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Advances in Materials Technology: MONITOR

Issue Number 18 [illegible]

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Dear Reader,

This is number 18 of UNIDO's state-of-the art series in the field of materials entitled Advances in Materials Technology: Monitor". This issue is devoted to Plastics Recycling.

In each issue of this series, a selected material or a material-related technology as in this Monitor, a group of materials is featured and an expert assessment made on the technological trends in those fields. In addition, other relevant information of interest to developing countries is provided. In this manner, over a cycle of several issues, materials relevant to developing countries could be covered and a state-of-the-art assessment made.

The leading article for this issue was prepared by Dr. E. G. Wogrolly, Professor on Plastics Technology at TGM in Vienna, Austria, as well as by Mr. H. Richter, Ms. G. Grossmayer and Mr. W. Ulbert.

We invite our readers also to share with us their experiences related to any aspect of production and utilization of materials. Due to paucity of space and other reasons, we reserve the right to abridge the presentation or not publish them at all. We also would be happy to publish your forthcoming meetings (please see section "Past Events and Future Meetings").

We would be grateful to receive your opinion on possible subjects for our forthcoming issues. In this way we expect to have a dialogue with our readership to establish the feedback which will allow us to effectively monitor the developments in the field and better serve our readers, especially in the developing countries.

For the interest of those of our readers who may not know, UNIDO also publishes two other Monitors: Microelectronics Monitor and Genetic Engineering and Biotechnology Monitor. For those who like to receive them please write to the Editor, Microelectronics Monitor; and Editor, Genetic Engineering and Biotechnology Monitor.

Industrial Technology Development
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Plastics Recycling

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The Laboratory for Plastics Technology at Technologisches Gewerbemuseum, LKT-TGM, founded in 1957, is an institute for training, testing and research in the field of plastics technology. Engineers are trained in the Top-level secondary technical school as well as in the College for plastics technology; materials are tested at the Authorized National Testing Institute, research is carried out in the research institute of the Association for the Promotion of Plastics Technology (GFKT).
The Federal Ministry of Education and Arts (Office: Technologisches Gewerbemuseum, TGM) as the legal entity exercises administrative power on a national level, the GFKT as the legal entity in private business is also responsible for the Institute's international research and training programmes.

Content

PLASTICS RECYCLING

1. INTRODUCTION

In many countries up to 80 per cent, and sometimes more, of domestic and industrial wastes are at present disposed of on the land. In some countries crude dumping on marshes, in ravines or quarries is the practice. The refuse is left to rot and serves as a breeding place for flies, rats and other pests, creating bad smells and nuisance through smoke from fires.

But as living standards increase so also does the demand for improved environmental benefits, and insanitary practices, including crude dumping of waste, becomes increasingly unacceptable to a better educated and well-informed public.

The dumping of waste into the sea is still being done by some countries, but it is to be hoped that with the growing awareness of the increasing pollution of the oceans far more effective restrictions to such dumping will come into force (for example, following the 1990 United Nations Conference on the Mediterranean).

Recycling of plastics is a relatively young and developing industry which shows a trend towards an increasing growth. This also applies to reclamation of plastics from discarded industrial and consumer products, which contain plastic components.

New technologies, with examples of related plant and equipment are described in this report. It is felt that new developments in some countries can be successfully applied to others, resulting in "know-how" and licensing agreements.

This report includes information on

Forms of Recycling Collection of Plastics Waste Basics and Problems Economics of Different Transport Systems for Refuse Disposal of Waste - Basics and Technologies

About a third of the total plastics consumption finds applications in products of less than a couple of years life span, such as films, one-way bottles and other packages.

Recycling of homogeneous plastics is a straight-forward operation. However, the recycling of mixed plastics, including plastics from Municipal Solid Waste streams and the recovery of plastics from products incorporating plastics, requires special technologies.

Amongst the earliest applications of plastics recycling was the production of polyethylene(PE)-films where the process uses scrap and trims either by mixing it with virgin polymers in film production or using the regrind in the core layer of the multilayer extruded film, the two outer layers being made from virgin material.

The recycling to energy by various technologies is growing, and the calorific value of polymers offers great advantages when compared to other materials.

Nevertheless, there is very little acceptance of waste incineration facilities in public opinion. It should therefore be taken as a recommendation for these countries where it is still possible to establish waste-fuelled power stations (i.e. waste incineration plants) not to delay, but to immediately start with the drafting and designing of such plants.

Some commentators feel that recycling of plastics waste to energy is to be recommended only when recycling to materials is not economically feasible. On the other hand, the high calorific value of plastics is an important factor in recycling to energy by incineration combined with production of hot water and steam.

The cost of the growing amount of rubbish in landfill operations is steadily increasing. Recycling to materials and/or energy is becoming an urgent task.

The economics of recycling operations should be taken into account when considering the costs of landfill (negative factor). This means that the economics of recycling have to be calculated as follows:

$$a - b + c - d$$

a = the revenue from recycled material or produced energy
b = cost of recycling
c = savings from non-disposal in landfill
d = cost of disposal in landfill of the remaining tonnages after recycling [24]

The world consumption of plastics is estimated at approx. 70 million tonnes. The production figures for Western Europe and the USA being 20 million tonnes respectively and about 10 million tonnes in Japan. The following table shows Western European plastics consumption for 1987 by end-use industries, indicating that:

short lifetime use (less than one year) accounted for 20 per cent medium lifetime use (1-10 years) accounted for 35 per cent long lifetime use (more than 10 years) accounted for 45 per cent.

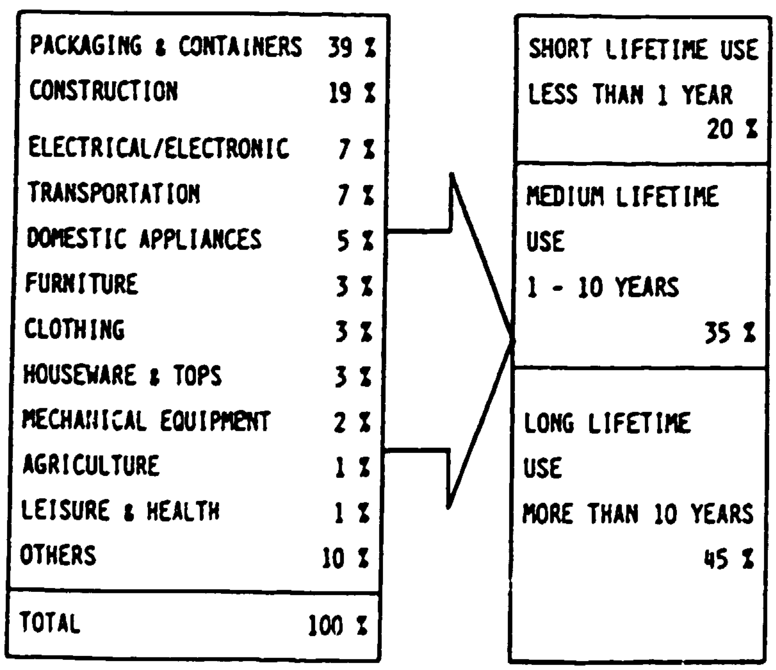


Figure:1

Municipal Solid Waste (MSW) in the Economic Community (EC) amounted to 100 million tonnes per annum, representing 4 per cent of the total solid waste of 2.200 million tonnes per annum (agricultural wastes of 1.300 million tonnes accounting for 59 per cent, and other solid wastes of 800 million tonnes accounting for 37 per cent). Plