cases annually. The recycled PP granules are used for other lower value-added injection products such as household goods, hangers, boxes and containers.

#### *Short-life application waste*

Plastics products classified under this category include consumer packaging items and disposables such as shopping bags, food box wrappers, bottles and containers (PET and PVC), disposable food trays and drinking cups (EPS, PVC, PP), egg cartons (PVC, EPS) etc. Hitherto, no appreciable level of plastics reclaim activities have embarked on this source of plastic waste in Malaysia. It is predicted that between 40 per cent to 60 per cent of plastics waste components from municipal solid waste are derived from the above-mentioned products. In Malaysia, the PET packaging for cooking oil and beverages is a new industry. Annual consumption of PET resin is about 1,300 tons, there is still no PET recycling in the country.

#### **Recovery and recycling of plastics from municipal solid waste (MSW)**

As mentioned earlier, the total amount of MSW in Malaysia is about 1.2 million tons per annum. It is estimated that the average plastics waste constitutes about 3 per cent to 5 per cent of the MSW throughout the country. Since the use of plastics is increasing, this composition ratio is predicted to rise appreciably in the near future to about 7 per cent. So far, no attempts have been made by the public and private sectors for the recovery and regeneration of the recyclable plastics included in the MSW. In order to reduce the amount of plastics waste, it is essential that plastics must be separated

(possibly before their collection) from the stream of organic and wet waste in order to prevent any kind of unnecessary pollution from homogeneous and recyclable groups. (Source: *Survey on Management of Plastic Waste in Asian Countries*; Author: Vincent Sciascia, Prepared for UNIDO, December 1994)

#### **Technology to reduce environmental pollutants (biodegradable plastics) in Japan**

##### **Objective:**

The goal is to develop biodegradable plastic materials, which are decomposed by micro-organisms in the environment (soil) until they become no longer hostile to the natural ecosystem. Such materials will make human life compatible with the natural ecosystem.

##### **Project items:**

1. Searching for micro-organisms producing plastics-like polymers; improving physical properties; and researching and developing growth technology for higher yields cultivation.
2. R&D of a process using polysaccharides to synthesize and process biodegradable plastics.
3. R&D of molecular design and controlled polymerization technologies for biodegradable polymers having excellent properties.

(Source: *Jetro*, November 1995)

#### **Saudi recycling**

The Government of Saudi Arabia has started feasibility studies for solid waste and plastics recycling complexes in Jeddah and Riyadh, respectively, that will cost a combined R 520 million (US\$ 138 million). The R 300-million Riyadh unit will have capacity for 500,000 m.t./year, while the R 220-million Jeddah complex will process 250,000 m.t./year. Both complexes will include a plant to separate mixed domestic waste; a plastics recycling unit with a planned capacity of 25,000 m.t./year; a compost plant; power generation units; and wastewater treatment facilities. The Ministry of Municipality and Rural Affairs hopes to start the complexes in 1996 and double capacity in 1998. (Source: *Chemical Week*, 13 September 1995)

#### **International status of plastics recycling**

Post-consumer plastics recycling in the US is expected to double from about 680,000t in 1994 to over 1.4Mt in the year 2000. Advances in recycling will be based on improved technologies, expanded collection networks and legislation on recycling rates and use of recycled products.

Polyethylene terephthalate (PET) and high density polyethylene (HDPE) will continue to be the two most recycled resins, together accounting for 80 per cent of all plastics recycled. Other plastics will experience increased recycling rates over the next decade as automatic sorting technologies and the expansion of plastic coding are developed.

Price fluctuations for virgin and recycled resins, and difficulties in maintaining product quality, present a threat to further advances in recycling. The lack of industry standards and controls on prices and quality of reclaimed resin grades is also a major factor inhibiting the growth of the plastics recycling industry.

*Companies.* There are about 400 companies involved in plastics recycling in the US, ranging from major resin suppliers to a large number of small producers. Most companies specialize in the recycling of one or two resins.

The PET segment of the plastic recycling industry is heavily concentrated. Four companies account for over 70 per cent of recycled PET capacity.

The recycled HDPE segment is fragmented, with the top six companies accounting for 35 per cent of total capacity.

*Countries.* International activity in plastics recycling encompasses about 1,000 European, 400 US and a limited number of Japanese recyclers. European recycling rates for post-consumer plastics are estimated at less than 10 per cent. This contrasts with a rate of less than 5 per cent in the US. Sources of recycled plastics in Europe are industrial packaging, consumer products and the agricultural, construction and motor industries. European recycling rates have been hindered by a lack of uniform recycling laws, which makes it difficult for processors and equipment manufacturers to comply with the various country, state and local regulations.

Germany, Italy, France, the Benelux countries and the UK are leading European plastics recyclers. Germany has made the most progress in plastics recycling because of its tough packaging laws. The country emphasizes "closed-loop" recycling of waste from the electronic, construction, motor and other industries—that is, producing the same products from which the recyclate came, for example, bottles are recycled into bottles. However, the cost of recycled plastics in Germany is high compared with virgin resins; this is threatening plastics' competitiveness in many markets.

European goals for recovering plastics are likely to be achieved only through a combination of mechanical (the melting of reclaimed resins to make new plastics products) and chemical recycling (reducing plastics waste to a feedstock). Chemical recycling is not as expensive as mechanical recycling, but not as economical as using waste plastics as feedstock.

Asian nations currently have low plastics recycling rates. In Japan, post-consumer plastic recycling rates are about 2 per cent; incineration is a major method of disposing of plastics waste because of the limited land space available. Japan has set a goal of 50 per cent recycling rate for PET from soft drink bottles, but an

inadequate collection infrastructure makes this unlikely. The country recycles 40 per cent of its polyvinyl chloride film under a subsidized system. However, this method is threatened by exorbitant recovery costs of \$43/lb compared with a sales price of \$28/lb.

Other countries have established recycling programmes to varying degrees. For example, the Canadian Industry Product Stewardship plan in Canada has established a 50 per cent packaging recovery goal for the year 2000. The recycling infrastructure under this programme will be funded by a levy on packagers.

*Outlook.* Although differences exist in the focus of plastics recycling in various countries, industrialized countries share much in common. For example, the amount of plastics used and recycled is increasing and the market is growing, with virgin resin companies becoming more involved. Increasing volumes of recovered plastics will be recycled or converted into fuels and chemicals, with landfills and incineration (for energy recovery) used as a last resort.

Expanding the post-consumer plastics collection network will remain a top priority, as further advances will be contingent on setting up a dependable supply of materials and steady markets for recycled products. Legislation will also be a driving force in the initial stages. Technological advances in sorting and processing (such as depolymerization) will improve recycling efficiency and make the price of recycled plastics more competitive with that of virgin materials. This will offset the differences in quality and processing that are inherent when using recycled resins.

As experience is gained on the learning curve, recycling will become more profitable and gradually integrated into the economic mainstream. Increased recycling of engineered resins like polycarbonate and nylon from scrapped motor vehicles, for example, is anticipated. Car manufacturers are investigating designs that can be easily disassembled to aid recycling. Companies that are likely to succeed in the plastics recycling market are those able to leapfrog obstacles, adapt to changing technologies, innovate when necessary and develop viable niche markets. (Source: *Chemistry & Industry*, 18 December 1995)



## C. NEWS FROM RESEARCH AND DEVELOPMENT CENTRES AND COMPANIES

### **Recycling plans scrapped as estimates drop**

BASF has shelved plans for a DM 300 million feedstock recycling plant in Germany after it was revealed that there will not be enough plastic waste to supply it.

The Duales System Deutschland (DSD), which collects waste plastic in Germany, originally thought up to 750,000 t of waste would be available for recycling, with more than half earmarked for feedstock recycling.

The DSD now expects just 580,000 t per annum of waste to be available for mechanical and feedstock recycling. BASF had offered to halve the capacity of its planned plant, but there were doubts about the commercial viability of such a plant, particularly in the face of stiff competition.

Cheaper and simpler feedstock recycling opportunities were offered by the power generator RWE, a coal-to-oil plant at Bottrop and in the furnaces of the steel company Bremer Stahlwerke. The DSD has now placed contracts with these.

BASF says it could build an industrial scale plant in the future, but this is thought to be unlikely. The pilot plant, however, will keep operating for the next few years to safeguard the technology. (Source: *Process Engineering*, September 1995)

### **Two big resin producers commit to biodegradables**

After some hesitancy, two of Germany's biggest polymer manufacturers are planning to test the waters with biodegradable plastics at K'95 in Dusseldorf, Germany. Spurred by government regulations limiting landfills but promoting composting, both BASF and Bayer now see chances of making money with such polymers, at least in the European market.

#### *Film grades yield strength, elongation*

BASF has developed a copolyester, for which it has filed a patent, consisting of aliphatic diols, aliphatic and aromatic dicarboxylic acids. By incorporating hydrophilic components, monomers with branching effect, and compounds that produce chain lengthening to increase molecular-weight yield, biodegradable materials can be produced for applications including films with elasticity, good ultimate strength, and high percentage of elongation at break.

The company, which sees potential sales of up to 200,000 tons/year, is also promoting blends of its yet unnamed copolyester and starch.

Bayer, in Leverkusen, is taking a different tack in overcoming the disadvantages of such resins. Company researchers are focusing on developing polyesteramide grades with properties similar to polyethylene. Raw materials for the polymer are taken from caprolactam, adipic acid, and several diols such as 1,4-butanediol.

By varying the production process, Bayer developed materials with melt points of 120° to 180°C, and crystallization rates that can be tailored from fast to none. The resin has 40 wt.% of ester and 60 wt.% of amide structures. The company says transfer into large industrial scale production has been successful. ASTM-controlled composting tests (B 5338-92) show the product is biologically degradable within 10 days. Stability under processing conditions is up to 300° C, while degradation into biomass,

CO<sub>2</sub> and water occurs when water, oxygen, enzymes and temperature act together during composting. (Source: *Modern Plastics International*, September 1995)

### **Mechanical recycling of plastics, German study**

A life cycle assessment of various plastic packaging recovery options in Germany has found that plastics recycling is not necessarily superior to types of recovery in which plastics waste is used as a reducing agent in iron smelters or converted back into petrochemical products.

Commissioned by the German packaging recovery organization, Duales System Deutschland (DSD), the German plastics and chemical industry associations, and the Association of Plastics Manufacturers in Europe (APME), the study concludes that mechanical recycling, feedstock recycling and energy recovery processes all have specific advantages and that any one of these options might be the most environmentally sound, depending on the circumstances. Use of plastics waste as a substitute for fuel oil in iron smelters ranks particularly high. DSD argues that this type of recovery should be considered recycling rather than incineration, since the waste is utilized for its chemical characteristics rather than its calorific value. Feedstock recycling (conversion into petrochemical products) also does well in the study, even though chemicals giant BASF has abandoned plans to expand its feedstock recycling facility after it became clear that DSD would collect less plastics waste than originally expected. Mechanical recycling, the study finds, is appropriate in cases where the post-consumer material can be used as a 1:1 substitute for virgin plastics, but should not be preferred in principle.

The head of the German environment ministry's waste department said the ministry's yet-to-be-finalized review of Germany's 1991 packaging decree envisioned a mix of mechanical recycling, feedstock recycling, and energy recovery for plastics waste where each of the three options would ultimately account for approximately one third of the material. The findings of the study supported that aim. The German plastics industry association rejected the idea of quotas, arguing that environmental and market conditions should be allowed to create the optimal recovery mix. Environmentalists and the recycling industry criticized the study for deliberately underrating the environmental benefits and growth potential of mechanical recycling. (Source: *Environment Watch: Western Europe*, 29 September 1995)

### **Norwegian Government, industry conclude packaging recycling agreement**

The Norwegian environment ministry has concluded an agreement with industry on establishing recycling schemes for five specific packaging materials. Under the agreement, the government commits itself to setting up return systems during 1996 to facilitate the collection of used packaging. In return, industry agrees to achieve the following targets during 1999:

- Total plastics: 30 per cent would be recycled, while 50 per cent would go to incineration with energy recovery.
- Polystyrene: 60 per cent would be recycled, of which a minimum of 50 per cent would have to be used in the type of packaging product it had come from.

- Metal: 60 per cent would have to be recycled into the same type of product.
- Cardboard: 60 per cent would be recovered, with a minimum recycling rate of 50 per cent. The remainder could go to incineration with energy recovery.
- Brown paper: 80 per cent would be recovered, 65 per cent of which would have to be recycled. The remainder could be used as fuel.

Norway already has return systems for glass, corrugated paper and beverage cartons. (Source: *Environment Watch: Western Europe*, 29 September 1995)

**EMC/Polyphenix in PET recycling pilot**

EMC and Polyphenix of France are to build a pilot plant for chemical recycling of PET, using the *Recypet* technology for which patents are held by Jacques Benzaria of Technochim and the Institut Française du Pétrole (IFP). The plant will be partly financed by Eco-Emballages, the French polymer recycling organization.

The three-stage process, which produces PTA and ethylene glycol, has been approved by Eco-Emballages for waste recycling. The pilot facility will start up at the beginning of 1996 and results are expected to be ready by September of that year. (Source: *European Chemical News*, 23-29 October 1995)

**100 tons/year pilot plant for manufacturing biodegradable plastics using polylactic acid**

Shimadzu Corp. Kyoto, Japan began to develop a new business based on lactic acid fermentation about 10 years ago. The company experimentally produced various kinds of products, established technology to manufacture biodegradable plastics from polylactic acid with a bench-scale plant of 500 g/l lot, and in 1994 constructed a pilot plant with a production capability of 100 tons/year.

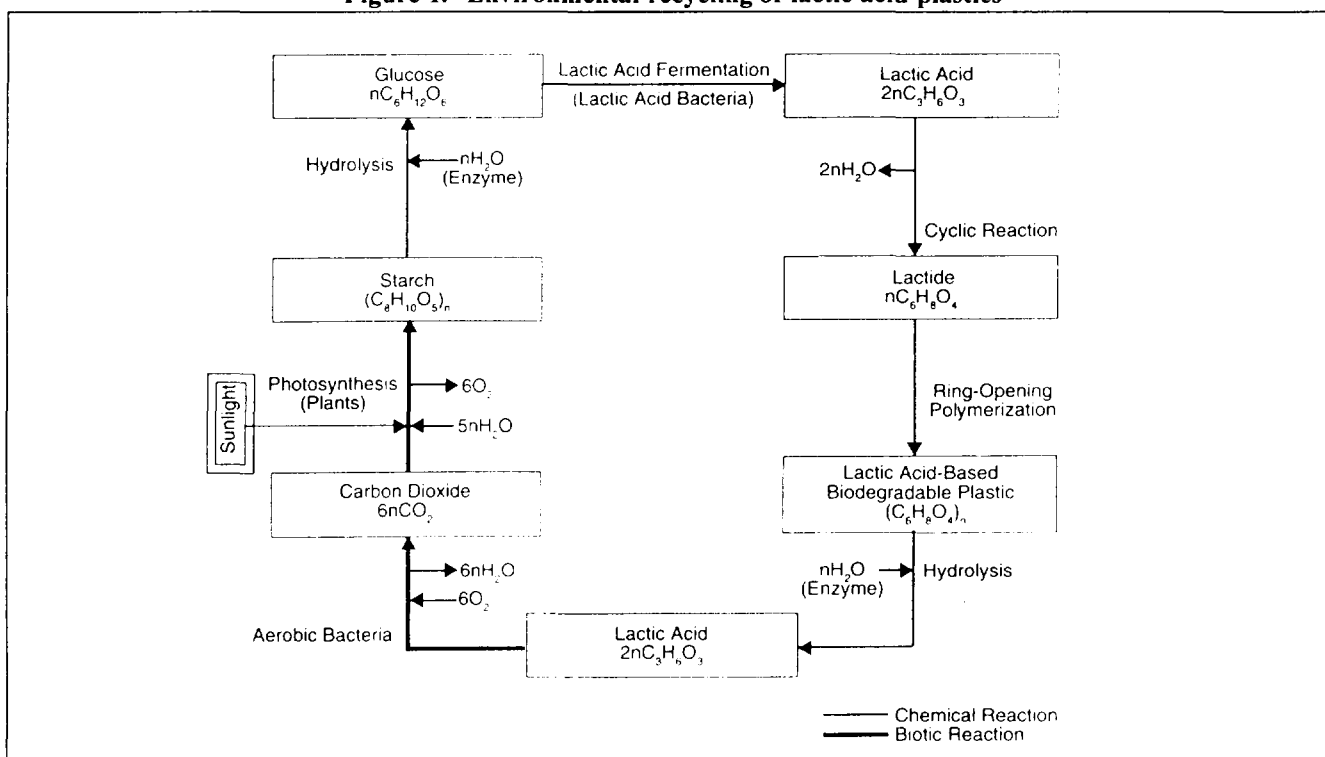
Ever since commissioning into service, this pilot plant has operated very smoothly without the various problems usually associated with initial-stage plant operation, and attained its target objectives successfully. At present, various process data and operational know-how are being collected with the aim of increasing the plant scale to the commercial level of 5,000-10,000 tons/year. This is one of the few pilot plants with a production capacity as large as 100 tons/year in the world.

The biodegradable plastics manufactured by this pilot plant have already been applied to manufacturing various products, several of which are sold as moulded products.

Most biodegradable plastics available today derive from fatty acid polyesters. These plastics utilize the ease of decomposition (biodegradation, hydrolysis degradation) of fatty acid ester bonds in the natural environment, but another vital matter that prompts the use of aliphatic polyesters is that the physical characteristics of these materials very closely resemble those of present plastic materials (or plastic resin) in the area of mouldability (thermoplasticity).

Lactic acid is an organic acid that is used widely in the field of food processing. It is a bifunctional substance possessing hydroxyl and carboxylic groups which are polymerized by an intermolecular dehydration condensation reaction. Polymer materials consisting primarily of lactic acid are a type of polyester known since the 1930s. The bonding of other fatty acids, as with the bonding of other fatty acid esters, is degraded in the natural environment and reduced to lactic acid. Further, in soil, the bonding is decomposed into carbon dioxide and water by the metabolic reaction of microbes, then reduced into the original lactic acid by plant photosynthesis and lactic acid fermentation by action of solar energy.

**Figure 1. Environmental recycling of lactic acid plastics**



The distinct characteristic of lactic acid-based materials is that they are derived from fermented lactic acid obtained as a glucose that can be regenerated in the natural environment, so the material is not only gentle to the environment but also can conserve finite fossil resources which have been used for manufacturing plastic products.

In addition, lactic acid has a chiral centre, and its main chains enable films and fibres to be formed with polymer materials featuring excellent rigidity and crystallinity containing a chiral centre in regular distribution, so the structures and physical characteristics of these films and fibres can be controlled and modified in the processes of elongation and thermal processing.

A pilot plant was constructed in July 1994. The main plant equipment consists of the raw material tank, solvent tank, solvent recovery tank, reactor, crystallization tank and centrifugal separator, dryers, and a polymerizer is provided between the system for converting lactide into pellets.

The L-lactic acid used as the raw material by this pilot plant is procured from outside sources, from which L-lactic acid oligomer is first produced. Usually, L-lactic acid polymerization is performed by the direct dehydration condensation reaction method or the lactic acid cyclic-dimer (lactide) synthesis method, then processing the cyclic-dimers by ring-opening polymerization. The Shimadzu process adopts the ring-opening polymerization method, which enables the molecular weight to be controlled from several tens of thousands to about half a million by changing the type and density of the polymerization-inhibition agents such as alcohol, and since this method enables the degradability and mouldability to be controlled by the type of

cyclic lactone such as caprolactone and by copolymerization.

The raw material lactic acid is L-lactic acid of over 98 per cent optical purity. The L-lactic acid is pumped by pipes from the raw material tank to the reactor accommodated at the top of the plant for producing LL-lactide, after which the solvent is recovered and the process advanced to crystallization by the process to crystallization. The crystallized LL-lactide is fed into the polymerizer to produce poly-L-lactic acid and the pelletizing system where it is heated and the strands drawn out from fine holes, then passed through water for solidification, after which it is cut into small plastic pellets with cutters.

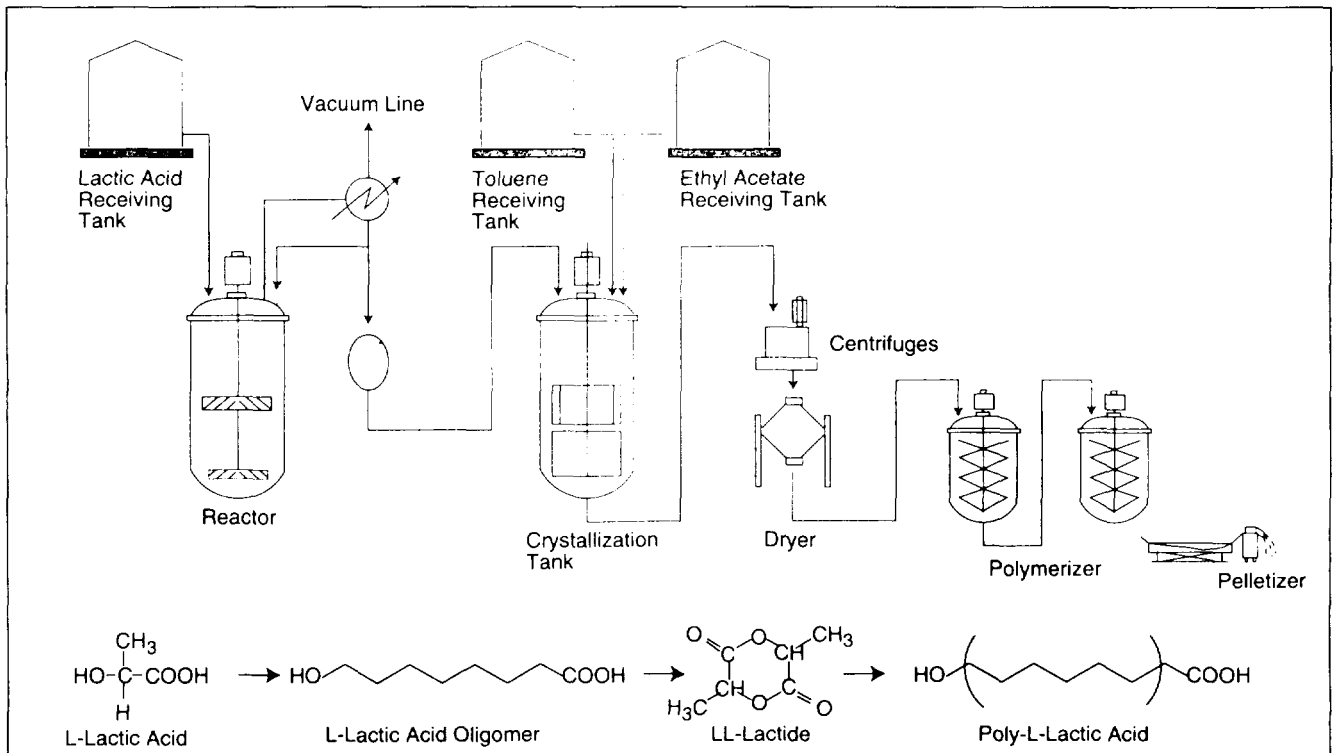
The company calls the manufactured plastic pellets (resin) "Lacty". This resin has a melting point of over 170° C and features the highest quality among aliphatic polyester resins. The moulding temperature and thermal decomposition starting temperature are close together, making temperature control at moulding vital. However, polylactic acid has a thermoplastic property that is quite similar to general-purpose resins such as PET and polystyrene, so it can be worked with existing moulding equipment.

According to the company's experiments, this resin features the following characteristics:

**(1) Mechanical Characteristics**

- (a) Tensile strength of 5-20 kgf/mm<sup>2</sup> that is several times stronger than that of polystyrene.
- (b) Elongation of up to 3.5 times.
- (c) Young's modulus of 200-400 kgf/mm<sup>2</sup> that is double compared with hardened polyvinyl chloride (PVC).

**Figure 2. Flowsheet of biodegradable plastic manufacturing process**



## (2) Transparency

The transparency is comparable to that of polyethylene terephthalate (PET).

## (3) Mouldability

The resin is workable with general-purpose moulding machines, and is especially ideal for injection moulding.

## (4) Other characteristics

The resin has excellent moisture- and oil-vaporization properties and can be given heat-sealing treatment, and displays a better gas-sealing property than polyolefins such as polyethylene.

The company used this resin to experimentally mould various kinds of products. For example, a biaxially rolled film has a light permeability of over 94 per cent, a tensile strength several times that of polyethylene film, an elasticity comparable to that of PET, and there is hardly any dimensional change even at temperatures of up to 100° C. Therefore, the film features an excellent heat-sealing property, and is ideal for coating printed labels. The coating paper given heat-sealing treatment, in particular, features an excellent lustre moisture- and oil-vaporization property, and when collected as waste, can be recycled with ease through alkali decomposition, or converted into regenerated paper with ease.

The resin is also suitable for readily high-speed molten spinning, and the filament features not only excellent tensile strength and knot strength, but can also be dyed and spun into yarn, woven cloth and non-woven cloth in the same manner as ordinary fibres. In addition, the resin can be used for producing transparent containers and blisters by vacuum moulding and pneumatic moulding.

This new plastic material is biodegradable in a natural environment. Chemically, the hydrolysis of ester bonds proceeds predominantly in the initial stage of polylactic acid decomposition, by which the molecular weight is reduced from  $10^5$  to less than  $10^4$ . The glass transition point and crystallization point are also lowered, crystallization primarily of spherical crystals proceeds in the soil, and the transparent plastic material is whitened. The material starts losing strength from this stage. Further, the surface area is increased, hydrolysis proceeds, and the material is degraded into lactic acid. This degradation process will differ with the conditions, but the company's new plastic material was confirmed to undergo decomposition in 3-6 months, and eventually reduced to lactic acid in 6-12 months.

Analysis is presently in progress on the safety of the intermediate substances generated during the degradation process, but so far no problem has been observed. For further information, contact: Shimadzu Corporation Advertising and Public Relations Dept.; 1. Nishinokyo-Kuwabara-cho, Nakagyo-ku; Kyoto 603. Tel.: +81-75-823-1110. Fax: +81-75-811-3188 (Source: *JETRO*, November 1995)

## **Recycling research facility identifies types of plastics**

A research centre in which new technologies are developed for the identification and recycling of plastics has been opened in Berkeley, Calif., by the American Plastics Council of the Society of the Plastics Industry Inc., Washington, D.C., in partnership with MBA Polymers Inc., also in Berkeley. A primary goal is to improve the quality and reduce the costs of recycling. The facility focuses on

three main areas of durable plastics recycling: technologies for identification, methods for separation, and processes for removal of paint and coatings.

To assist in identification, the APC centre uses an infrared system from Bruker Instruments Inc., Billerica, Mass. Called P/ID 28, the equipment has been modified to distinguish between 23 different plastics. In this system, infrared light from the instrument strikes the sample and is reflected back to a sensor, which correlates the unique reflected pattern with a specific chemical composition within five seconds. Unlike other instruments previously evaluated, this system can reportedly identify black-coloured plastics as well as those of other colours, and requires minimal sample preparation time.

The process is used to recycle plastics from automobiles, computers, business machines, and appliances.

For more information: American Plastics Council, 1275 K Street NW, Suite 400, Washington, DC 20005; Tel.: 202/371-5319; Fax: 202/371-5679. (Source: *Advanced Materials & Processes*, December 1995)

## **Hitachi Metals develops burner reactor for plastics that removes hazardous materials**

Hitachi Metals, Ltd. has developed an incinerator to be used exclusively for plastics. Plastics are first passed through a crusher and broken into pieces smaller than a certain size, and these pieces are fed to the incinerator for combustion at 1,000° C. Currently, the largest incinerator can process four tons per day. The new incinerator is capable of producing the complete combustion of plastics, which otherwise tend to burn incompletely, by air control. In the secondary combustion chamber of the incinerator, toxic components of the exhaust are decomposed for high efficiency.

Combustion takes place in two stages in this incinerator. Plastics have the tendency of not completely burning due to the lack of oxygen caused by the violent combustion of plastics. In order to prevent incomplete combustion, an air inlet is installed for each block of the primary combustion chamber to control the air flow to each block, and air can also be supplied to the entire hearth. In addition, crushed plastic pieces are continuously fed to the incinerator to maintain uniform combustion. The exhaust from the primary chamber is sent to the secondary chamber for decomposition.

The operation data indicate that both combustion temperature and oxygen concentration in the exhaust were maintained at stable levels. Not only does the incinerator emit black smoke, but it also drastically reduces the level of carbon monoxide, to well below the level specified in the dioxin guidelines of the Ministry of Health and Welfare issued to municipal waste incineration facilities.

Plastics are lightweight, nonperishable, and readily moulded, so they are used in wide-ranging fields. However, they tend to generate black smoke and toxic gases during incineration, and in some cases, tend to damage incinerators. Therefore, many plastics have been regarded as unsuitable for incineration because of these problems. The disposal of these plastics has become a serious issue, as it has become extremely difficult to find landfill sites. Although there have been other plastics-exclusive incinerators that gasify plastics prior to incineration, Hitachi Metals' incinerator is unique in that combustion takes place at the high temperature of 1,000° C. (Source: *Tokyo Kikkan Kogyo Shimbun*, 17 May 1995, p. 15)

**Plastics Recycling Centre at Tennessee Technological University: R&D, education and Business Programmes**

A Centre for Plastics Recycling is being established at Tennessee Technological University (TTU) within the College of Engineering as a joint effort of the Department of Chemical Engineering and the Centre for Manufacturing Research and Technology Utilization. The mission of the Plastics Recycling Centre is to implement multidisciplinary research, development, demonstration and technology transfer activities thereby improving the quality of human life by resolving some serious environmental problems through recycling plastics wastes into useful consumer products. Support for the Centre is expected from those who will most directly benefit from its activities.

The Centre is one of the major components of the new and rapidly expanding polymer science and engineering programme at TTU. Technical activities for the Centre include several long-term fundamental and applied packages: (1) fundamental and applied research on plastics recycling processes and related equipment development with a main focus on the unique Solid State Shear Pulverization (SSSP) process to produce very fine powder from thermoplastic and thermosetting plastics wastes for feed material for new or improved products; (2) develop environmentally friendly processes for use of SSSP powders as fillers and/or reinforcing agents in production of advanced foamed and solid plastics and composites, concretes or ceramics for specialized applications; (3) develop a family of lightweight foamed composites and/or structures based on thermoplastic wastes recycled through combined remelting and foaming processes; (4) develop families of solid and foamed "plastic waste-wood waste" composites.

**Mission Statement:**

- To develop multi-disciplinary R&D and educational programs in the area of plastics recycling, to resolve some serious environmental problems related to the disposal of solid plastics waste and to improve the quality of human life.

*Industrial/business goals:*

- In partnership with both Tennessee and Federal environmental institutions and agencies, and with industrial companies, to identify, address and develop the most challenging short-term and long-term economic and environmental needs in plastics recycling.
- The results of our R&D developments will transfer into practical commercial processes, materials and end-products to make a significant impact on local economic development.

*Educational goals:*

- To integrate environmental consciousness into all facets of the TTU curriculum resulting in environmental literacy for undergraduate and graduate students.
- The development of the environmentally oriented polymer/plastics recycling educational programmes at several degree levels.
- Through our foreign students, to transfer the knowledge and experience in the area of plastics recycling

and environmentally friendly processes and materials to many other countries throughout the world.

**Scope of the Programmes:**

*1. Recycling of plastics wastes:*

Development of New Manufacturing processes and Materials:

- Solid-state shear pulverization (SSSP) process: Development of lab-scale single screw extrusion technique and scaling up of pilot-scale equipment.
- SSSP of thermoplastics waste (PET, PE, PP, PVC, PC), thermosetting waste (polyurethane, phenolic,
- Reinforced foamed and solid plastics filled with SSSP powder,
- Concrete and ceramics materials filled with SSSP powders,
- Foamed plastics based on thermoplastics waste (PET, PE, PP, PVC, PC) and their mixtures: porous plastics lumber, boards and profiles,
- Solid and Porous "artificial wood" based on mixtures of 'plastic wastewood waste (sawdust)';
- Foamed and filled asphaltens: bitumen and coal derivatives mixed with theroplastics and thermosetting waste.

*2. Biodegradable polymeric materials:*

Development of new manufacturing processes and materials

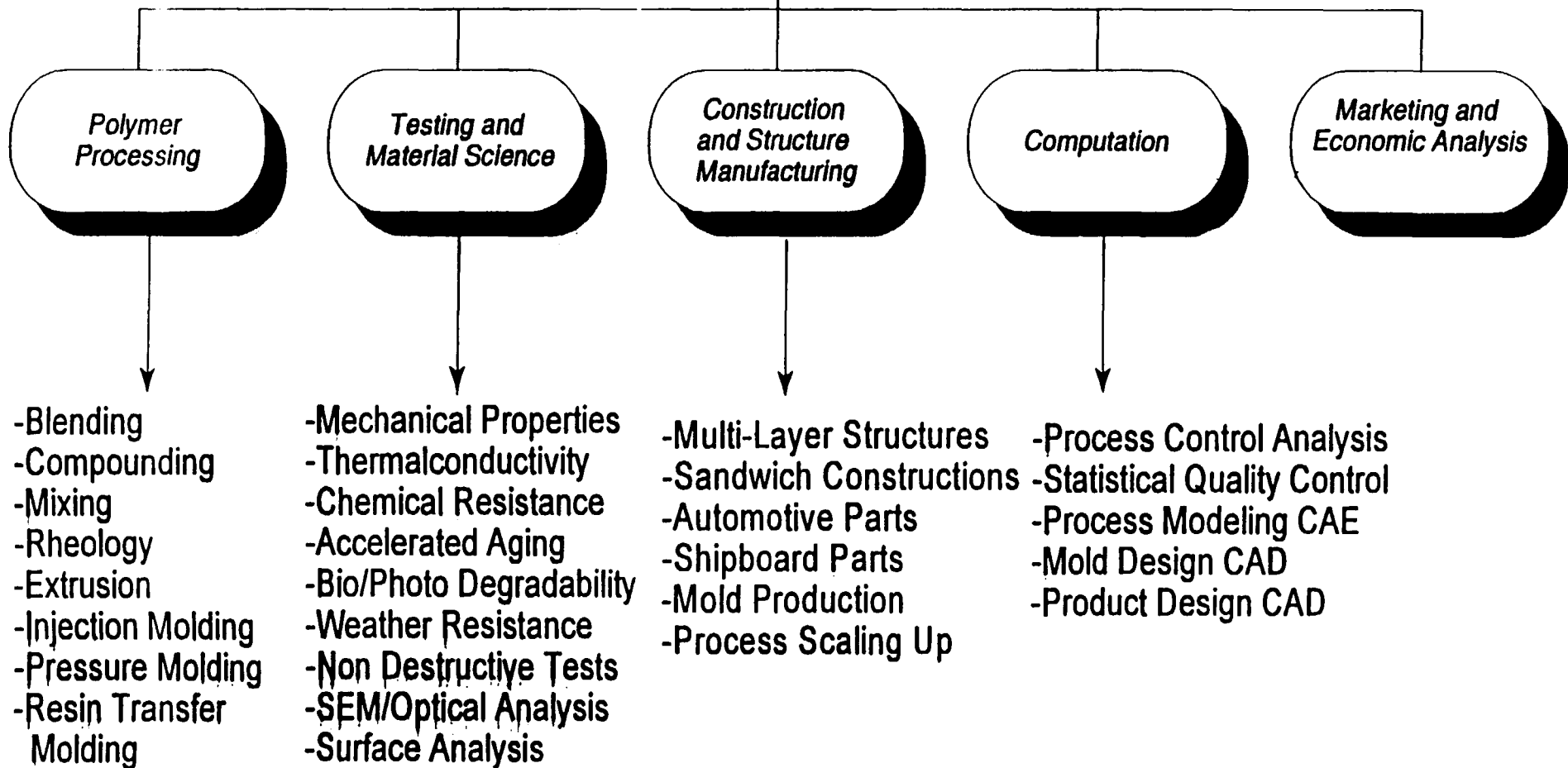
- Solid and foamed materials based on natural biodegradable agro-waste (hulls of wheat, soya, rice, corn, etc.) with natural biodegradable binders.
- Solid and foamed materials based on natural biodegradable fibres (cellulose, jute, hemp, kenaf, etc.) with natural biodegradable binders.
- Foamed packaging materials based on commercial synthetic biodegradable polymers: copolyesters, cellulose acetate, polylactic acid, etc.
- Solid and foamed commercial synthetic biodegradable polymers filled with natural biodegradable fillers (hulls and fibres).
- Additives (powders and fibres) based on commercial synthetic biodegradable polymers.
- Solid and foamed synthetic plastics filled with biodegradable synthetic additives.

*3. Foamed polymers and light-weight structures:*

Development of new manufacturing processes and materials

- PET foams with environmentally friendly chemical blowing agents, approved by EPA and FDA for direct food contact.
- Thermosetting foamed composites, reinforced or filled with polymer fibres or powders based on virgin polymers (PET, PE, PP, Engineering resins), or with powder produced from plastics waste (see section 1).
- Structural/integral foamed PET and engineering resins.
- Foamed and filled cellulose-based resins.
- Laminated foamed structures.
- Multi-layer foamed/solid plastics structures and constructions.
- Syntactic foams based on PET binder and hollow microspheres.
- Foamed thermoplastic fibres (PET, HDPE, LDPE, PP).

**STRUCTURE  
of  
Polymer Engineering/Plastics Recycling  
R&D and Education Programs**



## D. POTENTIAL MARKET FOR RECYCLED PLASTIC

### **Additive makers vie for reclaimed resin markets**

As more and more manufacturers of consumer and durable goods move to add recycled plastics to their products, the demand for additives able to restore resin properties lost by processing and use has reached a new high. As a result, additive suppliers have stepped up their marketing efforts in the recycle sector.

Companies are following very different approaches, however. Most of them are offering the same grades of additives for recycled and virgin resins, but one major company has been marketing a line of additives geared expressly for recycle. The reasons additive suppliers give for these divergent strategies shed light on how they perceive the present and future of plastics recycling.

Despite the recent wave of activity, recycled resins — along with the additives that go into them — are largely viewed as a niche market. Additives intended for upgrading post-consumer polymers tend to be used on a specialty basis by processors to meet their individual needs.

The perceived specialty nature of the recycled resins business is the primary reason why the majority of additive suppliers have not launched many products targeted exclusively at this sector. Instead, they stress the cost benefits available to recycle processors who use their additives manufactured for mass-market virgin resins.

In order to justify a separate line of additives expressly for recycle, companies would have to see that there are different technical requirements for such products.

However, there are several characteristics of recycled resins, particularly those from mixed-waste sources, that set them apart from virgin resins and justify the creation of separate products.

No matter how much recyclers try to separate post-consumer resins at their source, contamination is inevitable. For example most post-consumer polyolefins contain trace quantities of PVC, which can seriously degrade performance of the recovered plastics in processing and in finished products. Further most PP from automotive battery cases contains trace impurities from the battery chemicals, which also hamper resin performance in new products. Simply adding extra amounts of conventional polyolefin additives to stabilize these recovered polymers is not always effective, because of the special nature of the contaminants.

The widespread belief that the volumes of recycled plastics are not high enough to warrant special additives is also questioned.

Despite an ample supply of waste plastics in the pipeline, however, quantities of high-quality recovered resins ready for further processing are tight. This has made recycle more expensive than virgin resins in many cases.

The inadequate number of facilities for cleaning, grinding and repelletizing used plastics is a bottleneck. Because of short supplies and high prices of recycle some end-users, particularly people who produce bottles for packaging consumer products, have quietly backed off their timetables for steadily increasing their use of post-consumer resins. But additive suppliers selling into the recycle market need not worry, because overall there is a trend towards more recycling, not less.

How much the boom in recycling will translate into increased sales for additives is hard to estimate. One reason

is that most recycled plastics are used in lower-value or less demanding applications during their second lifetimes. For these less demanding uses, it may not be necessary to add extra additives to recycle. At a minimum, it is recommended that fabricators try to use recycled resins that match as closely as possible the processing and performance properties of virgin resins used for the same applications. Often, achieving this goal requires adding at least some extra antioxidants to recycled thermoplastics that have been oxidatively degraded by previous thermal processing.

Even when second-hand resins are "downcycled" into cheaper items, the additives they may require run the entire gamut of additive products. The most common classes of chemicals used to boost recycle properties are heat and light stabilizers, impact modifiers, compatibilizers, and flame retardants. Compounders and processors also frequently add pigments to recycled plastics to impart new colours.

Heat and light stabilizers top the list of compounds most often used to upgrade recycled resins. One reason is that stabilizers tend to be decomposed or dissolved during cleaning, drying, compounding and other operations that accompany resin reprocessing. In addition, earlier thermal processing of the resins leads to formation of reactive species such as hydroperoxides, carbonyl groups, or unsaturated bonds that can induce reactions that impair melt-flow properties or mechanical performance of polymers.

Ciba-Geigy has the most extensive slate of products intended to "restabilize" used resins. The entries, marketed under the company's Recyclostab line, are intended exclusively for recycle. They sell for prices equivalent to virgin resin stabilizers.

Among the grades of Recyclostab are 411, an antioxidant designed for recycled high-density polyethylene (HDPE) and mixed polyolefin wastes. Ciba is also offering Recyclostab grade 421, an antioxidant formulation intended primarily for reclaimed low-density polyethylene (LDPE) films. One of the newest Recyclostab entries, grade 441, is a stabilizer of proprietary composition targeted at recovered PET, primarily originating in soft-drink bottles.

Meanwhile, France's Rhone-Poulenc, Paris, sees important recycling applications of its Rhodiastab stabilizer for PVC. The system is a calcium/zinc formulation with long-chain beta-dike-tone costabilizers. These added synergists boost the effectiveness of the calcium-zinc stabilizers so that they can match the performance of older lead-based PVC stabilizers, which are being phased out in Europe for environmental reasons.

Another company involved with products to stabilize reclaimed PVC is Akros Chemicals, Eccles, UK. The company says it is developing a calcium-zinc system with added synergists to stabilize PVC recovered from such sources as window profiles and flooring.

Impact modifiers for recycle represent another primary market for additives. One company that has a major presence in this sector is GE, which recommends two of its impact modifiers, Blendex 338 and Blendex 360, for improving the impact properties of recycled ABS, SAN and PVC.

The products are being used by researchers at the US Department of Energy's Argonne National Laboratory, Argonne, IL, in an experimental programme to recover and

reuse ABS from the interior liners of refrigerators. While the Argonne effort has recovered ABS from the refrigerators in about 99 per cent purity, slight contamination of the ABS—chiefly by high-impact polystyrene—makes it unacceptable for reuse. The GE additives have been used to restore the impact properties of the recycled ABS to near-virgin levels.

Dexco Polymers, Houston, TX, USA, a partnership between Dow and Exxon, is offering its Vector SBS line of styrenic block copolymers as performance enhancers for recycled polystyrene, polyethylene, and commingled polyolefin streams. The additives, which are prepared from styrene and butadiene monomers, are particularly useful in upgrading mixtures of high-impact polystyrene and crystal polystyrene.

Suppliers are also investigating new compatibilizers for recycle. BASF researchers, for instance, are looking at an unidentified polymeric additive that can compatibilize mixtures of polystyrene with polyethylene or polypropylene, and ABS with polypropylene. The main advantage of the product, which is in the R&D stage, is that it could allow some mixed-waste plastic streams to be usable without the need to separate the components. (Extracted from: *Modern Plastics International*, February 1996)

### **Housing may be built from scrap in low-pressure process**

A house built out of panels injection moulded in scrap plastic was the centrepiece of injection machine builder Hettinga Technologies' stand at K'95. The company says the panels are a significant alternative to plywood, pressboard and other wood-based materials.

The controlled-density moulding (CDM) process used to make the panels accommodates a range of plastics, including mixed industrial- and post-consumer scrap. Hettinga, Des Moines, IA, USA, has licensed it to processors in Europe and the US.

Panels have a thin, smooth outer skin around an integral core foamed *in situ*. Unlike wood, they resist rot and mildew. They have the handling characteristics of pine, and hold nails and screws like hardwood. The cost of production is said to be around 60 per cent that of plywood.

CDM panels are made by injecting the melt, which incorporates a dissolved blowing agent, into a closed mould at a pressure high enough to stop gas coming out of the solution. Once a skin has formed on the part, the mould opens, internal pressure falls, the blowing agent gasifies, and the part expands to fill the increased space. Decorative finishes can be applied in the mould. Ultimate densities depend on part design and material, but the company says the lowest density achieved is 0.28 g/cm<sup>3</sup>, with polypropylene.

The company says the key to the technology is the use of its proprietary low-pressure injection moulding that enables all types of polymer in a mix to be fully plasticated without degrading. One licensee uses Hettinga's self-clamping mould with 5000 kN clamp force to make panels 1.2 by 2.4 m, with thickness variable between 5 and 20 mm. To optimize appearance and mechanical properties, the mould is filled using a "cascade" system: a hot-runner system injects melt through up to eight gates, the opening and closing of which is carried out sequentially to prevent formation of large weld lines. (Source: *Modern Plastics International*, September 1995)

### **Recycling Automotive Seats**

Managing the automobile's life-cycle has become a major issue among industry and government groups in North America and Europe. This requires practical and economically viable methods for recovery and recycling car parts.

US and Canadian automotive seat manufacturers consumed about 240 million lb of prime polyurethane foam in 1994. By using a regrind process, scrap foam can be turned into a powder to make new polyurethane foam seating with comparable performance to virgin seating. Assuming the powder recycle could be incorporated at a 10 per cent loading, a demand would exist for about 27 million lb.

The recycling community could easily meet this demand. Assuming 80 per cent of the nine million vehicles scrapped each year end up at dismantling sites, and a 35 per cent seat foam recovery rate, there is a potential polyurethane supply of approximately 50 million lb/year. A typical vehicle contains about 20 lb of polyurethane seating foam.

The first step for seat recycling could come at auto dismantlers where the foam would be removed from seats. This critical process significantly affects the economics of recycling. An experiment by the Polyurethane Recycle and Recovery Council recovered foam from 1,000 dismantled seats. Each seat yielded an average 5.3 lb of foam. But because of insert-wire contamination, about 3.9 lb, or 74 per cent, was reusable foam. Other studies indicate that when dismantlers concentrated on foam recovery efficiency, 80 to 90 per cent of the original seat foam comes out in 3 to 4 minutes.

Once removed from the seat, foam chunks are mechanically reduced to a powder feedstock. In the process, foam chunks are first cut into 0.5 to 3 in. pieces using conventional knife cutters. This ensures an optimum feedstock charge to the next stage and reduces labour-intensive handling of randomly sized foam chunks. The process would also detect and remove metal at this stage.

The next stage, the two-roll mill, is the central element of this entire recycling scheme. Conveyors carry cut foam crumbs to the two-roll mill. Counter-rotating rollers run at a 3:1 to 4:1 speed differential to shear foam crumbs into a powder which drops through a screen separator. Particles under 150 µm go into a box, bag or silo storage, while larger particles are conveyed pneumatically or mechanically back onto the roll mill.

Powder bulk density is about 0.3 g/cm<sup>3</sup>. The mill produces a realistic 100 to 150 µm "first pass" yield of 20 to 25 per cent for high-resilience foam. On this basis, a two-roll mill should deliver 400 to 800 lb/hr of finished powder. A final stage introduces the powder recycle into the seat-production process. Conveyors bring the powder into a hopper fitted with a feed auger where it is metered into a conventional blend tank containing polyol and additives. From the tank, pumps move the powder-polyol blend into a production area ready for processing.

An economic analysis of the process includes the cost of recovering scrap foam at the dismantling stage, as well as the cost of purchasing, operating, and maintaining the equipment to process the foam into a powder. Economic analysis also considers investment in the polyurethane chemical metering equipment modifications. Dismantling seats and recovering the foam is the most critical factor in the cost of polyurethane powder recycle. This cost can



represent one half to two thirds of the cost of finished powder.

Consequently, seat design becomes the key to seat dismantling and recovery economics. To increase foam recovery efficiency and lower costs, designers should find trim covering that comes off easily and use trim wire more sparingly. (Source: *Machine Design*, 23 February 1995)

### **Plastic soft drink bottles recycled for auto seat backs**

Polyethylene terephthalate (PET) fibres from recycled plastic soft-drink bottles are reportedly being used in pads for automotive seat backs and cushions by Johnson Controls Inc., Plastic Containe Div., Manchester, MI. According to the company, the PET seat pads are recyclable and lighter in weight than the polyurethane foam pads now typically used in auto seats. They also are said to offer more breathability, and can be moulded into a wider variety of densities for a range of seating applications.

The company claims to have developed a new process in which heat and low pressure compress the fibres into seat pads having an improved high-temperature durability, comfort and material requirements. It reportedly uses no adhesives and contains no hazardous chemicals.

For more information: Doug Scik, Plastic Container Div., Johnson Controls, 912 City Rd., Manchester, MI 48158 USA; fax: 313/428-8887. (Source: *Advanced Materials & Processes*, December 1995)

### **Recycled beverage containers used for clothing**

Insulation for outdoor apparel may be the next big market for recycled plastic. EcoTherm, a blanket-like thermal lining made from over 50 per cent post-consumer recycled plastic beverage containers, is now reaching consumers. Among its first uses is in skiwear, and other kinds of outdoor apparel, including gloves, footwear and sleeping bags.

The material was developed by architectural insulation supplier Schuller International Inc., Littleton, CO, and has been licensed to Lortex Inc. for marketing and manufacturing.

EcoTherm thermal performance and cost are competitive with similar products. The insulation, offered in "outdoor green", is a spin-off from the development of fibreglass insulation for buildings, a material which contains about 30 per cent recycled product. The key to the good insulation performance is the use of extremely small-diameter fibres. The company modified the process for making fibreglass to spin fibres out of a variety of different kinds of plastics — polyester, polypropylene, polycarbonate and others.

The small-diameter fibres are about 20 times smaller than a human hair. They effectively limit heat loss by allowing the material to trap air in small pockets. Similarly, this helps present an effective barrier to heat waves radiating from the body. (Source: *Machine Design*, 23 March 1995)

### **Recyclers of appliances, durables looking to Germany's proposals**

As the number of discarded appliances and other durables grows, so too does the pressure to collect and recycle them. Companies are reacting with pilot projects and studies which show that the engineering plastics used in them can be effectively recovered and reused.

The pressure is particularly strong in Germany, where a government directive to make this the responsibility of

manufacturers is expected to go into force in late 1996. Regulatory agencies around the world view the directive as a possible model.

Two key issues in the debate are the methods of collection and whether recycling costs will be assessed at the point of sale or at disposal. The German Federal Ministry of the Environment says it is imperative that a national regulation be passed to ensure that companies which voluntarily invest in recovery and recycling schemes are not at a disadvantage.

Most companies say the high-value engineering resins in appliances can be mechanically recovered and reused with virgin resins in blends that show little or no significant degradation in structural or processing characteristics.

The results of a study showed that much of the thermoplastics recovered could be reused in similar applications. Based on this finding, the Hüls subsidiary HM Gesellschaft für Wertstoff-Recycling has established a 2000 ton recycling plant in Frankfurt for appliances (and small car parts).

In the study, vacuum cleaners, kitchen appliances, hair dryers and irons were collected in public disposal bins. The only labour-intensive input required was segregation of the appliances by category and the manual removal of components containing hazardous materials. The units were ground and the various materials automatically separated by a mechanical technique that segregates resins by type.

A little more than 25 per cent of the weight of the vacuum cleaners—the majority of the collected appliances—was recovered as more than 99% pure ABS.

Almost a third of the weight of discarded coffee machines was recovered as polypropylene with purity greater than 99%. The material also exhibits excellent property retention.

In Japan, Hitachi Ltd., Tokyo, is working on a liquid nitrogen-based cooling technique to embrittle, pulverize and automatically sort materials found in appliances and other equipment.

Most appliance and electronic equipment manufacturers are also developing the technology to recover and reuse materials in products they sell. Typically, they strive to reduce the variety of resins used; simplify disassembly; eliminate coatings, labels, and inserts; avoid halogenated additives; and identify plastics with markings. Refurbishment and repair are priorities.

One company recycling equipment is Siemens Nixdorf Informationssysteme (SNI), Munich, Germany. Consumers dispose of equipment made by the company at service shops in Germany. Products range from computers and peripherals to automatic teller machines. An average fee of \$30 per unit is charged.

The equipment is sent to the company's recycling centre in Paderborn, Germany. Units are manually disassembled and their components sorted by material. For units whose parts have no identification markings, IR spectroscopy confirms composition.

The recovered housings, made primarily from PC/ABS blends, are ground and shipped to resin-maker Bayer AG, Leverkusen, Germany. The recyclate is blended with the company's virgin Bayblend PC/ABS resin at a ratio of 3:1 virgin-to-recyclate. This is used by SNI to mould equipment housings. The company says that the material exhibits no property degradation compared to all-virgin material.

Similar results are reported by Philips, Hamburg, Germany, and AT&T, Princeton, NJ, USA. In a study by

the former, non-flame-retardant PS from TV sets was used to injection mould housings. The company concluded that there was no significant reduction in the material's properties.

AT&T ships equipment collected at service depots in the US to a recycling centre in Chicago, IL. Housings, primarily ABS, are ground and sent to compounders for blending with virgin, usually at a ratio of 3:1 virgin-to-recyclate. Blends are sold on the market with a quality rating comparable to virgin grades. (Source: *Modern Plastics International*, March 1995)

### **Round-up of applications for recycled plastics**

#### **Agriculture:**

- Pig slats (slatted floors for pig-sties)
- Fruit tree supports
- Ranch fences
- Vine stakes
- Gates
- Duck boards
- Electric cattle fences

#### **Marine engineering:**

- Boat docking
- Dock-side fender
- Groynes
- Coast erosion protection

#### **Civil engineering:**

- Road delineators
- Barriers
- Fences

#### **Packaging industry:**

- Pallets
- Protecting profiles

#### **Gardening and horticulture:**

- Gates
- Enclosures
- Garden furniture

#### **Playgrounds/Sport grounds:**

- Fences
- Benches and seats
- General equipment (climbers, swings, etc.)

#### **Extrusion line:**

- Sub-frame profiles with co-extrusion
- Cable tray and cover
- Boards
- Plant stakes

#### **Separated plastic (LDPE,HDPE,PP):**

- Shopping bags
- Garbage bags
- Film for packing
- Film for building use
- Film for agricultural use
- Film for industrial use
- Injection material
- Moulding material
- Material for waterproofing use
- Oleoduct pipes wrapping material
- Base material for master

(Source: *Survey on Management of Plastic Waste in Asian Countries*, Author: Vincent Scrascia, prepared for UNIDO, December 1994)

## E. REGULATIONS AND STANDARDIZATION

### **The changing regulatory environment**

As landfill capacity in many industrialized countries has decreased and incineration continues to receive a bad press, legislation to reduce the quantity of waste and to encourage reuse and recycling has proliferated. Protection of the environment is like motherhood and apple pie—no one is against it—but industry is concerned that measures are being adopted without a full consideration and understanding of their environmental and commercial implications.

This chapter highlights some of the main waste disposal legislation initiatives of recent years. In the process certain trends and implications for plastics producers, processors and end-users are identified. A fuller discussion of the advantages and disadvantages of various methods of plastics waste disposal is conducted in following chapters.

The following points should be noted:

- Some Governments (e.g. Canada and Netherlands) have negotiated voluntary agreements with key sectors. This more flexible approach enables industry to choose the most appropriate method to reach the agreed targets. Underlying such agreements is the serious threat that the failure to observe and reach the agreed targets will result in the introduction of legislation.
- The majority of waste disposal legislative initiatives to date have been directed at packaging waste. Packaging is highly visible and has a short life-span. Increasingly, however, legislative attention will turn towards other sectors such as the automobile industry, household goods and electrical and electronic equipment. This is already happening in Germany and Denmark.
- The main thrust of waste disposal legislation to date has been directed towards encouragement of recycling. Other methods of waste disposal are not favoured. Incineration with energy recovery, in particular, is not regarded favourably in some countries despite being preferred in others with good environmental reputations. As the problems of placing all the environmental eggs in the recycling basket become apparent, governments will need to adopt a more balanced approach to the whole question.

### **Consequence of the industrialized countries' legislation on developing countries**

Industrialized countries have created a multitude of various packaging waste handling systems during the past few years. In principle they all set the same requirements for both domestic and imported packaging. Looking at the European situation from the point of view of an exporter e.g. to China, Philippines, Thailand or Malaysia, it seems that a fairly large group of nations in a small area have several different sets of rules. Now this exporter is wondering how many different sets of packages, markings or contracts does he need to be able to export the same product to Germany, France, The Netherlands and Belgium. In theory, the importers in these countries should take care of the contracts, and give the exporters information and instructions on the acceptability of various packaging materials, on the printing of the "Green Dot", the colour for plastic packaging. In practice, quite a few of the importers do not do this.

### *Some consequences of recycling schemes*

Asian textile exporters traditionally use jute as packaging material. Jute is a renewable, indigenous, natural material. However, two years ago, German importers of textiles informed Asian producers that, as recycling is mandatory in Germany and as they do not have a system for recycling jute, exporters should replace jute by woven polypropylene, because there was a recycling system for this material. Later, this situation changed and jute is allowed again.

Exporters of frozen shrimps mainly use waxed cartons for packaging. From France's Eco-Emballages, they could get the "Green Dot", as France allows incineration. France and Germany mutually accept each other's "Green Dots". However, Germany does not accept incineration and waxing is undesirable in the recycling process. As a consequence, the exporter could not export directly to Germany, only via France.

Exporters of electronic equipment use expanded polystyrene for the protection of their equipment. German recyclers have announced that the formed blocks have to be white. However, the protection of the equipment requires that the EPS be treated with an agent that makes it antistatic. At the same time this agent dyes the EPS reddish and thus it becomes unacceptable. In many countries, no alternative cushioning material is produced.

In some cases, packaging material, which would be more economical in the recycling systems of Europe, has to be imported by developing countries, which increase their costs. Already now, the packaging costs for enterprises in developing countries are relatively much higher than for companies in industrialized countries. This is due to the fact that a lot of the packaging materials, or the raw materials for packaging, have to be imported—mainly from industrialized countries. If the waste handling systems in industrialized countries further increase their packaging costs, it may greatly influence the competitiveness of the exporters in developing countries.

### *General problems caused by schemes in industrialized countries*

Many developing countries are in the process of creating their own packaging waste collecting and recycling systems. In fact, developing countries have for a long time been recycling a lot more than industrialized countries, not for environmental reasons but out of necessity. In countries like China, India and Malaysia, collection of glass, plastic or corrugated board is the source of livelihood for a lot of families. It has been economically feasible, because it replaced the need for imported raw materials. It has basically not been organized by any "umbrella" organization or by the Government.

Now some countries are planning a systematic collection and recycling of used packaging according to their own needs. This is made more difficult by the efforts of Europeans to spread the "Green Dot" system to developing countries. The marketing of the "Green Dot" has included some unsound features, such as giving it the image of being an eco-label, whether intentionally or not.

European waste handling systems and policies have received wide publicity in the media all over the world. From the European viewpoint, it is important to discuss

these matters for the obvious reasons that some countries in Europe are producing a lot of waste and have little space for landfills. However, when all this is quoted and underlined in developing countries, the results are sometimes unsound; many countries have started to copy the discussion on packaging waste although their problem is not packaging waste but the wastage of food, and other products, due to the lack or inadequacy of packaging.

#### *Future issues*

The mandatory and voluntary recycling systems in industrialized countries are in reality creating new barriers to trade with developing countries. There are too many different sets of rules. From the viewpoint of developing countries it would be desirable if:

- Usually, directly copying any waste handling systems from one country to another has proven to be a costly mistake;
- Industrialized countries would help developing countries to create environmental policies and eco-packaging schemes suitable to their conditions;
- The European Union could agree on common rules for treating packaging waste. One set of rules and one set of markings would help.
- Industrialized countries would inform exporters in developing countries accurately about their requirements;
- Industrialized countries would understand the difficulties that exporters in developing countries are facing in relation to the availability and costs of packaging materials.

#### **Policy instruments for waste management**

There are a number of policy instruments which a government can employ to control waste. The more commonly used, each of which poses different problems for industry, include:

- Recycling targets: this approach has proved most popular with many governments but the targets, especially for plastics materials which currently have lower recycling levels than most other materials, are often set at levels which are unrealistically high and within impossibly tight time-frames. As experience shows, account also needs to be taken of a country's recycling capacity and the availability of markets for recycled goods;
- Reusability targets;
- Targets for the percentage of recyclate in new products;
- Procurement policies which favour recyclable products or products with recycled content: such policies are commonly used to assist the creation of markets for recycled products;
- Mandatory deposit schemes to promote reusable containers: these schemes yield high recovery rates;
- Bans on certain materials; PVC bans have been popular in Europe where incineration of plastic waste is widely used. Polystyrene has attracted greater antagonism in North America;
- Mandating of degradable products in certain applications: this instrument has been widely used in the USA in relation to six-pack ring holders. However, this particular instrument is only appropriate for certain niche applications;
- Taxes on certain materials or products: taxes have been used in several European countries, and to some effect—the European Commission estimated that the

Italian tax on plastic bags resulted in a 40 per cent fall in the consumption of these bags;

- Material and recyclability labelling: commonly to facilitate recycling.

The accumulation of such legislation has important implications for the plastics industry and its end-users. The requirements for recycling affect the choice of material and product design, while direct bans have obvious consequences for producers of that material and impose additional costs on industry.

The proliferation of legislation also creates potential trade barriers. Companies subject to tough legislation in their domestic market may find their cost higher than those of their rivals in major export markets. Companies trying to penetrate those markets with higher environmental standards will need to develop different products for different markets, again increasing cost and rendering products uncompetitive.

#### *The EC packaging directive*

In 1992, the European Commission approved and published a draft directive on packaging waste (Com 92 278) in line with its overall waste management strategy. The Commission decided to act because it noted that:

- Only 18 per cent of the 50 million tons of packaging waste generated within the EC each year was recycled;
- The proliferation of national measures was in danger of fragmenting the single market and of distorting trade within the EC market. In the summer of 1993, the European Economic Area (EEA) came into being, effectively extending many of the provisions of the single market to the member States of the European Free Trade Area (with the exception of Switzerland which voted against the EEA in a referendum). Any new barriers would therefore have an even greater distorting effect.

The main provisions of the draft packaging waste directive can be summarized as follows:

- All packaging, including secondary packaging and packaging for transport, is to be included within the scope of the directive;
- 90 per cent of the weight of packaging waste is to be recovered and 60 per cent of the weight of each material in the waste is to be recovered and 60 per cent in the waste stream is to be recycled within 10 years of the directive coming into force. Incineration can be considered for a possible 30 per cent which is recovered, but not recycled. Final disposal will be 10 per cent of the weight of output. The targets will be reviewed within six years of implementation.
- Member States have five years in which to implement the directive in national law and to ensure that the necessary return and management systems are established;
- Within five years, all packaging will carry approved, harmonized labels, which show the recyclability and the nature of materials used. Harmonized markings are considered necessary to avoid trade barriers;
- Packaging will have to conform to "essential requirements" before it can be used within the EC. These aim to ensure that the weight and volume of packaging is minimized; that it can be reused easily; and that the presence of noxious metals and other hazardous chemicals is minimized;
- Databases will be established to inform consumers about packaging;

- Economic instruments (i.e., taxes) may be used to raise funds to support national plans.

The draft directive acknowledges the complexity of waste management issues and allows for changes in the preferences given to various techniques if the life cycle analysis, still in its early stages, shows existing assumptions to be misplaced.

The Commission also acknowledges the different situations of member States in terms of the composition of their waste stream, and of their abilities to deal with different disposal methods. The overall objective of the directive is to make general national provisions for recovery and recycling. Within this harmonization framework, member States will be able to develop their own strategies to reach the targets.

The directive does not have an explicit hierarchy of disposal methods, although it does accord the prime position to recycling. By implication, however, energy recovery by incineration will be allowed, a factor which is opposed by some member States.

Although the need to harmonize regulations on environmental and trade grounds is recognized, there have been major disagreements about the content of the legislation, and lobbying has been heavy. The following changes are being urged by various interested parties:

- Greater emphasis on source reduction;
- Greater emphasis on reuse;
- A hierarchy of priorities: Belgium, Denmark, Germany and the Netherlands, supported by the European Parliament and Economic and Social Committee, want the inclusion of a specific hierarchy of waste disposal methods. Significantly, this is opposed by countries wholly dependent on landfill like Ireland, or which accept incineration, like the UK and Italy, or with financial problems in meeting the targets, like Greece and Portugal;
- The removal of incineration as a form of recovery;
- Greater flexibility in relation to targets. Poorer States believe they should be given more time to achieve the directive's objectives. Greece and Ireland, in particular, have raised the question of the financial hardships involved;
- Reduction of recycling targets. Some countries, including the UK, believe the recycling targets are excessive and fail to take into account different waste management facilities throughout the EC;
- Ireland and UK oppose the idea of one target for all materials and favour individual targets for each material;
- Germany and other member States with well-developed commitments to recycling want the EC to set minimum targets but want to retain the right to set stiffer targets domestically. This position gives rise to fears of trade distortion.

The packaging waste directive was approved by the European Commission in July 1992. This is only the first stage in getting the directive approved in EC law. The Vertamati Report (from the Environment Committee of the European Parliament) was published in June 1993 and proposed 95 amendments to the directive, including the possibility of banning halogenated compounds, including PVC, throughout the EC, and of stipulating minimum recycle content for packaging material. Amendments were also designed to permit member States to introduce or protect existing national measures which exceed those in the Commission's draft. Agreement at the Council of Ministers level is a long way off.

The World Packaging Organization has also expressed concern that tougher EC packaging laws will create problems for developing countries which export to Europe. The lack of technology, finance and even information about their obligations, will make it very difficult for them to fulfil the provisions of the directive. In other words, as far as many non-EC countries are concerned, this particular legislation will effectively act as a new trade barrier.

#### *Australia*

In 1992, the national and federal governments, together with representatives of the plastics industry, worked out a National Recycling Plan which established recycling targets to be achieved by 1995 for major types of rigid and semi-rigid packaging. Targets included 10 per cent for polystyrene consumable; 15 per cent for rigid polypropylene containers; 15 per cent for PVC soft drink bottles; 30 per cent for PET bottles and 50 per cent for HDPE bottles. Consideration of recycling targets for flexible plastic packaging is under way.

This scheme is voluntary and has enabled industry to respond to the environmental demands of packaging in a flexible way. Only the State of South Australia has introduced a compulsory deposit scheme: this has resulted in the recycling and reuse of over 80 per cent of such containers in the state. South Australia has also decided to give a price preference of 5 per cent for a limited period of time to the purchase of recycled goods. This policy is intended to help create markets for recycled products, a problem which has hampered many well-intentioned recycling schemes.

#### *Belgium*

The Belgian Government, faced with the need to gain support from minority environmental parties for constitutional reforms, has passed a controversial law imposing taxes on major packaging items. The main provisions of the law are summarized below:

- BF 15 per litre tax (with a minimum of BF 7 per bottle) on carbonated soft drink and beer bottles;
- All PVC bottles to be subject to the full BF 15 tax;
- Containers with a minimum deposit of BF 7 if over 50 cl, and at least BF 3.5 for up to 50 cl, and which are reused at least seven times, are exempt from the tax;
- Containers not presently reused will be exempt, if the producer or importer increases the percentage of containers reused and recycled during the first five years of the bill;
- 70 per cent of plastic drinks containers must be recycled by 1 January 1998 (an 80 per cent recycling rate is established for glass and metals);
- Incineration is not considered a recycling method.

This law has faced opposition on the following grounds:

First, it involves what many regard as a de facto ban on PVC. Belgium is the home of Solvay, one of Europe's largest PVC producers. Solvay, along with its employees who fear major job losses, is opposing the law on the grounds that it is based on misguided environmental assumptions. Significantly, the imposition of the PVC part of the bill has been delayed.

Secondly, CEFIC, the European chemical industry trade association, argues that the bill, one of the toughest in Western Europe, acts against the principles of the single market by effectively keeping products out of the Belgian market which are perfectly legal elsewhere in Europe. The

Belgian initiative also ignores the standstill on introducing stricter national legislation pending the passing of EC legislation.

Thirdly, the bill jeopardizes projects which were agreed to by regional governments and industry. In 1990, the Flemish government and 17 trade associations reached voluntary agreements of recycling targets of 28 per cent for household waste by 1995, and 46 per cent by the year 2000. The targets were more stringent in Brussels and Wallonia: 80 per cent for metal; 75 per cent for glass; 30 per cent for plastic and 25 per cent for paper by 1995; and 80 per cent for glass and 60 per cent for plastic by the year 2000. The Brussels and Wallonia initiatives became law.

Belgian retailers, packaging manufactures and end-users have responded to the law by setting up a recovery and recycling service for packaging waste in return for exemption from the tax. This scheme, known as Fost Plus, is to be funded by an industry levy and based on the French Eco-Emballagescheme, including the "Green Dot" logo. The intention of Fost Plus is to give companies the choice of how they fulfil their legal obligations and to achieve at least the recovery levels in the EC's draft packaging directive — 90 per cent recovery by weight and 60 per cent directly to recycling.

#### *Canada*

In 1990, a National Packaging Protocol was negotiated between the Government and relevant sectors. The objective of the protocol is to reduce packaging waste, which comprises about one third of MSW in Canada, by 20 per cent from 1988 levels in 1992; by 35 per cent in 1996 and by 50 per cent in the year 2000. It is anticipated that the objectives will be reached by an equal combination of source reduction and material recycling.

The Protocol is voluntary, but underlying it is the understanding that legislation will be passed if the objectives are not respected. The Government is committed to supporting the attainment of these goals in whatever way it can — for example, through the revision of procurement policies and the passage of minimum recycled content rules.

The National Packaging Protocol has given rise to initiatives at the provincial level. The majority of Canada's 10 provinces have introduced deposit and refund systems for beer and/or soft drink containers and several provinces have levied taxes on non-refillable containers.

#### *Denmark*

Denmark is not new to controversy in relation to its environmental legislation. From 1981, Denmark banned the use of non-returnable bottles for beer and soft drinks. This law was challenged by the European Commission at the European Court of Justice on the grounds that it distorted trade. The case was the subject of a landmark decision: the court ruled that the Danish law was incompatible with Article 30 of the Treaty of Rome on the free movement of goods within the EC, but that the Danish action was justified because the obstacles to free movement were not disproportionate to the environmental aims. If the packaging directive comes into force, this decision may be challenged.

During the 1993 Danish general election campaign, the winning party proposed income tax reductions in exchange for new or increased environmental taxes on fuel, electricity, water and waste. The proposals include taxes on handled carrier bags with capacity exceeding 5 litres. The proposed levels were DK 9 per kg for paper bags and

DK 20 per kg for plastic bags. The tax is non-discriminatory between materials, working out at about DK 0.5 per bag and is expected to generate almost DK 275 million per annum. Although introduced primarily for revenue-raising purposes, the tax will encourage further reductions in the quantity of packaging.

A draft law exists which would give the environment minister emergency powers to require producers and suppliers to take back waste products and materials or to pay part or all of a product's disposal costs. The law would not apply in a general way like the German system, but would also be invoked when companies fail to reach agreement on how to achieve binding environmental objectives for their sector. This law effectively makes the producer of a product responsible for it until its final disposal. The draft is intended to force producers to incorporate the cost of disposal into production costs and thereby to influence the choice of materials. Initial sectors targeted are transport packaging and glass. However, electronic goods, white goods, cars and automotive parts are believed to be high on the agenda.

The Government has also reached an agreement with Danish industry and retailers to drastically reduce the amount of PVC packaging: the overall objective is to achieve an 85 per cent reduction in PVC packaging by the year 2000 from the levels of the early 1990s.

#### *Finland*

Finland uses tax and deposit regulations to control packaging waste. Extensive use of returnable glass bottles, which are either reused or refilled, has resulted in much smaller quantities of packaging waste entering the waste stream than in other industrialized countries. Refillable bottles are effectively exempt from taxes. Non-refillable bottles are almost exclusively imported which thus bear a cost disadvantage relative to domestic products.

#### *France*

Like the German packaging ordinance, a 1992 decree on packaging waste obliges manufacturers and distributors to take responsibility for the disposal of their products. However, given the involvement of French industry in the formulation of the decree, there is more flexibility on how this responsibility can be assumed. The 1992 decree deals with household waste and was due for introduction in 1993. The provisions follow those of the 1992 decree.

The 1992 decree sets a target of 77 per cent for the recycling of packaging waste by 2002 but, unlike the German law, adopts a broad definition of recycling: when conventional recycling is uneconomical or impractical, for example, plastic waste may be incinerated with a view to energy recovery. By the year 2000, it is anticipated that 50 per cent of packaging waste will be recycled and 27 per cent will be converted into energy by incineration. At the time of the decree, less than 1 per cent of the plastics waste created by French households each year was recycled and 16.5 per cent incinerated.

Local authorities, as opposed to industry, as in the Netherlands and Germany, are responsible for setting up waste collection systems. Companies comply with the decree by participating in local authority collection and recovery schemes or by setting up their own recovery systems. In fact, industry and councils have set up their own collection network, Eco-Emballage, which is run on similar lines to Duales System Deutschland (using the "Green Dot" logo) but is not so expensive. Eco-Emballage charges are one fifth to one seventh the amount of German

charges. In its first year of operation, Eco-Emballage claims to have 20,000 members who each pay a levy of 1 centime for rigid packaging between 0.2 and 3 litres, and variable levies for flexible packaging. In 1993, Eco-Emballage hoped to raise FF 400 million, which would be put towards the collection and sorting of waste by local authorities.

Eco-Emballage has founded Valorplast SA to handle the recycling and disposal of plastic packaging. Valorplast has an annual budget of FF 40 million which is funded by the French Government and Eco-Emballage participants. Valorplast favours incineration with energy recovery as a form of plastics waste disposal and forecasts that by the year 2000, 65 per cent of small plastics waste will be incinerated.

Eco-Emballage intends to found three other companies for the disposal of plastic bottles — one will deal with PVC mineral water bottles, one with PET carbonated drinks bottles and the other with HDPE bottles for household cleaners.

#### Germany

Germany has introduced Europe's most ambitious and most controversial provisions for recycling packaging waste. The heart of the legislation is the packaging ordinance; the main provisions include the following:

- The ordinance covers all packaging materials except those with residues of hazardous materials;
- Targets for collecting plastic packaging waste are 30 per cent by January 1993, rising to 80 per cent by June 1995;
- In order to encourage reusable and refillable packaging, used packaging must be returned to manufacturers and distributors, preferably at the site where it was purchased;
- Reuse has priority over recycling;
- Incineration with energy recovery is not included in the recycling targets. Hamburg wants to introduce an amendment to the packaging ordinance which would allow the incineration of plastics, but incineration remains a far from popular option in Germany;
- The ordinance came into effect for transit packaging from 1 December 1991; for secondary packaging from 1 April 1992; and for sales packaging (e.g. containers and bottles for beverages, soap powder and cleaning products) from 1 January 1993;
- Sales packaging also includes disposable items, such as cutlery, dishes and similar items used by take-away establishments or private households. However, 220 German towns and districts have gone further and during the last two years have actually banned the use of disposable cutlery and dishes—giving rise to further complaints about trade distortion.

A possible extension of the ordinance under consideration includes increasing the share of beverages in refillable containers to 84 per cent within 10 years, and extending take-back rules to containers of hazardous goods.

Obligations to take back used packaging are set aside for those manufacturers and distributors who belong to Duales System Deutschland (DSD). DSD is an umbrella body which organizes collection and sorting of consumer waste before selling it for recycling. Members of DSD are entitled to mark their products with the "Green Dot" logo. The presence of the dot implies that the packaging is recyclable and that the manufacturer or distributor has paid a fee to DSD. Segregated "Green Dot" waste must be

recycled and not incinerated and all relevant collection and recycling targets must be met.

Charges were originally based on volume and varied between DM 0.01 and DM 0.2. New charges are based on weight and an assessment of the cost of collection, sorting and cleaning. Charges for all items have increased, but in the case of plastics, the new charges represent an increase of eight to 10 times for some items. This reinforces the concerns of plastics producers that the structure of DSD charges discriminates against them and encourages switching to alternative packaging materials.

#### Non-packaging disposal requirements

The majority of the regulations outlined concern packaging waste, which has attracted the majority of the legislators' attention because of its short life and high visibility. However, the German Government has turned in the last year to other sectors: the environment ministry estimates that 1 million tons of waste is generated in Germany each year from electronic equipment alone.

A draft framework law requires industry to account at regular intervals for types and quantities of waste produced. The law contains provisions similar to those in the packaging ordinance and requires manufacturers of cars, household appliances, office equipment, industrial equipment and suppliers to the construction industry to take back and recycle their products. If the product is not made in Germany, the obligation to take back the product falls on the importer. The proposals have been approved by the German cabinet but must still find their way through parliament; the draft also requires manufacturers and distributors to give the Government an annual list of parts that have been recovered.

Strong opposition is to be expected, in view of the problems encountered by the packaging ordinance and the additional financial and administrative burdens for manufacturers, who will ultimately have to push up the prices of their goods at a time when they are greatly concerned about their competitiveness.

Similarly, given the possible constraints which the proposals may impose on trade, the draft ordinances are likely to come up against fierce opposition from Germany's trading partners, especially from within Europe, who view this as a serious infringement of the principles of the single European market. These measures are to be reinforced by imposition of taxes on waste disposed of in landfill or via incineration. The German provinces have also played a role in the passage of environmental legislation. The State of Hesse has passed a bill banning the use of PVC in new buildings on its territory. With effect from 1 January 1993, the State of Wiesbaden banned the use of PVC pipes, floor and wall coverings in public housing projects and buildings financed by the state. The ban will be extended to PVC windows and door frames from January 1995.

#### Case study: the German packaging ordinance

Germany's 1991 packaging ordinance sets out the most sensitive recycling regulations in the EC, if not the world. However, the scheme has run into severe difficulties and has been roundly criticized by an array of opponents. The critics claim the ordinance:

- Is collection-led and ignores market consideration—i.e. insufficient attention has been paid to whether a market exists for the resulting recycled product;
- Sets recycling targets for all materials, without due regard as to whether sufficient capacity is available;

- Is based on dubious environmental and economic assumption: recycling is the focus of the ordinance which ignores other options, such as incineration with energy recovery, which can sometimes be more environmentally appropriate;
- Breaches the Treaty of Rome by forcing exporters to Germany to devise special packaging arrangements for their products, thereby distorting cross-border trade and fragmenting the single European market;
- Undermines emerging recycling initiatives in other European countries;
- Infringes competition at home: the Cartel Office is investigating complaints that DSD's plans to start the collection of sales packaging from commercial premises would inhibit the growth of other disposal companies;
- Discriminates against plastics through the charging system. The collection scheme has already affected material choice; DSD itself has estimated that plastics accounted for only 27 per cent of German packaging in 1992 compared with 40 per cent in 1990.

The DSD organization, one of the major vehicles for implementing the ordinance, has faced severe financial difficulties. These difficulties were temporarily solved by a combination of a DM 162 million cash injection from retailers; increased charges and plans to charge local authorities for packaging collection bins which do not have the "Green Dot"; this currently accounts for 40 per cent of all collected material.

The source of DSD's difficulties lay in the unexpected willingness of the German public to collect packaging waste for recycling. In the initial days of the recycling scheme only about half of the German population was included. However, unexpectedly large quantities of collected material plus an insufficient recycling capacity proved to be hurdles.

Unable to cope with recycling at home, the DSD has exported its collected waste throughout the world: German waste with the "Green Dot" logo has been spotted as far afield as Indonesia, China and South America, as well as in Bulgaria, Hungary and the rest of the EC. In order to dispose of it, DSD has offered financial incentives of up to DM 600 per ton to non-German recyclers to take the waste. This action has seriously unbalanced nascent recycling markets in several European countries. UK recyclers, for example, have accepted German waste with the consequent collapse of prices for waste plastics collected in UK (price falls of 60 per cent are reported for the period 1989-1992), and the ensuing difficulties for plastics recycling schemes which are only just getting under way in the UK. This pattern is repeated in France, the Netherlands and other European countries.

This situation led to the UK tabling a formal complaint with the European Commission against the German scheme on the grounds that the lack of adequate recycling capacity in Germany is causing acute distortions to trade; and that unilateral action by one member State is causing serious disruptions in plastics and paper recycling throughout the rest of the Community. This action was supported by France, Spain, the Netherlands, Italy, Ireland and Luxembourg. The German scheme was partially responsible for the initiative on packaging waste which was brought forward by the UK Government in July 1993.

#### Italy

Italy has been aware of recycling for many years and has had recycling legislation of some sort for over a decade

(for instance, the 1988 decree on household batteries, glass and expired medicine). Legislation resulted in the setting up of a mandatory body, IVR (Istituto per la Valorizzazione Riciclo Materiali) to oversee the operation of plastics recycling schemes. Law 475/88 laid down that by 1993, 40 per cent of plastic bottles must be recovered for recycling (compared with targets of 50 per cent for glass and metal).

According to a proposal originally foreseen for April 1993, the failure to meet the targets could have led to the imposition of taxes of Lit 20 on liquid containers up to 300 cc in size and Lit 100 for those above 300 cc. However, the earliest expected date for the introduction of this or any related legislation was spring 1994.

Notwithstanding internal problems, a landfill levy came into effect on 1 June 1993. Operators of landfill sites pay Lit 25/kg on all MSW they process. Originally intended to fund recycling facilities and landfill clean-up, the revenue can now also be used to promote the separation of waste by type: 70 per cent is expected to go towards the cost of recycling and energy recovery plants with the residue destined for landfill cleaning. Taxation to support environmental objectives is not new: since 1989 Italy has levied a Lit 100 tax on plastic carrier bags, which must be made of polyethylene (PE) or a degradable material, and a 10 per cent tax on materials in non-reusable liquid containers, including those in the beverage, cosmetic and pharmaceutical sectors. Revenues raised in this way are used to fund recycling schemes.

Unlike some other countries, Italy regards incineration with energy recovery as recycling. This was built into the recycling law and was confirmed by a 1990 decree which calls for the "optimization and recycling of old materials for the generation of energy."

#### Japan

Incineration is the main method of waste plastics disposal in Japan and recycling has not attracted much attention. However, Japan is not well-endowed with indigenous energy and other natural resources and concern has grown about future scarcity of these resources.

In 1990, guidelines were issued for the treatment of the major categories of waste. For paper, glass bottles and steel and aluminium cans, increases in recycling rates were envisaged. Recycling of post-consumer plastic waste is less developed than for other materials. Consequently, the guidelines for plastic were less specific, merely urging the promotion of recycling, energy recovery and reuse, and products with thinner walls and longer life-spans.

Two pieces of legislation in particular are concerned with plastics. The Waste Disposal Law, which falls under the jurisdiction of the Ministry of Health and Welfare, spells out clearly who is responsible for waste management at the various stages of production, distribution and consumption. Enterprises are responsible for the disposal of waste from their activities and are also required to reduce the volume of their waste and take the necessary action to ensure that the materials involved in all aspects of their business activity do not become difficult to dispose of.

The Recycling Law, which was implemented in October 1991, falls under the auspices of MITI, the Ministry of International Trade and Industry. This Law defines the industries obliged to increase their recycling rates, and their use of easily recyclable structures; and requires companies to ensure their products have labels describing the materials used. Products obliged to use easily recyclable structures and materials include cars, unit-



type air conditioners, televisions, electronic washing machines and refrigerators. The collection and recycling of polystyrene foam packaging is also required.

Japanese manufacturers of cars and household and electrical appliances have consequently stepped up their efforts to improve the recyclability of their products and are looking at ways of improving the ease of disassembly and of using the more recyclable polymers.

#### Luxembourg

A law has been considered which proposes increasing the market share of refillable bottles from 40 per cent to 55 per cent by 1995. Failure to meet this target could lead to the compulsory imposition of a deposit.

#### The Netherlands

The Dutch have so far adopted a voluntary approach to packaging waste in the June 1991 Packaging Covenant between government and industry. The Covenant reaffirms the targets of a memorandum presented to Parliament in 1988 entitled "The Prevention and Recycling of Waste Materials".

Although voluntary, the Covenant's aims are ambitious, requiring recycling rates of 60 per cent for all packaging waste by the year 2000. The remainder is incinerated. This aggregate 60 per cent recycling target translates into 80 per cent for glass; 75 per cent for aluminium cans; 60 per cent for paper and board; and 50 per cent for plastic bottles and film. There is to be no increase in the amount of packaging waste generated, and landfill as a disposal method is to be eliminated.

The voluntary nature of the agreement can, however, make it difficult for exporters to the Netherlands to know what is acceptable. Retailers have effectively agreed to ban the use of PVC packaging. Soft drinks bottles are being standardized to facilitate refill and return schemes. Deposit schemes operate on PET carbonated soft drinks bottles and may be introduced on still bottles. Secondary and multi-packaging is disappearing and the weight of packaging is decreasing generally. Concentrated detergents and refillable packaging are gaining in popularity.

Voluntary control gives businesses some flexibility in meeting environmental goals, but leaves the Government open to criticism that it leads to inaction. Dutch industry has taken the Covenant seriously; but reports suggest that the Dutch Government is considering the introduction of a statutory scheme, perhaps along German lines.

#### Norway

In common with other Scandinavian countries, Norway operates a deposit system for soft drink, beer and other alcoholic beverage bottles and also for the cases in which the bottles are transported. A tax is also levied on non-returnable beverage containers. Consequently, refillable containers dominate the Norwegian beverage market.

#### South Korea

A law passed in December 1992 prohibits the use of polystyrene in toys and packaging for gift sets. The law also calls for a general reduction in polystyrene packaging for electrical appliances and requires that all polystyrene packaging for electrical appliances dispatched directly to the customer must be recovered. Six Korean expanded polystyrene producers have formed the Korean Foam Styrene Recycling Association to help ensure compliance with the law.

#### Spain

The Spanish packaging industry has put forward a plan, accepted by the environment ministry, which commits the industry, on a voluntary basis, to accept sorted waste collected by the local authorities for the purpose of reuse, recycling or incineration with energy recovery. Spain lacks an effective and credible collection system at this stage. The scheme will be funded by a levy on each packaging item and will minimize the quantities going to landfill. The industry, in anticipation of the EC draft packaging directive, based its scheme on legalization to regulate the system once it is under way.

#### Sweden

Since 1973, Sweden has operated a mandatory deposit and refund scheme on most beverage containers. Beer and carbonated soft drinks sold in glass bottles have achieved return rates of almost 100 per cent.

Tough new packaging laws, closely based on German legislation, came into effect recently. But by 1 January 1997, 90 per cent of aluminium cans and PET bottles, 70 per cent of glass, steel cans and other aluminium packaging and 65 per cent of corrugated board, paperboard and other plastic packaging must be recycled. The targets for glass and aluminium cans are regarded as feasible; the PET target as possible; but the targets for paper and other plastics, given the 1992 recycling rate of about 5 per cent, are regarded as problematic.

These targets have been criticized by the Swedish packaging industry as political and inappropriate for a country which already incinerates 65 per cent of its waste. Sweden has more space available for landfill than central Europe, making Germany an inappropriate model for Sweden to follow. Sweden is also a country with a low population density, which substantially increases waste collection costs.

Sweden maintains a ban on non-returnable PET containers, and from June 1990 the use of PVC in packaging was banned. A total ban on the import and production of PVC is under consideration.

#### Switzerland

Waste laws affect only beverages, which must be marketed in reusable or recyclable containers. The threat of a mandatory deposit scheme hangs over the packaging industry, if ambitious recycling rates of 90 per cent for glass, plastic and metal beverage containers are not met. PVC containers are banned, along with all composite aluminium and steel cans.

#### Turkey

In 1991, Turkey introduced recycling targets for PVC, PET, aluminium and other metal containers used to package a number of liquid consumer products, including milk, milk products, fruit juices, edible oils, beer, bottled water, soft drinks, wine, cider, spirits, detergents, shampoo, bleach and fabric softeners. The targets are increased on a yearly basis to reach 70 per cent for PET and PVC containers and 60 per cent for metal containers. Failure to meet the targets will result in the introduction of a deposit.

#### United Kingdom

In common with many other policies, the UK has until now adopted a *laissez-faire* approach to the waste management issue. Its voluntary approach is increasingly threatened by legislative initiatives in other EC member States, especially by the German "Green Dot" scheme. In

view of the disruption of the UK recovery and recycling markets resulting from the German scheme, and the slow progress towards a common European approach, the UK Government called upon the UK packaging industry to draw up plans which would ensure recycling of between 50-70 per cent of all packaging waste by the year 2000. The Government has an overall target to recycle 25 per cent of household waste by the end of the century.

The UK industry has mixed views about such moves, in light of the German experience and the reluctance of industry to utilize recycled material. However, the Environmental Secretary has said that if the relevant industries do not convince him of their commitment to the achievement of these objectives "we will need to move towards a legislative approach". If legislation does go ahead, it is believed it will be modelled on the French Eco-Emballage approach, rather than on the German system.

Unlike Germany, however, the UK Government regards incineration with energy recovery as a recycling option and, following a report from the Royal Commission on Environmental Pollution, the introduction of a landfill levy to encourage the switch towards incineration and recycling is widely anticipated.

#### United States

Serious attempts to introduce recycling and other solid waste management issues began earlier in the US than in Europe. Consequently many of the resulting problems have also come to light earlier. Nevertheless, legislative proposals keep coming forward: in 1991, 160 new recycling laws were enacted in the US and Canada; and 520 bills affecting solid waste were introduced in 1992, of which 100 were passed. Over half of these bills contained mandatory recycling requirements—an increase over 1991. Industry is concerned that many of these targets imply a de facto ban on certain materials, because they establish completely unrealistic targets.

Laws and regulations affect the disposal of plastic waste at federal, state and local level. State and local initiatives have so far dominated waste disposal laws. However, periodic attempts are made to push legislation through Congress. In 1993, US mayors asked Congress to introduce legislation to force packaging manufacturers, consumer product companies and publishers to pay for the cost of collection and recycling. This request, which introduces principles similar to those at work in Germany, has arisen because the costs of many of the recycling schemes set up as a result of the legislative avalanche of the previous five years are borne by the tax-payer and are endangering other aspects of state budgets. Cuts have been made in some recycling programmes: in 1992, for example, Philadelphia stopped collecting plastic waste entirely because the waste disposal budget was impairing its ability to carry out important spending in the educational sector.

Whether or not this particular attempt is successful, this initiative marks an important shift in US environmental thinking. There is increasing pressure for manufacturers to take responsibility for the whole life-cycle of their products, including the point at which they become waste.

When recycling schemes were introduced, it was anticipated that the costs of collection would be recovered via the sale of recovered material to recyclers. This expectation has proved to be unfounded: the cost of collection and disposal of waste can be several times the market value of the recovered material. Plastics materials are particularly costly to collect and recycle. The backlash to this is likely, in

some way, to make manufacturers, and ultimately consumers, bear the cost of product disposal with the possible squeezing out or elimination of some plastics materials.

However, the plastics industry itself is fighting back against environmental initiatives which it believes to be ill-considered. Recent examples include the following:

- The Polystyrene Packaging Council sued the town of Fairfax in California for its 1992 ban on polystyrene foam take-away food containers;
- In November 1992, voters in Massachusetts rejected a proposal which required all packaging originating in the state either to contain 25 per cent recycle; to be reusable five times; to be source reducible by 25 per cent over five years; or to use material which is recycled at a 25 per cent rate. Initially, polls showed voters were in favour of the proposal, but the plastics industry mobilized effectively in the state, and in the end 59 per cent of the electorate voted against the measure;
- In 1993, the American Plastics Council organized a vigorous advertising campaign to counteract the deterioration which they perceive in the public acceptability of plastics materials and which they believe is giving rise to ill-conceived legislation based on incomplete assessments of the environmental effects of plastic.

(Source: *Survey on Management of Plastic Waste in Asian Countries*. Author: Vincent Sciascia. Prepared for UNIDO, December 1994.)

#### Wrapping revolution slowed by red tape

A revolution is taking place in the world packaging industry, shaped by high-tech industries and spurred by the increase in environmental legislation.

The commercial production of polyhydroxybutyrate (PHB), a polyester-like resin made by fermenting sugar with a naturally occurring bacterium, *Alcaligenes eutrophus*, provides an indication of future trends. The bioresin, marketed under the trade name *Biopol* can be used for paper coatings, flexible films and rigid plastic containers. But its full potential is still being explored by its developers.

The developer of *Biopol*, Zeneca Bio Products, is working with United Paper Mills in Finland to produce a *Biopol* board that could become a rival to some of the plastics and paper products currently used for food cartons, drinking cups and sachets.

In a parallel development, researchers at the University of Warwick are studying genetically-altered oilseed rape plants as a potential source of the PHB biopolymer. Although they have not yet created an entire PHB-producing plant, the Warwick researchers believe commercial production, at about 10 per cent of the price of petroleum-based polymers, will be possible soon after the year 2000. Along similar lines, the Michigan Biotechnology Institute (MBI) has developed two new families of corn-based plastics that are fully biodegradable.

MBI has also collaborated with Burger King's parent company, Grand Metropolitan, to develop bioplastics to replace polyethylene and wax coatings on paper and paperboard containers.

A move is apparent in the polymer industry away from commodity resins towards more customized materials tailored for specific applications. Examples include high heat-resistant PETs, ultra-clear PPs and PE films engineered for maximum stretch and strength.

Some Western European recycling targets

	Material	Target (per cent)	Deadline	Comments
Austria	Packaging	80		
Belgium	Bottles:			Draft law
	Plastics	70	1 Jan. 98	
	Glass	80	1 Jan. 98	
Flanders	Household waste	Metals	80	1 Jan. 98
			28	1995
		46	2000	
Brussels & Wallonia	Metal	80	1995	Voluntary
	Glass	75	1995	
	Plastic	30	1995	
	Paper	25	1995	
	Glass	80	2000	
	Plastic	60	2000	
France	Packaging	77	2002	Incineration OK
Germany	Plastic packaging	30	Jan. 93	Incineration not OK
		80	Jun. 95	
Italy	Bottles:			Incineration OK
	Plastic	40	1993	
	Glass	50	1993	
	Metal	50	1993	
Netherlands	All packaging	60	2000	Voluntary
	Glass	80	2000	
	Aluminium	75	2000	Incineration OK
	Paper/board	60	2000	
	Plastic	50	2000	
Sweden	Aluminium	90		
	PET bottles	90		
	Glass	70		
	Steel cans	70		
	Corrugated board	65		
	Paper-board	65		
	Other plastics packaging	65		
Switzerland	Bottles			
	Glass	90	1993	
	Metal	90	1993	
	Plastics	90	1993	
UK	Household waste	25	2000	Voluntary

Today, glass, plastic, paper, metal and composite containers are 10-20 per cent lighter than their 1970s counterparts and this trend is set to continue, with the added factor of greater recyclability.

Reduction successes achieved by plastics are enormous. A yoghurt pot now weighs 4.5 g, down from 12.5 g; a four-litre detergent bottle weighs 105 g, down from 300 g; a carrier bag weighs 6.5 g, 70 per cent less than in the 1980s.

“Less is more” is a critical message and, backed by eco-balance data, is acting more and more as a critical design principle. In some cases it is replacing the onus on recycling. Plastics packaging now typically accounts for as little as 1 to 3 per cent of a product’s weight. For example 150 g of biscuits needs just 1.5 g of packaging. If you design to minimize resources you often make recycling less viable. But recycling has an important part to play.

Further source reduction is probably one of the most critical challenges facing the food packaging industry, because it involves the fine line that needs to be drawn between product protection and product failure. Composites provide a way of ensuring that source reduction can take place without compromising the functionality of the package in terms of product protection. Non-traditional composites such as silicon oxide and aluminium oxide film or coatings on plastic cores, polyester coatings on tin-free steel, acrylic skins on glass and PET coated with various organic compounds, will increasingly be used in the future.

Plastics packaging recycling is complicated by collection, sorting, economic and technical difficulties. Different national regulations in Europe are also a hindrance. Plastics recycling is not an easy task. The material needs to be clean and homogeneous and there is also the problem of mixed materials such as a plastics yoghurt pot with an aluminium lid. The European plastics industry is committed to recycling as part of its policy to conserve resources and minimize waste. The importance which governments and consumers place on recycling is recognized and wherever it is economically and environmentally possible is encouraged.

Despite "significant research and investment", the amount of recycling has remained relatively static over the past two years. This is because there are limitations posed by mechanical recycling methods. When quality and technical barriers are considered, only 22 per cent of plastics waste is assessed as mechanically recyclable. Total European post-user plastics waste is 16.21 tons, with 10.92 tons coming from municipal solid waste. A quarter of this is recovered, 5.6 per cent is by mechanical recycling.

But efforts by the packaging industry to create a single European packaging market have so far been hampered by the plethora of European Union member State legislation. Some of these difficulties have arisen partly as a result of different member State interpretations of past and present EU packaging and packaging waste legislation.

In order to create some semblance of harmony the Packaging Chain Forum led by Europen, the European organization for packaging and the environment, is developing a common EU "packaging language" directory. Work is nearing completion on the volume. The directory will contain all the known definitions in legislation within the 15 member States. The Packaging and Packaging Waste Directive contains a set of definitions, but these do not always coincide with existing definitions in national legislation.

The aim of the EU's Packaging and Packaging Waste Directive 94/62/EU is to harmonize national measures concerning the management of packaging and packaging waste. It has two objectives: to reduce the overall impact of packaging and packaging waste on the environment; and to remove obstacles to trade and distortions of competition.

EU members are obliged to ensure that systems are established for the return or collection of used packaging and have to ensure that by July 2001, the following targets are met: at least 50 per cent and no more than 65 per cent by weight of packaging waste must be recovered; a minimum of 25 per cent and maximum of 45 per cent by weight of the tonnage of packaging waste must be recycled; and no material shall be recycled at a rate of less than 15 per cent.

The problem of interpretation of the EU's first Directive to deal with waste, 75/442/EC and its 1991

amendment 91/156 led to different national packaging waste legislation.

German legislation uses the term "movable property" to define waste, in contrast to EU legislation and that of most other member States. This choice of terminology in the German legislation is probably due to the prevailing principle that all waste has economic value.

The argument about what is and what is not waste is yet to be solved and extends beyond packaging and used packaging sectors. It cuts across parts of the Basel Convention on transboundary movements of hazardous waste and the opinion of the OECD on what is waste and what is secondary material.

But problems with definitions still exist even within the new EU Directive. For example, Article 7.1 (b) talks about "reuse or recovery", while Article 8.2 refers to "reuse and recovery".

Another problem is how member States will define the percentage of materials which are considered as recycled. Some States are basing their recycling rates on the amount of materials collected for recycling, while others base their calculations on the amount recycled.

Meanwhile, the publication of the Packaging Chain Forum volume on packaging language definitions is set to be the first step in ensuring that the provisions of the single European market can be applied to the packaging and packaging waste industry.

Ensuring that national legislation is in harmony should at least mean an end to "invisible packaging borders." (Source: *European Chemical News*, 25 September-1 October 1995)

### **EU debate on marking packaging reopens**

With a framework directive on packaging and packaging waste in place since 1994, the European Union is now struggling to reach follow-up decisions on how packaging should be marked and identified. The debate on marking, sidestepped during negotiations on the directive because it was too difficult, is reopening long-standing national divisions over which options in the waste management hierarchy should be preferred.

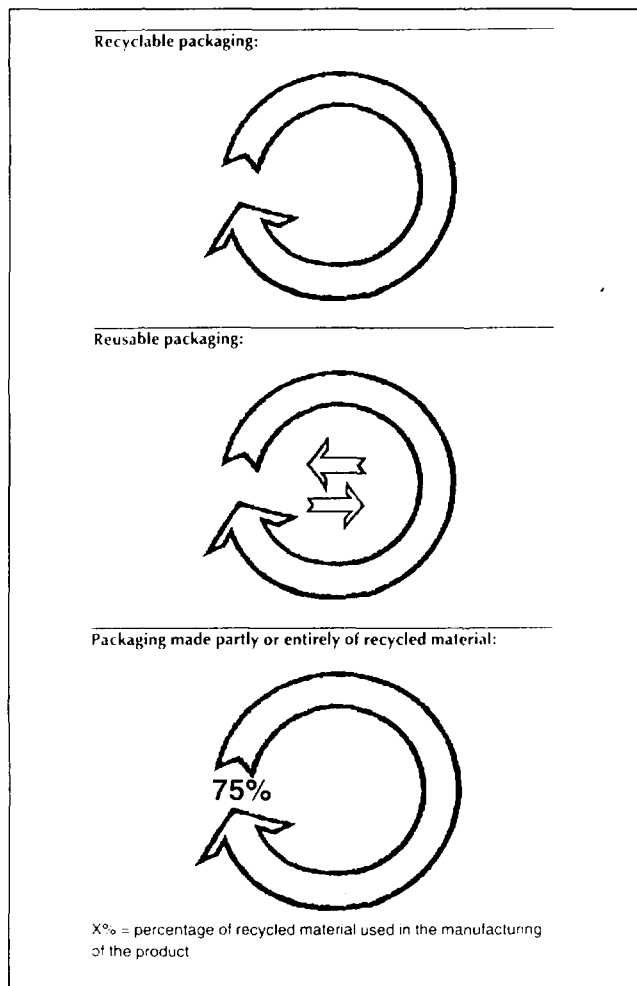
The European Commission's environment directorate has disappointed the packaging chain with its latest draft of a planned directive on marking. The draft proposes creating three symbols to denote packaging that is reusable, recyclable, or that contains recycled material (see figure 1). Use of the markings would be voluntary, but the directive would prohibit the use of any other markings—such as those already employed by industry—to denote the same characteristics.

The draft contrasts with an earlier working paper that, instead of the "recyclable" symbol, had suggested a marking to denote that the packaging conformed with the packaging directive's essential requirements. The working paper also envisaged that the markings would be mandatory.

Germany, whose packaging law mandates high refill quotas, restated that it wants only a "reusable" marking. Bonn is also said to be concerned that the proposal could sweep away the Green Dot symbol used on virtually all packaging sold on the German market. Though the Green Dot formally signifies only that a handling fee has been paid to the packaging recovery organization DSD, the design and colour of the symbol has been criticized for suggesting to consumers that the packaging is environmentally superior. France, by contrast, wants only a

marking that denotes conformity with the directive's requirements.

Figure 1



One participant from a country considered as environmentally progressive said he saw little point in any of the proposed markings. Echoing objections shared by the packaging chain, he and others noted that almost anything can be termed recyclable, but that what is more important is whether a system is in place to recycle it in practice. A marking to denote reusability is also felt by some to be superfluous since reusable packaging is almost always covered by a deposit-return system with which the consumer is familiar. As for recycled content, this is seen as raising difficulties of verification.

In an explanation of its proposal, the environment directorate makes clear that its aim is to promote reusable and recyclable packaging in the market-place. This is in line, it says, with a provision in the preamble to the packaging directive that states that "until scientific and technical progress is made with regard to recovery processes, reuse and recycling should be considered preferable in terms of environmental impact".

But the directive is deliberately ambiguous on this question, reflecting the different attitudes among the member States. The packaging chain points out that the same provision also mentions the need for life-cycle assessments to be carried out to justify a clear hierarchy between reusable, recyclable, and recoverable packaging.

European and other major organizations in the packaging chain want the EU marking system to be based on symbols denoting only that packaging is "recoverable, including recyclable". The symbols should be those already long used by the aluminium, steel, glass, paper/cardboard, and plastics industries to identify their materials. This, the organizations argue, would have the benefit of using symbols already familiar to the public. It would also provide a single solution to the dual issues of marking and identification.

The environment directorate accepts that the questions of marking and identification are closely linked and that proposals need to be developed in parallel, but it appears unwilling to seek a single solution. This is not least because the packaging directive stipulates that the Council of Ministers must decide on markings (the directorate intends to involve the European Parliament fully as well through the co-decision procedure), whereas the identification system is to be decided on by the Commission on the basis of a vote among member States in the directive's follow-up committee. The directorate also argues that basing the EU system on markings developed by industry would create problems with intellectual property rights.

The directorate has thus developed a separate draft proposal on material identification. The system it proposes is highly detailed, creating subcategories of plastics, metals, paper/cardboard, glass, natural materials and composite materials to which combinations of identification numbers and abbreviations are allocated. Use of the identification system would initially be voluntary but would become mandatory after four years, except for small packaging, paper/cardboard, glass and natural materials, for which it would become compulsory after eight years. Once mandatory, each item of packaging would have to bear the relevant identifier.

Industry and some member States find the proposed system far too elaborate and doubt whether creating detailed subcategories of materials is necessary to achieve the stated aim of facilitating collection, reuse and recovery of packaging. The categorization of composite materials also presents problems. (Source: *Environment Watch: Western Europe*, 15 September 1995)

**Portugal approves packaging recovery legislation**

The Portuguese Government has approved the framework legislation for a packaging waste recovery system along the lines of the EU packaging directive. Under the new law, industry, retailers and local authorities will share responsibility for achieving a 25 per cent recovery rate for packaging waste — through reuse, recycling, incineration with energy recovery, and composting—by mid-2001.

The proposed system is based on France's Eco-Emballages scheme. Local authorities would be responsible for collecting packaging waste—along with other household waste—and sorting it. Financial support for this would come from industry and retailers (primarily supermarket chains), while manufacturers of packaging and raw materials would guarantee the recovery of the collected waste. These responsibilities could be transferred to an Eco-Emballages-type organization set up for this purpose.

Complementary legislation that is still under discussion will lay down the details of the new scheme, such as the operating conditions for a packaging recovery organization. It will also cover requirements for packaging such as maximum permissible concentrations of heavy metals and other hazardous substances and packaging markings.

However, these requirements would not come into effect until January 1999, allowing for an adaptation period during which packaging already on the market could be used up.

The 25 per cent recovery rate to be reached by 2001 is an interim target granted by the EU to Portugal as well as Greece and Ireland. By the same date, the other member States must recover between a minimum of 50 per cent and a maximum of 65 per cent by weight of total packaging waste, and recycle between 25 per cent and 45 per cent. At least 15 per cent of each type of packaging material must be recycled. Portugal must meet these targets by the end of 2005.

At present, however, sorted collection and recycling still play a minor role in Portuguese waste management. Progress so far has been limited largely to glass recovery. Incineration with energy recovery might help Portugal achieve the recovery targets — two household waste incinerators are due to be built in the two largest cities, Lisbon and Oporto, and may start operating by 1997 — but would not be counted as recycling under the terms of the EU directive. (Source: *Environment Watch: Western Europe*, 15 September 1995)

#### **EU packaging data reporting requirements agreed**

In the first follow-up decision to the EU's directive on packaging and packaging waste, member States have voted in favour of a set of data reporting requirements that are considerable less detailed than those originally proposed by the European Commission. According to industry representatives and national officials who participate in the committee overseeing implementation of the directive, member States will have to report data only on the total amount of packaging produced (by category of material), recovered, and recycled each year. More detailed reporting can be done on a voluntary basis. In a move that is important to the packaging industry, the precise definition of composite packaging has been left open for now; the extent to which the percentage weight of any one component should be limited is to be decided by the committee before the end of 1997. On the basis of the committee's majority vote, the Commission will now publish a decision formalizing data reporting requirements.

The committee delayed a separate vote on an identification system for packaging after member States made a plethora of changes to the Commission's proposed text. Participants said it had been agreed that use of the identification system by industry would be voluntary for the first four years. This will be reviewed in the light of a planned directive on marking that should have been adopted by then. Like industry, many member States appear to want the content of the decision on identification and the directive on marking to be closely coordinated, even if the two measures are formally separate. The environment directorate has circulated drafts of the planned marking directive but has yet to finalize its proposal. (Source: *Environment Watch: Western Europe*, 15 December 1995).

#### **German packaging plan amended**

Germany's Federal Environment Ministry has presented the long-awaited draft of a revised amendment to its 1991 federal packaging ordinance designed to bring it into line with the EC directive of December 1994.

The Federal Environment Minister hopes to have the amendment passed by the Parliament by October 1996. However, many observers see this as unrealistic in view of

the criticism anticipated, from within Germany as well as from the EC.

Like the existing ordinance, the new legislation calls for a deposit system on reusable packaging such as glass which is not disposed of within the dual packaging waste collection system (DSD). The EC believes this could constitute an illegal trade barrier as it discriminates against the large volume of one-way (needing recycling) packaging imported into Germany from the rest of the EU.

In line with the EC directive, the deadlines for meeting recycling quotas for plastics packaging waste have been revised. They now call for 50 per cent of plastic packaging wastes to be collected and recycled by 1 January 1996, with 70 per cent mandated from 1 January 1998.

The 1991 ordinance mandated an 80 per cent quota by 1 January 1995. Difficulty in meeting this target led to large quantities of waste plastics being shipped abroad. Under the current draft, at least 50 per cent of plastics packaging materials must be recycled. Even this has been criticized by the DSD and producers as being too rigid. However, packaging made of renewable raw materials may be incinerated for energy recovery. (Source: *European Chemical News*, 12-18 February 1996)

#### **Approval uncertain for 13th draft of Spanish packaging law**

Spain's Government hoped to have its packaging decree adopted before the end of 1995. Even though the Government now plans to ease passage of the new legislation by making it a royal decree (a move that bypasses the Parliament for the short term), its approval is by no means certain. Several of the powerful regional governments, as well as industry, have made clear they are not much happier with the 13th draft of the decree than with previous versions. The Environment Ministry's deputy director for standardization said that in its present version, the decree basically follows the minimum recovery and recycling targets set by the EU packaging directive — 50 per cent and 25 per cent, respectively, by weight of total packaging waste. These targets would have to be achieved by the mid-2001 deadline prescribed by the directive, with the long-term aim of bringing the rates closer to the directive's recovery and recycling ceilings of 65 per cent and 45 per cent, respectively. In addition, the Government wants to mandate a 10 per cent reduction of packaging waste at source and a 20 per cent cut in the country's PVC production, both by 2001. As the reason for the PVC cut, the Environment Ministry cites the material's suspected health risks as well as the fact that Spain has yet to define its waste incinerator policy.

Key questions that remain to be resolved are who will monitor and enforce the new legislation — a responsibility likely to fall on the 17 regional governments, who will also be in charge of implementing it — and how recovery/recycling schemes would be funded. On this issue, the Government has presented two proposals. One calls for a deposit on all returnables, the other for some sort of levy on all packaging materials. The revenue from such a levy would be channelled into non-profit organizations set up by industry that would then fund the collection and processing of packaging waste under the supervision of the local governments. (Source: *Environment Watch: Western Europe*, 15 December 1995)

#### **Recycled plastic products in North America**

Great progress has been made in North America in the recycling of polymeric materials and products. The efforts

of ASTM Committee D-20 on Plastics have clarified terminology in the field of recycled plastics and given guidance on specifying and using those materials.

Over the course of the last three years, ASTM Committee D-20, through its Subcommittee D20.95 on Recycled Plastics, developed a standard, D 5033, Guide for the Development of Standards Relating to the Proper Use of Recycled Plastics.

Guide D 5033 does two things. First, it provides a unified and standardized position regarding terminology. It also provides a guide on how and when to use recycled polymers.

In the beginning of the effort to standardize the use of recycled plastics, there was a great deal of confusion and many strong positions regarding terminology. Of course, terms are essential in referring to recycled plastics, and in many cases have legal connotations. Terms such as "recycled", "reclaimed", "reconstituted", "repro", "regrind" and "rework" caused a great deal of confusion. Many manufacturers felt they were manufacturing "repro", others "recycle" and still others "regrind" or "rework".

One of the first key terms defined was "recycled plastics". Recycled plastics are those plastics composed of post-consumer materials or recovered materials only, which may or may not have been subjected to additional internal processing steps of the type used to make products designated as regrind, reprocessed or reconstituted plastics. In direct opposition to that is the definition for "virgin plastics"—plastic materials in the form of pellets, granules, powder, flock or liquid that have not been subject to use or processing other than that required for their initial manufacture. That may include other internal material such as regrind that is circulated in various processing steps.

Other key terms clarified by D 5033 include:

- Commingled plastic;
- Industrial plastic scrap;
- Off-spec or off-grade virgin plastics;
- Post-consumer materials;
- Purge (plastic);
- Reconstituted plastic;
- Recycled-regrind plastic;
- Regrind (plastic);
- Reprocessed (plastic);
- Reworked plastic; and
- Source reduction.

In all, some 20 terms are defined in D 5033. These definitions have now received wide acceptance.

The next development phase for D 5033 was an outline of "how and when to use or specify recycled products". The guide should balance recycled vs. virgin resins. The goal was to discuss how to specify, how to define percentages and whether to identify the fact that the finished product included recycled materials. Discussions included additional restrictions regarding possible contamination, whether recycled plastic should be recommended and restrictions relating to the use of recycled plastics vs. virgin materials.

Some of the key elements within the guide that could be of assistance in determining the use of recycled polymers are:

- D 5033 encourages the inclusion of recycled plastics in standards relating to materials and products specifications to reduce problems relating to waste disposal and to conserve energy;
- The guide states that standards should not be downgraded to allow for the use of recycled materials. Necessary levels of performance should be main-

tained. If it is necessary to define a second and lower level of performance, then a different standard would be formed. This is quite acceptable. In many standards, products are classified, i.e. Class A for virgin, Class B for recycled;

- The document says standards activities should concentrate on the increased use of recycled plastics without trying to address modifications relating to "regrind," "reprocessed" or "reconstituted" plastics. These are intermediate materials produced in the normal, first-time manufacturing;
- The standard discusses identification or labelling to assist buyers in purchasing;
- Also, D 5033 states that it may not be required to mention the use of recycled plastics with labelling when recycled polymers are not restricted by performance standards.

Other key paragraphs of the guide relate to performance vs. design standards, quality assurance, labelling and marking, the possible colour coding of degradable products, available ASTM references, separation and segregation problems, the importance of identification of the polymer "class", the presence of contaminants and contaminant removal, the use of recycled materials as fillers, and the use of colours as additives in recycled plastics.

The third area that was necessary to address related to identification and labelling of the products.

Identification and generic labelling are very helpful and necessary for separation and sorting and are of great assistance in keeping materials clear and clean. They are helpful in identifying generic polymers so that producers can obtain the maximum utilization of recycled plastic in the highest quality products, and in identification of additives, reinforcements, fillers, flame retardants, etc.

Some of the remaining issues in the area of recycled plastics include the question, "When can recycled plastic be used?" and the need for specifications for recycled resins and recycled products.

A key controversy still exists—"Do the present specifications, i.e. plastic pipe, allow for the use of recycled resin?" In D 5033, paragraph 6.2.1 stated:

"Unless a specification or other standard specifically restricts the use of recycled plastic, and justifies the restriction based on performance standards, then recycled plastics can be used as a feedstock. It is not necessary to specifically mention in a specification or standard that recycled plastic can be used."

This has developed into a great controversy in the United States and other countries concerning standards that do not specifically mention recycled plastic in any way. Many of these standards were developed 10 or 20 years ago when recycled plastic was not a consideration. The subcommittee had to face the issue of whether it is acceptable to use recycled resins in the standard and do so without notification or labelling.

Since reference to recycled plastics in older standards remains an area of controversy, changes have been proposed to D 5033 recommending the clear indication of whether recycled materials are to be included.

Many new specifications are being written for recycled plastics. An example is standard D 4066, Specification for Nylon Injection and Extrusion Materials (PA). Various grades (i.e., 5, 6, 7 and 8) are listed for resins made from recycled nylon.

Another key specification for recycled resins is standard D 5203, Specification for Polyethylene Plastics Moulding and Extrusion Materials from Recycled Post-

Consumer (HDPE) Sources. This is a resin specification addressing only resin of 100 per cent recycled materials. This document covers resins made from recycled blow moulded bottles (household chemicals), blow moulded bottles (milk, juice and water) and items fabricated from spunbond materials of high density polyethylene.

There are many activities under way right now within ASTM Committee D-20 and Subcommittee D20.20 on Plastic Products regarding specifications for products made from recycled resin. One is a draft document, Specification for Manufactured Recycled Plastic Lumber and Shapes.

An additional new project being pursued is for recycled plastic flooring. This too is being developed in Subcommittee D20.20. The draft document is titled Specification for Recycled Plastic Flooring. This standard is aimed at plastic flooring similar to traditional "oak flooring" (planks laid in with tongue and groove fittings). The material has been evaluated against the standard lumber tests including indentation, friction, compressibility, flex, long-term creep, etc.

Another area of development relates to plastic rods, sheets, tubular bars and plates. Again, this is within D20.20 and involves the draft document, Specification for Nylon Extruded Shapes (PA). This standard, while being developed for virgin material, will also include categories for recycled materials. In this case, the recycled products are being separated by classes and identified as such. This subcommittee is drafting similar standards (for extruded products) for acetal, polycarbonate, polypropylene and polystyrene.

There remains a great deal of confusion about recycled products. There should be no doubt as to the quality of products made from clean, single-source recycled materials. Almost any single-source, clean product can be recycled into a very high-quality, useful end use product. However, the issue is one of quality assurance. Problems have been, are, and always will be related to obtaining consistent quality. Therefore, the aspect of quality assurance is a key element.

Subcommittee D20.95 on Recycled Plastics has developed a document covering quality assurance of recycled resins and products. Outlining the need for quality management systems, the draft is based on general principles from ISO 9000 and the new automotive standard QS-9000.

A second key area relating to quality is the proper sampling of mingled waste and the quality of finished parts. There is a need for the use of sampling and selection plans, and acceptable quality levels (AQL).

A solid foundation has been laid regarding the terminology, specifications and systems of recycling plastics. This upward trend will have tremendous effect on the recycling programmes in North America and will go a long way towards making the programme viable and economically feasible.

There will be growth in the recycling of plastic, but only if failure rates are low. The industry must continue to implement the proper matching of systems (source to product), product innovations, process developments and stringent quality assurance systems. (Source: *ASTM Standardization News*, July 1995).



## F. CALENDAR OF EVENTS

### Recent and future events

#### **Plastics Waste Disposal '95**

28-29 November 1995

Hotel Intercontinental, Frankfurt  
Wilhelm-Leuchner-Strasse 43  
60329 Frankfurt am Main

#### *The Conference Desk*

First Europe Communications  
85 Clerkenwell Road  
London EC1R 4AR  
UK

#### **13-15 February:**

*Plastics Fair Dallas*, Exhibition.

Dallas Convention Center, TX, USA.

Contact: Louise Bouhasin, Advanstar Expositions,  
7500 Old Oak Boulevard, Cleveland, OH 44130, USA.

Fax: +1 216 826 2801

#### **14-15 February:**

*ColourPlas '96*, Conference, UMIST, Manchester, England.

Contact: Corporate Development Consultants,  
3 The Plain, Thornbury, Bristol BS12 2AG, UK.

Fax: +44 1454 413 421.

#### **16-21 February:**

*IndPlas '96*, Exhibition & Conference,

Netaji Indoor Stadium Calcutta, India.

Contact: India Plastics Federation,  
13/A Govt. Place East, 2nd floor, Calcutta 700 069, India.

Fax: +91 33 248 0765

#### **29 February - 3 March:**

*Plastex III*, Exhibition, Cairo International Convention Center, Egypt.

Contact: Arab Communication Group,  
30 Adnan El-Madany St., Sahafieen, Giza, Egypt.

Fax: 0090 202 302 3628

#### **18-22 March:**

*Globec '96/Recycle '96*, Environmental Technology Conference,

Congress Center, Davos, Switzerland.

Contact: Maack Business Services,  
Moosacherstrasse 14, CH-8804 Au, Switzerland. Fax: +41 1 781 1569

#### **19-23 March:**

*Entsorga 1996*. International waste management and recycling trade fair.

For more information, contact:

Messe-und Ausstellungs-GmbH Köln,  
P.O. Box 210 760, 50532 Cologne, Germany.

Tel: +49 221 8210; Fax: +49 221 821 2574.

## G. PUBLICATION—BOOK REVIEW

### Plastic Waste—Options for Small-Scale Resource Recovery

Editors: Inge Lardinois, Arnold van de Klundert, Waste Consultants

#### Introduction

Since the publication of Jon Vogler's book *Work from Waste* in 1981 there has been silence in the field of small-scale resource recovery, which often takes place within the so-called informal sector. No second edition or new books have appeared dealing specifically with micro-recycling businesses. Within that time, however, the scale of resource recovery in many economically less developed countries has increased at an impressive rate.

Government authorities often regard informal waste recovery activities with disdain. It is usually the poorest people, often those at the margins of society, who roam the streets and waste dumps to find items that can be salvaged and sold, to earn their daily bread. Scavengers are often seen as social outcasts, their businesses as informal, and their work as a nuisance to modern urban life. Nevertheless, municipal authorities everywhere are facing mounting problems in dealing with the growing volumes of solid waste. Conventional approaches to dealing with waste have included the purchase of "high-tech" equipment such as compaction vehicles, incinerators and computerized routing programmes, usually with little regard for its potential impacts on existing informal systems of recovery. In particular, potentially valuable components of the waste are destroyed, resulting in the loss of means of survival for the large numbers of people who work in the informal waste sector. Although a great deal has been written about the need for appropriate technology, decision makers in less developed countries, as well as donor agencies, seem to have underestimated the complexity and thus the vulnerability of such high-tech waste disposal technology, as well as its high maintenance costs and the need for skilled operators.

But the atmosphere is changing, and attention is now focusing on finding ways of dealing with the problem of waste in cities that do not depend only on high-tech equipment. Waste technology that is feasible in high-income countries is usually inappropriate for the socio-economic conditions in less industrialized countries. The most appropriate solutions are now regarded as those that take into account the needs of the people who are already involved in the (informal) recycling business, and the financial capabilities of municipalities and national governments. Whereas industrialized countries have often taken the road of capital-intensive development, in low-income countries the large labour surpluses and low salaries should favour the choice of labour-intensive options. Wider issues such as the availability of space, climatic factors, and the existence and enforcement of environmental legislation also influence the choice of the most appropriate approach adapted to local circumstances.

In many newly industrializing countries, various types of local machinery and equipment have been developed in the waste recycling sector. A wealth of valuable experience has been gained in adapting and upgrading resource recovery processes so far, even though the processes in use could still be improved. One way to achieve this might be

to provide the micro-entrepreneurs with scientific knowledge at no or low cost.

Innovation in this sector could also be stimulated through the exchange of information (knowledge and experience) between micro-entrepreneurs in various parts of the world: the so-called South-South technology transfer. For example:

Waste plastics are often covered with sticky liquids and mixed with organic matter, making the sorting of plastics a dirty job for the thousands of scavengers at road and waste dumps. In India, this problem has been tackled by washing the waste plastics in a large concrete basin with water pumped by a small electric engine before sorting. The washed plastics are then dried in a rotating mesh drum and spread out on the ground to dry in the sun. This approach has helped to improve working conditions considerably: the waste plastics to be sorted are almost clean.

Such adaptations of processes and technology found in the Philippines or India may be useful for micro-entrepreneurs elsewhere to improve the quality of their products and working conditions. Although these changes may result in higher costs, they will also increase the monetary value of the waste products, and thus improve incomes and employment opportunities. This book documents several recycling activities set up by entrepreneurs, the technical and commercial problems involved and the solutions found.

A large proportion of the waste in less developed countries is recycled, and there are many success stories of the recycling sector, but little has been described in terms of micro-businesses. Individual experiences are passed on from parents to children, and neighbouring entrepreneurs may perhaps also benefit from innovations. But only rarely does information from Asia, for example, reach entrepreneurs in sub-Saharan Africa. Documentation of this locally adapted recycling knowledge and experience could assist many entrepreneurs in other less industrialized countries either to set up or to improve their businesses. It could also demonstrate to decision makers that feasible opportunities exist for removing and recovering solid waste.

There are of course many differences between, for example, Asian and African countries in terms of their economic and industrial development circumstances, so it may not always be possible for some experiences to be replicated. Asia, for example, has had a longer (formal) industrial tradition than Africa, which has its spin-off to the informal micro-enterprises in terms of the availability of knowledge and of second-hand machinery and (locally made) spare parts. These larger and formal industries also provide a market for semi-manufactured end-products. These differences in economic development, plus other differences such as population size, influence market demand and the waste materials produced.

This book is the second in a series on urban solid waste recovery, and represents an attempt to document the experiences of small-scale recycling entrepreneurs in cities around the world. There are considerable differences between these cities and the level of recovery of the materials investigated. For example, some waste materials such as plastics, rubber, glass and tin cans are reprocessed by many micro-enterprises, especially in Cairo and in Asian

cities, and are turned into either final products or semi-manufactured materials ready for use by formal industries. On the other hand, micro-enterprises are rarely engaged in the recovery of organic waste except where it is used for animal raising.

The recovery of solid urban waste certainly has the potential to contribute to solutions of problems such as unemployment and inadequate waste disposal. There is scope for implementation on a much broader scale than has been the case so far. If the urban poor populations of less industrialized countries are to benefit, however, the range of small-scale, low-cost and environmentally sound options needs to be developed and improved. It is hoped that this book will make a contribution to these efforts.

Further information can be obtained from:

WASTE Consultants  
Crabethstraat 38F  
2801 AN Gouda  
The Netherlands

Copies can be ordered from:

TOOL Publications  
Sarphatistraat 650  
1018 AV Amsterdam  
The Netherlands

ISBN: 90-70857-34-0; Price: US\$13.

Excerpts of particular interest are reproduced below.

**1. The economics of plastics recovery**

This chapter discusses some of the economic factors that are relevant for plastics reprocessing activities. Sections 1.1 and 1.2 deal with financial considerations (cost and benefits) at the micro-level. External macro-level factors that influence the feasibility of small enterprises, such as government policies and world market prices, are discussed in section 1.3.

**1.1 Costs**

The costs associated with plastics recovery can be divided into three main categories: raw material costs, production costs and transportation costs.

**1.1.1 Raw material costs**

The costs of raw materials for reprocessing differ according to the source, the quality and the type of waste plastics that will be used. Although the market situations in each country and city are likely to vary considerably, some general observations can be made. Industrial, commercial and agricultural waste plastics retrieved directly from the source can sometimes be obtained for free. When the plastic waste is picked straight from the streets, dustbins or collection trucks it may also be free, although the crews may sometimes demand a small fee. Waste plastic items obtained from households by door-to-door collection often have to be paid for.

The costs of raw materials for reprocessing enterprises depend, among others, on the type of upgrading carried out, for example sorting and cleaning and on the number of intermediate dealers involved. More information on the prices of the various plastics used as raw materials can be found in section 1.2. The end-product of one reprocessing stage, such as shredded material, can be used as the input material of the next stage, such as pelletizing. Thus, for each stage or activity in the recycling process, a separate cost-benefit analysis should be made.

Improving the quality of the end-product, such as by adding virgin plastics to the waste material, or by including additives such as pigments, will also add to the material costs.

**1.1.2 Production costs**

The most important production costs are labour, transportation (see also section 1.1.3), electricity and water, equipment and rent. Generally it is difficult to obtain reliable data on production costs, since (informal) reprocessors usually do not keep records. As an example, Table 1 lists the main production costs of a pelletizing workshop in Istanbul. This workshop is also partially involved in manual sorting, shredding and mechanical washing. In this case, sorting forms the most labour-intensive activity.

**Table 1. Main production costs (as percentages of total costs) of a pelletizing workshop in Istanbul, 1988**

	Percentage
Labour (five workers)	31
Transport*	22
Electricity, water, etc.	18
Rent (two floors)	7
Loan repayments and interest	9
Other costs	13

Source: Konings, 1989.

\* Long-distance and bulky low-density material.

The further extension of plastics reprocessing activities to include product manufacturing basically means that higher investments will be needed in machinery, and that these will incur greater expenditures on spare parts and maintenance. Also, a product manufacturing machine will consume considerably more electricity (by the larger motor) and more water (for continuous cooling) than a shredding machine. The necessary moulds for product manufacturing also add to the production costs. However, labour costs will diminish in relation to the other costs.

**1.1.3 Transportation costs**

As can be seen in table 1, transportation costs may constitute a considerable proportion of overall production costs, especially in the case of bulky low-density plastics. PE film from agricultural waste plastics, for example, is quite voluminous and is likely to be expensive to transport from the farm to a reprocessing plant in the city.

One way to reduce the costs of transporting such waste plastics is size reduction, by cutting or shredding. In Cairo, for example, transportation costs vary from \$5 to \$7.50 per ton for non-shredded polymers, but after shredding, these costs fall to \$2.50-3.50 per ton. In Istanbul, waste plastics imported from Europe are transported in compressed bales. For unknown reasons, this method of compressing plastics in order to reduce transportation costs is not used by local reprocessors and dealers.

The site of the reprocessing plant should therefore be carefully chosen in order to minimize transportation costs. Factors that need to be taken into account include the distances to the sources of plastic waste (such as waste dumps or factories) and customers, as well as the frequency

of collection. As a rule, suppliers of waste plastics in Istanbul do not provide delivery services, and reprocessors have to collect their raw materials themselves.

### 1.2 Benefits

For the reprocessor (involved in size reduction, pelletizing or product manufacturing), the clearest benefit is the income generated by selling the end-product. These reprocessors mostly deal only with plastics, and derive no income from selling the by-products. Waste pickers and traders may deal in more than one waste item.

The prices of recycled plastics depend, among other things, on their physical characteristics. For example, recycled pellets with poor properties may sell for only half of the price of pellets made from virgin material, while the prices for high-quality materials may approach those made of the virgin material. Prices also vary according to the cleanliness of the material. Dirt, foreign objects and moisture may represent as much 20 per cent of the original weight of the waste plastics, which will be lost during the sorting, washing and drying processes.

Table 2 shows the market prices of various waste plastics, the original polymers and high-quality imported waste plastics in Istanbul. It can be seen that the market prices of the various materials vary considerably, and increase with

each upgrading stage. It can also be seen that transparent and white scrap plastics yield pellets of higher value, since pigments can be added to give them any colour.

The market value of waste plastics and their products is determined by a number of other factors, including the availability and the price of virgin materials (which are determined by the price of oil); the accessibility of other scrap material (including the amounts of waste plastics imported from industrialized countries); the seasonal demand for the final product; the relative strength of the domestic economy; and government policies on trade, including import restrictions. The market for recovered plastics is characterized by a competitive structure but also by a high degree of volatility; the demand for and prices of waste plastics and reprocessed pellets can fluctuate enormously.

Table 3 lists the average market prices of reprocessed plastics in Istanbul, the increase in value after each reprocessing stage, and the value as a percentage of that of the comparable virgin material. It is clear that washing and manufacturing provide the largest increases in market value of the plastic material. The profit margins of small-scale industries that sort, wash, shred and pelletize waste plastics are about 20 per cent of total sales. Manufacturing can yield profit margins of up to 50 per cent.

**Table 2. Market prices (in \$/kg) of waste plastics after the different reprocessing stages, Istanbul, 1988**

Polymer type	Category	Sorted	Clean and dry	Shredded	Pelletized	Manufactured product
PE/PP	Original <sup>a</sup>	2.1-2.2				
Mixed	Contaminated unsorted waste	0.2-0.3				
PE (Alketon)	Transparent	-	1-1.5	-	2	-
	White	-	0.9-1.2	1.2-1.7	1.4-1.8	-
	Mixed colours	0.4-0.5	0.5-0.6	1	1.2-1.5	2.8 (30 mm diameter pipe)
PP (Mobylen)	General	-	0.5-1.2	-	1.5	-
PS (Anti-shock)	Industrial	-	1-1.5	-	2	-
PVC (Soft)		0.3-0.5	-	1		3.6 (Shoe soles)
PE/PP	Imported waste from Europe	-	1	-	-	-

Source: Konings, 1989.

<sup>a</sup> Obtained from PETKIM, the State-owned petrochemical industry.

**Table 3**  
**Increases in the average market prices of waste plastics after the various reprocessing stages, and their value as a percentage of that of the virgin material in Istanbul, 1988**

<i>Reprocessing stage</i>	<i>Market price (\$/kg)</i>	<i>Value increase (\$/kg)</i>	<i>Value of material relative to that of virgin material (%)</i>
Collecting	0.25	0.25	11.6
Sorting	0.40	0.15	18.6
Washing	1.00	0.60	46.5
Shredding	1.35	0.35	62.8
Pelletizing	1.60	0.25	74.4
Manufacturing	3.20	1.60	-
Imported virgin granules (PE)	2.15	-	100

Source: Konings, 1989.

As with the prices of the plastic waste material, the prices of end-products also vary enormously, depending on the form and purity of the material. The differences in prices also reflect the various reprocessing techniques, transportation and handling costs.

### 1.3 External influences

The viability of a waste plastics recycling plant will depend upon a number of important technical factors, and socio-economic and political circumstances. Macro-economic factors such as international prices and trading policies, government policies (including import restrictions), and municipal policies related to solid waste management will all determine the level of recycling that will be feasible.

In Cairo, for example, plastics were one of the first non-organic waste products to be reprocessed once their potential value was recognized. The increase in the value of waste plastics was due to a number of interdependent factors: the fluctuating prices of imported plastic polymers, the rising exchange rate against hard currencies, and rising domestic inflation. The Egyptian Government has played a crucial role by introducing laws prohibiting imports of most plastics products, with the exception of certain essential items such as spare parts. The Government has also encouraged the domestic production of polymers, resulting in a sharp increase in the production of plastics products. Consequently, the plastics reprocessing industry has provided employment for both technicians and unskilled labourers. This has led to a situation in which, of the 25 tons of waste plastics generated in Cairo each day, almost 15 tons are now collected, sorted and reprocessed.

In Kenya, the Government increased the levels of duty on imports several times in the 1980s, in accordance with a policy to reduce national expenditures on imported raw materials, technology and equipment. These moves have created positive conditions for the reprocessing of waste plastics for the future.

On the other hand, higher import duties may adversely affect other industrial sectors, for example local industries that depend on imported raw materials. In the Philippines, a 9 per cent import levy on goods of foreign origin was reduced to 5 per cent, despite the fact that the imposition

of the levy would boost resource recovery activities, especially of plastics (due to high raw material costs). Thus, there are limits to the level of import duties that can be imposed, but it will certainly affect plastics re-processing.

Municipal policies related to solid waste management also influence the level of recycling to a certain extent. Many municipalities have chosen to introduce capital-intensive waste collection and treatment systems, thereby overlooking the usually strong informal waste collection and recovery sector. The expensive waste compacting trucks that have been introduced by some city councils provide an example of an inappropriate technology that usually has a negative impact on the informal system. In low-income countries compaction does not reduce the volume of waste very much (the waste densities are already high because of the large proportion of organic material), but merely crushes the waste and mixes it thoroughly, making waste picking (including plastics), separation and recycling more difficult.

In several Asian countries the informal plastics recycling sector flourishes alongside the formal industries. Some small-scale entrepreneurs receive their training within the formal sector, and the availability of second-hand machines and locally manufactured equipment means that huge savings on capital investments can be made. The same is true in Turkey, particularly Istanbul, where for the last few decades the small-scale plastics reprocessing industry has benefited from the existing plastic goods manufacturing industry. Also, the prices of reprocessed pellets depend on the prices of the virgin polymers that are produced locally by PETKIM, the State-owned petrochemical industry, and those of German imports.

These examples demonstrate that favourable government policies and the existence of a well-developed indigenous plastics processing industry are crucial for the feasibility of plastics reprocessing enterprises.

### 2. Environment and health

Over the last decade, public awareness of environmental issues has grown considerably, especially in the industrialized countries of Western Europe and North America. Technologies have been developed to clean up

water, soil and air pollution (so-called end-of-pipe solutions), but these have become so expensive that priority is now being given to the minimization and avoidance of pollution. Rising transportation and disposal costs, as well as the shortage of land for waste dumps, have also clearly demonstrated the need to minimize the amount of waste that is generated, and to develop alternative waste treatment systems. Although the importance of environmental protection strategies has now been recognized, the implementation of possible measures is often rather slow due to economic constraints, the lack of political will, and because the change to cleaner production processes takes time.

In many economically less developed countries, environmental awareness is also increasing, particularly within government institutions and non-governmental organizations. However, in these countries it is even more difficult to change policies and to take appropriate measures than in the industrialized countries. Protection of the environment is not always a priority when survival economics dominate, and when foreign currency is so badly needed.

This chapter discusses the environmental and health problems that may be encountered during the various reprocessing stages. The sorting of plastics from municipal solid waste may be unhygienic, since this waste may contain pathogens that cause diseases. The waste may also contain chemical substances such as heavy metals, which may pose problems during reprocessing. Some steps that can be taken to improve the safety of reprocessing activities are also described.

## **2.1 Waste: a potential health threat**

For the individuals handling urban solid waste, one of the greatest health threats is posed by the pathogenic micro-organisms that may be present in faecal material in raw municipal waste. The micro-organisms that are the causative agents of such diseases as diarrhoea and dysentery spread from the excreta of infected individuals, via faecal oral transmission routes, and eventually reach other people either orally (in drinking water contaminated with faeces) or through the skin. Waste can also attract rats, and thus the diseases they carry, such as plague, endemic typhus and rat-bite fever. Flies and other insects are also responsible for the transmission of pathogens. These dangers are also present in collecting and sorting plastic waste from mixed municipal waste.

Waste recovery may create income-generating opportunities that can conflict with environmental and health considerations. Although, on the one hand, the reuse of plastic waste helps to prevent environmental degradation and pollution, the recovery methods themselves are often not environmentally sound and may pose serious health hazards to the workers. It is often difficult to determine the exact causes of human health problems, since they are likely to be influenced by a number of factors, and disease transmission routes may be long and complex. But, since it is known that waste collection and recovery activities pose environmental and health risks, ways should be sought to minimize these dangers as far as possible. Full assessments of the effects on both the environment and on human health should therefore be made in any choice of technology.

## **2.2 Hazardous effects of plastics**

### **2.2.1 Polluting substances**

In terms of environmental and health effects it is important to differentiate between the various types of

plastics. Most polymers (macromolecules) are considered non-toxic (PVC is an important exception). Polyethylene (PE) and polypropylene (PP), for example, are inert materials, but it should be realized that polymers are not completely stable. Under the influence of light, heat or mechanical pressure they can decompose and release hazardous substances. For example, the monomers from which polymers are made may be released and may affect human health. Both styrene (which is used to make polystyrene (PS)) and vinyl chloride (used to make PVC) are known to be toxic, and ethylene and propylene may also cause problems.

The environmental effects of plastics also differ according to the type and quantity of additives that have been used:

- Some flame retardants may pollute the environment (e.g. bromine emissions).
- Pigments or colorants may contain heavy metals that are highly toxic to humans, such as chromium (Cr), copper (Cu), cobalt (Co), selenium (Se), lead (Pb) and cadmium (Cd) are often used to produce brightly coloured plastics. Cadmium is used in red, yellow and orange pigments. In most industrialized countries these pigments have been banned by law.
- The additives used as heat stabilizers (i.e. chemical compounds that raise the temperature at which decomposition occurs), frequently contain heavy metals such as barium (Ba), tin (Sn), lead and cadmium, sometimes in combination.

From the heavy metals mentioned, lead and cadmium are the most serious environmental pollutants, and have different effects on human health, depending on their concentrations. When present at or above specific concentrations, they interfere with processes in plant and animal tissues, and in the soil.

Polymers such as PVC may also have serious impacts on the environment because they contain a number of hazardous substances. For example, PVC contains chlorine which can be released during heating as hydrochloric acid (HCl). As is the case with many other hazardous materials, HCl in itself is not an unfamiliar nor a necessarily harmful substance (it is produced by the stomach to digest food), but at high concentrations in the air it affects the human respiratory system. Pure PVC contains 58 per cent chlorine; when plasticizers are added, it contains about 49 per cent chlorine. From a survey of the composition of waste carried out in the Netherlands, it was found that the chlorine present in PVC contributes about 50 per cent of the total chlorine content of municipal waste.

Other potentially hazardous substances in PVC include the relatively large quantities of additives such as plasticizers (up to 60 per cent) and heat stabilizers (sometimes up to 3 per cent). In the opinion of some environmental and consumer organizations in Western Europe, the use of PVC and other plastics containing chlorine (or bromine), especially for packaging, should be halted entirely.

### **2.2.2 Air pollution**

Taking into consideration the process of plastic recycling, the most important environmental problem caused by the (aforementioned) polluting substances is air pollution, either within the reprocessing units or in the open air. During the extrusion process several substances, such as additives, may be released. Since PE and PP do not contain large amounts of additives, potential problems with PE and PP are far less than with PVC. While extruding

PVC, additives may be released, but also vinyl chloride and HCl.

One way of dealing with waste is to incinerate it. However, unless the combustion is complete, burning plastics within the waste may release considerable quantities of polluting substances. With complete combustion, almost 90 per cent of the plastic material is reduced to carbonic acid (CO<sub>2</sub>) and water (H<sub>2</sub>O). PVC is an exception to this rule, since the chlorine it contains produces HCl when burned. The incomplete combustion of PE, PP, PS and PVC can cause further problems, as CO and smoke may be produced. As a result of incomplete combustion of PVC also dioxins and other hazardous substances may be formed.

In the Netherlands, the largest proportion of total hydrochloric acid emissions into the atmosphere is produced by the incineration of waste. Chlorinated polymers, particularly PVC, are the principal sources of hydrochloric acid emissions. During waste incineration chlorodioxins are formed, which are highly toxic.

In the plastic waste reprocessing sectors of economically less developed countries, on the other hand, dioxins are not generally formed because the temperatures reached during the recycling processes are not high enough. However, the combustion of plastic material during the recycling process should be avoided at all costs in order to prevent the release of smoke and other hazardous substances.

In reprocessing machines, PVC may decompose and give off fumes of hydrochloric acid, which will speed up decomposition may damage process machinery, and may discolour and spoil the finished product. Processing temperatures for PVC range between 150 and 210° C, but decomposition may occur at temperatures as low as 180° C. These serious difficulties can be overcome by keeping the moulding period very short, and by adding a heat stabilizer.

### 2.3 Safety measures

In low-income countries many informal recycling activities do not comply with labour and health regulations. In Calcutta, for example, a survey showed that practically none of the plastics reprocessing units had obtained a health licence. The lack of safety arrangements and precautions, together with the polluted atmosphere in many working areas, may present serious health hazards, particularly for the workers themselves, but also for residents in the neighbourhood of the units.

Of course, if waste materials could be separated at source this would prevent mixing, resulting in cleaner waste fractions that are both easier to process and present fewer health hazards. The environmental and health risks arising from plastics recycling are different for each stage of reprocessing, but in general, plastics contaminated with unknown substances and mixed plastic waste pose the greatest dangers to human health and the environment.

However, a number of basic precautionary measures can be taken to improve general standards of hygiene and safety, and thus to protect employees, in plastics recovery activities. The following safety measures are strongly recommended:

- Protective clothing and gloves should be worn when sorting dirty waste plastic materials.
- Plastic materials should be washed before they are sorted; this will improve working conditions considerably.
- When using the burning test to identify types of plastics, try to avoid inhaling the fumes.

The sorting of plastics from mixed municipal waste may give rise to unhygienic working conditions, whereas clean material (e.g. from industrial sources) creates few health problems. Urban solid waste may contain large quantities of pathogenic micro-organisms that may cause infections.

The initial stages of reprocessing, such as washing and sorting, are often done in the open.

- Protection from the sun may sometimes be necessary. Mechanical reprocessing (e.g. shredding, pelletizing) of plastic waste is mostly done in workshops.
- Keep all working areas properly ventilated and kept as clean as possible.
- Ensure that dust and other emissions are prevented from escaping from the reprocessing equipment, and that waste in general is kept to a minimum.
- When handling machines, protective clothing (such as gloves, ear plugs, glasses) should be worn.
- During the shredding operation, face masks should be worn to avoid the inhalation of dust.

During the extruding process, the higher the degree of contamination of the plastics, the worse will be the odour created. This is because it is more difficult to fine-tune an extruder to the optimal melting temperature if the inputs are not homogeneous.

- All waste should be thoroughly cleaned and sorted before it is reprocessed; this will help to minimize odours, and will improve the quality of the end-product.
- Do not allow plastics to burn; the gases released may be toxic and pose a health risk to the workers.
- Avoid the use of PVC for recycling.

### 2.4 Product safety

Plastics reprocessing involves remelting the materials at high temperatures. This alters the chemical structure and results in an inevitable degradation of the material. Even the reprocessing of pure and well-defined plastic waste entails some sacrifice in terms of the quality of the end-product. It is important to realize that the process of recovering plastics in fact only delays the time of inevitable final disposal. Considering the benefits of plastics products for society, this delay should be prolonged to a maximum; this can be partly achieved by conserving the properties of the material as far as possible.

Some recycled plastics, depending on the type of waste, should not be used in products that will come into contact with food. In the case of a manufacturer's own waste materials that have not left their point of origin, the re-user is in complete control and can therefore be sure they are not contaminated. Such waste materials may be safely used for products that will come into contact with food. However, it is not advisable to use waste from unknown sources for such purposes, since the reprocessor cannot guarantee that the plastics contain no additives or contaminants, nor can they be removed by washing. In particular, poisonous substances such as pesticides pose a direct health risk. Also, oil or food residues may have been absorbed by the scrap plastics, which may spoil the properties and the appearance of the final product, or may even create an unacceptable smell.

Waste plastics from unknown sources should also not be used for toys, kitchen utensils and drinking water pipes, since it is impossible to know whether they are contaminated or not. In hospitals, plastics are used for many applications including packaging materials, which are

sometimes used for recovery. Plastic wastes from these sources must be approached with care as they may contain dangerous or unhygienic materials.

### **3. Future prospects**

Resource recovery may provide part of the solution to the problem of what to do with the uncollected heaps of waste found in the streets and around collection depots. It may also offer opportunities for income generation and the improvement of environmental and health conditions.

In many economically less developed countries the plastics reprocessing industry offers good prospects, mainly because of increasingly Westernized consumption patterns. The demand for plastic products is growing, and so are the amounts of plastic waste being generated as a result. Plastics recycling has some positive benefits for these countries: it can generate incomes, it requires relatively low levels of investments, it can yield reasonable or high profits, and involves relatively technically uncomplicated production processes.

This chapter gives an overview of some general conclusions that can be drawn from the information and the examples given in this book, and addresses some dilemmas concerning the future of small-scale plastics recycling in a sustainable waste management system.

#### **3.1 Feasibility and product quality**

The existence of hundreds of small plastics reprocessing businesses in, for example, Istanbul, Cairo and Calcutta clearly shows the viability of this sector. Part of this success is due to the use of cheap and sometimes freely available waste materials, which increases the profitability of small plastics reprocessing enterprises considerably. In principle, all the stages within the plastics recycling process can be profitable. The study carried out in Istanbul showed that washing and product manufacturing yield the highest profit margins (see table 3), even though the machinery being used was operating at only 60 per cent of its production capacity.

In Asian countries in particular, many people are engaged in plastics recycling activities. The initial stages of collecting, cleaning and sorting are labour-intensive and require low capital investments and little or no specific technical skills. In general, women tend to be involved in the initial stages, whereas men tend to be involved in pelletizing and product manufacturing activities.

As noted before, the quality of the end-product depends to a large extent on the percentage of waste plastics used. In general, the higher the proportion of waste materials used, the poorer will be the quality of the end-product, and the lower will be the price. Thus, the low-income groups will be able to afford plastic products made using a high percentage of reprocessed pellets. In Istanbul, for example, products of poor quality made entirely of waste plastics are sold at half the price of those made of virgin plastics, and therefore the demand is high.

Although the demand for low-quality plastic goods provides viable business opportunities in the short term, several other factors should be taken into account when seeking longer-term solutions to the problem of disposing of waste plastics. First, the life-span of products made from low-quality materials is short, and second, the degradation that inevitably occurs during the reprocessing of plastics reduces opportunities for further reprocessing in the future. Both the socio-economic and the long-term environmental benefits will be enhanced if the quality of the material and of the product can be preserved for as long as possible. At

present, however, both the producers and the consumers benefit from cheap but low-quality products. Ultimately, this dilemma can only be resolved by aiming at the improvement of the socio-economic status of the people involved, so that, in turn, they will be able to afford higher-quality durable goods.

#### **3.2 Starting a plastics reprocessing enterprise**

The effective operationalization of recycling activities in terms of product manufacturing in a low-cost environment requires, first, the establishment of an "industrial mentality". As illustrated in the case of the Zabbaleen small industries programme, this may take several years, and requires high investments in terms of continuous project guidance by experts. On the other hand, the Zabbaleen case also shows that in the long term there is a potential for newly established industrial product manufacturing workshops to become sustainable, which in the end may result in spin-off activities that generate additional employment.

However, if there is no local tradition in small-scale manufacturing of consumer goods, short-term successes may be easier to achieve by initiating activities such as collecting, washing and sorting plastic waste materials rather than product manufacturing.

Depending upon the demand, several types of plastics, such as PE and PP (various grades and colours), can be collected. These can be feasible activities and require only basic skills, such as the ability to identify the types of plastics. Such activities can be organized and implemented at short notice and have a high likelihood of becoming sustainable. The products (clean and sorted plastics) can be sold to existing formal plastics processing industries, which in itself will create useful business relations with these industries. Also for these activities, the achievement of maximum quality should be a major starting goal, not only to improve environmental conditions, but also because clean and sorted plastics fetch higher prices.

It is recommended that contacts with these industries are gradually extended in order to take advantage in terms of sorting skills, incidental know-how, second-hand equipment, spare parts and operating and maintenance skills and facilities. Then, a choice can be made to start the production of either shredded or agglomerated plastics material, based on the availability and the market potential of hard (rigid) or soft (film) plastics. Another important consideration is whether the necessary machinery is available locally. Once these early processing stages have been established on a firm, profitable basis, the development of a pelletizing, and eventually a product manufacturing, workshop can be considered.

#### **3.3 Improving working conditions and the environment**

Although the reprocessing of plastics can bring many benefits, including environmental improvement, recycling activities in themselves are not always environmentally sound and may pose health risks to the workers. Some examples of ways to improve working conditions have been given throughout this book, such as to collect clean industrial and agricultural waste, and to follow a preferred sequence when handling waste: mixed plastic materials should be washed before they are sorted. Also, a number of precautionary measures should be taken, such as wearing protective clothing and ensuring that the workshop is well ventilated.

However, it should also be recognized that the goal of improving working conditions for low-income groups will not be easy to achieve, because of the meagre financial



margins, the surplus of cheap labour and the low level of organization among workers. Another difficulty is the lack of knowledge of the precise dangers for human health when dealing with plastic waste within an informal setting. This applies not only in the collecting and sorting stages, when plastics are taken from mixed waste, but also and especially in the reprocessing stages when hazardous substances may be released, particularly during the reprocessing of PVC.

These considerations may pose a dilemma as to whether certain activities should be encouraged or not. Ideally, the same standards and criteria used in Western Europe and North America should be applied in less developed countries. But these health and pollution risks should also be seen in relation to the existing danger of exposure to other sources of contamination, such as domestic drinking water supplies and sanitation facilities. It is even of little use to improve working conditions or to forbid certain activities, when these individuals are often already struggling for survival and lack access to basic services. Also, no other income-generating alternatives may be available. For the long term, an integrated approach should be adopted, with the ultimate aim of improving the living conditions of the low-income groups and creating safe and environmentally sound employment opportunities.

### **3.4 Technology transfer and development**

Methods of recycling plastic waste have developed in very different ways in the various continents. In the industrialized world, only a small proportion of municipal plastic waste is reprocessed, and if it is done, the processes are capital-intensive and based on mass production of goods (such as fence posts). In contrast, in Asian countries, for example, many small enterprises are involved in such activities.

Until now, the transfer of (plastics reprocessing) technology has tended to occur from the industrialized to the economically less developed countries, although often the technology has not been directly applicable. The type and composition of waste, the lack of capital and specific technical know-how, the need for employment generation, the existence of a large informal waste collection sector and cultural attitudes are just a few examples of characteristics that must be considered when developing a sustainable solid waste recovery system in low- and middle-income countries. Technology transfer consists of more than just technical solutions; answers also have to be found to a number of other problems, including the provision of finance (e.g. to cover maintenance costs), the building of institutional capacity (e.g. management) and the avoidance of environmental pollution.

Due to these differences, efforts simply to transfer reprocessing technologies based on high-cost equipment should be discouraged. However, there should be a permanent awareness as to which specific incidental know-how or techniques or parts thereof could be of value to economically less developed countries. An example could be the development of safe and environmentally sound recycling technologies. Some important limitations, however, underlie this notion. In the Netherlands, research and development on processes is to a great extent executed and financed by the plastics industries themselves. Detailed information on processes is therefore not easily accessible, since it is screened off from the outside, competitive environment.

Also, the difference in prices between locally available machinery and imported Western equipment is enormous.

Low-income groups cannot afford such high investments; the question then is who will pay for this safe and environmentally sound technology. This poses a difficult dilemma as to which track for technology development should be followed in low- and middle-income countries.

While advanced technologies continue to be developed in the industrialized countries, very few innovations are being made within the informal sectors of most low-income countries. Thus, the gap between high- and low-income countries in terms of technology seems to be becoming even wider. This trend is alarming; instead of becoming a world where resources and wealth are more equally divided, the poor and rich seem to be drifting even further apart.

South-South exchange and technology development have not yet received the attention they deserve, and yet offer some opportunities. Entrepreneurs, especially in Asian countries, have shown that they are capable of inventing and adapting recycling technology to local circumstances, such as shredders or product manufacturing machines. This technology could be more suitable for transfer to sub-Saharan African countries, for example, and the machinery is also much cheaper than that developed in industrialized countries. The most important problem with this kind of technology is the hazardous situations it may create for both the employees and the direct environment.

In conclusion, opportunities should be created to optimize South-South exchanges of technology (through networking, exchange visits, etc.), and to enable a free flow of information from North to South. Also, possibilities should be created to attract funds for innovation within the informal sector.

### **3.5 Interdependence of the formal and informal sectors**

It appears that there are enormous differences in the scale and the technologies used in plastics reprocessing by continent and by country. As described previously, this depends partly on historical influences, such as whether there is an existing tradition of manufacturing, government policies and the level of industrialization within each country.

In many Asian countries, the informal plastics reprocessing sectors are flourishing alongside the formal sector industries. In terms of technology, to a certain extent, the informal sector is dependent on the formal one. Entrepreneurs often receive their training there and the formal industries often represent markets for reprocessed products, such as pellets, from the informal sector. The use of second-hand machines and the locally manufactured equipment means that huge savings on capital investments are possible.

Direct competition with formal industries should be avoided, however. In Nairobi, for example, the high level of competition from existing industries is a factor that has prevented the manufacture of high-quality reprocessed products.

In setting up and maintaining small enterprises, it is essential to establish business linkages with formal large-scale industries, because they are more powerful. Without their active participation, little collaboration is possible. Practical experience in Kingston, for example, and oral information suggest that formal industries (including multinationals) are becoming more interested in contributing to employment generation on the one hand, and recycling on the other. They are becoming aware of their responsibilities and the possibilities to create employment for low-income groups, and are striving to build up a "green" image, to

demonstrate that they care for the environment. Small enterprises may be able to benefit from these tendencies and to take advantage of the expertise available within these industries.

### **3.6 Public authorities and private initiatives**

From the viewpoint of environmental health management, the collection and disposal of waste is usually considered to be the responsibility of government or municipal institutions. However, municipalities in many low-income countries are often unable to cope with the ever-growing quantities of waste because of inadequate public funds, increasing populations, the lack of equipment and spare parts, and often poorly trained staff.

One major difficulty in municipal solid waste management is that the total costs of safe and environmentally acceptable solid waste disposal are poorly documented and are therefore underestimated. Besides, the potential of resource recovery is not used to its full extent, because its economic, social and environmental benefits are not fully recognized and valued. It is against this background that informal resource recovery needs to be supported in order to improve existing practices and to integrate it within municipal solid waste management systems. The various recycling possibilities should be incorporated at both the implementation and policy levels. In some countries, the contribution of the informal sector to waste collection and recovery is slowly being recognized and valued, and ways are being sought to integrate public and private systems in order to optimize both. Private companies and community-based organizations are increasingly taking over part of the responsibilities of the municipality.

Nevertheless, government authorities play an important role in the promotion and viability of plastics reprocessing activities, not only by their approach to local waste management, but also by the economic policies they adopt. For example, import regulations on virgin pellets may determine the feasibility and the level of recycling.

Some issues that Governments (as well as intermediary organizations) could address, depending on their resources and responsibilities, include the needs for the following:

- To facilitate plastics recovery activities.
- To recognize and integrate existing informal recycling networks within municipal solid waste management systems.
- To stimulate the development and implementation of appropriate technologies for plastics recovery.
- To formulate policies to protect and encourage the horizontal growth of small-scale resource recovery initiatives.
- To create legal frameworks and control mechanisms that will both improve safety in the workplace and protect the environment.

- To disseminate information both to the general population and to enterprises on the benefits of preventing the generation of waste and of recycling.

### **3.7 Towards sustainable integrated waste management**

The best way to prevent environmental and health problems caused by waste would be simply to avoid the generation of waste in the first place. Prevention should always be an important first measure. This is especially true for high-income countries where, for example, the packaging industry uses plastics unnecessarily. Stimulated by government legislation and the influence of environmental action groups, steps are slowly being taken to encourage the use of more efficient packaging. However, because of strong economic interest groups, for example, it is proving difficult to reduce or prevent waste generation, an objective probably not a priority at the moment for low- and middle-income countries, whose populations still cannot meet their basic needs and lack access to resources. To improve standards of living implies that without investments (for example, in developing cleaner technologies generating less waste and consuming less energy) the amounts of waste being generated (including plastics) will continue to increase. On the other hand, economically less developed countries are also responsible for creating sustainable livelihoods for their own populations and, despite obvious limitations, they should take preventive measures (such as to avoid unnecessary packaging, as well as to produce fewer types of plastics), as far as possible.

The treatment of waste near its point of generation, and the separation of waste at source could also be an important means of preventing the shifting of environmental problems to adjacent urban areas, to urban fringes, to more remote places, or to future generations. If waste is separated at or near its source, less sorting and processing will be needed later, and the raw materials are less likely to be contaminated.

The problem of integrating small-scale (informal) resource recovery activities within a sustainable urban waste management system is more a matter of perception than one of technology. To be effective, such a system requires interdisciplinary cooperation at different levels among various actors, such as municipal departments and councillors, national governments, non-governmental organizations (varying from welfare to environmentalist groups), research institutions, academics, community representatives, etc.

Many questions remain unanswered, however, such as how small-scale recycling activities can be optimized under local circumstances, and can best fit within a broader waste management perspective. From the practical experiences already gained all over the world, some of which have been described in this book, important lessons can be learned and conclusions can be drawn. Hopefully, these experiences may result in the adoption of more appropriate and sustainable solid waste management systems, including the increased and improved recycling of plastic waste.

**Appendix 1**  
**Characteristics of recyclable plastics**

<i>Resin type</i>	<i>Density (g/cm<sup>3</sup>)</i>	<i>Softening or melting range (° C)</i>	<i>Properties/applications</i>
Low-density polyethylene (LDPE)	0.910-0.925	102-112	Largest volume resin for packaging; moisture-proof transparent film
High-density polyethylene (HDPE)	0.94-0.96 0.95 (Coloured bottles) 0.96 (Clear bottles)	125-135	Tough, flexible and translucent material, used primarily in packaging; product examples include milk and detergent bottles, heavy-duty films, wire and cable insulation
Polypropylene (PP)	0.90	160-165	Stiff, heat and chemical resistant, used in furniture and furnishings, packaging; product examples include drinking straws, fishing nets, food containers, vehicle bumpers
Polystyrene	1.04-1.10	70-115	Brittle, transparent, rigid, easy to process, used in packaging and consumer products; product examples include foam take-away containers, insulation board, cassette and compact disc cases
Polyvinyl chloride (PVC)	1.30-1.35	150-200	Hard, brittle and difficult to process, but processed easily using additives; a wide variety of properties and manufacturing techniques are possible using different copolymers and additives; product examples include sheet, bottles, house siding, cable insulation

Source: B.A. Hegberg et al., *Mixed Plastics Recycling Technology* (Noyes Data Corporation, Park Ridge, NJ, USA, 1992).

## Appendix 2 Tests to distinguish polymers

<i>Polymer</i>	<i>Flexibility</i>	<i>In water</i>	<i>Relative density</i>	<i>Burning</i>	<i>Smell on burning</i>	<i>Scratches with finger nail</i>	<i>Can it be perfectly transparent</i>	<i>Notes</i>
<b>Low-density polyethylene (LDPE)</b>	Very flexible	Floats	0.91-0.92	Blue flame with yellow tip. Melts and drips burning droplets	Like candle wax	Yes. Easily	No	Has a waxy feel. Intermediate densities between 0.92 and 0.96 also exist
<b>High-density polyethylene (HDPE)</b>	Much less flexible than LDPE film. Crackles when bent	Floats	0.96	Ditto	Ditto	Yes with difficulty, especially when cold or weathered	No	Very tough, hard to tear
<b>Polypropylene (PP)</b>	Hard to bend but does not break when bent	Floats	0.90-0.91	Yellow flame with blue base. Can drip burning droplets	Ditto but less strong	No	No	Very strong. Forms an almost unbreakable hinge if folded
<b>Polyvinyl-chloride (PVC)</b>	Rigid PVC is brittle. Plasticized PVC can be very flexible	Sinks	1.2-1.6	Yellow, sooty smoke. Does not continue to burn if removed from flame	Pungent hydrochloric acid. DANGER. Do not inhale	Rigid PVC—No. Flexible plasticized PVC. Yes	Yes	Touch with a red hot copper wire to flame. Green flame indicates PVC or other polymer containing chlorine
<b>Polystyrene (PS)</b>	Very rigid and brittle	Sinks	1.0-1.1	Burns strongly with yellow sooty flame. Leaves no ash	Sweet	No	Yes	Makes metallic ring when dropped on a hard surface
<b>Acrylonitrile butadiene styrene (ABS)</b>	Less rigid than PS	Sinks	1.0-1.1	Ditto but leaves some ash	Rubbery	No	No	Often has silky surface finish. No metallic ring when dropped.
<b>Cellulose acetate (CA)</b>		Sinks	1.5	Like paper, not if flame is removed	Woody	No	Yes	Weak
<b>Polymethyl methacrylate (Perspex, acrylic) (PMMA)</b>	Brittle	Sinks	1.2	Yellow flame with blue base. No smoke. Does not drip	Fruity, sweet like flowers	No	Yes	Strong but brittle but will break if bent. Does not ring
<b>Nylon (N)</b>	Very flexible	Sinks	1.1	Blue flame. Melts and drips. Does not continue to burn if removed from flame.	Like burning hair	No	No	Very tough and flexible
<b>Polyethylene terephthalate (polyester) (PET)</b>	Very flexible	Sinks	1.4	Strong yellow flame with a little black smoke	Little smell—butter	No—unless very thin	Yes	Tough and flexible. Shiny surface. Crystal clear
<b>Polycarbonate (PC)</b>	Very tough	Sinks			Sweet			Can be bent (with pliers) without breaking
<b>Thermosets</b>								Hot wire will not penetrate

Source: J. Vogler, *Small-scale Recycling of Plastics* (Intermediate Technology Publications, London, 1984).

## **Glossary**

**Additive:** a substance added intentionally to a polymer mixture to alter its physical or chemical properties.

**Agglomeration:** the coalescing of small particles into a clump.

**Antioxidant:** an additive that inhibits a plastic from chemically reacting with oxygen.

**Blow moulding:** the established technique for producing bottles and other containers based on simple hollow shapes.

**Capital-intensive:** indicates that a relatively large percentage of the total production costs is associated with the initial costs rather than the operating costs; also used to differentiate from technologies which are labour-intensive.

**Colorant:** a dye or pigment added to the plastic to give it colour.

**Compound:** mix or combine (for example, plastic material with additives or pigments).

**Compression:** the reduction in volume causing an increase in pressure.

**Degassing:** removing unwanted gas.

**Extrusion:** the process of forming continuous shapes by forcing molten plastic through a shaped die by means of pressure.

**Feasibility study:** a technical evaluation to determine the economic or social viability of an activity.

**Flexibility:** the ability of a material to be deformed without fracture.

**Garbage:** household fraction of municipal refuse, which includes kitchen residues and other organic wastes.

**Granulation:** the size reduction of plastic materials into small particles using a granulator.

**Granulator:** a machine with rotating and stationary knives that cut the plastic material into small particles.

**Homogenize:** make or become of the same kind.

**Informal sector:** extensive economic activity which takes place beyond the boundaries of formal sector activity, usually small-scale, labour-intensive, unregulated and competitive.

**Injection moulding:** the process of manufacturing with plastic by forcing molten plastic into a mould under pressure.

**Labour-intensive:** a process or procedure requiring a large workforce.

**Macromolecule:** an alternate name for a polymer; giant molecule.

**Mandrel:** a cylindrical rod around which the plastic material is shaped.

**Market:** processor or end-user.

**Marketing:** the process by which buyers and sellers are brought together.

**Mixed plastic:** a mixture of plastics, the components of which may have widely different properties.

**Monomer:** a molecule that typically contains carbon and is of a low molecular weight (compared with the molecular weight of plastics), which can react to form a polymer by combination with itself or with other similar compounds, or: the small molecule that is reacted to produce a polymer.

**Municipal solid waste:** waste generated from household, commercial and industrial sources.

**Parison:** a hollow tube or other preformed shape of plastic that is inflated inside a mould in the blow moulding process.

**PE:** polyethylene.

**Pelletizing:** the process of melting and extruding small, clean pieces of plastic into small regularly shaped pellets.

**Plastic:** derived from the Greek work *plastikos*, meaning easily shaped. It is now used as a general term for all synthetic macromolecular materials.

**Plasticization:** the process of plastic material becoming soft and mouldable.

**Plasticizer:** an additive used to increase the flexibility or plasticity of a polymer.

**Plastics recycling:** a process by which plastic materials that would otherwise become solid waste, are collected, separated, processed and returned to use.

**Polymer:** the word is derived from the Greek words for many—poly, and small part—mer. A polymer is indeed made up of many small parts (monomers) to form a large molecule.

**Polymerization:** process whereby polymers are produced from monomers.

**Polymers:** a group of materials made of large molecules, which include plastics and rubber.

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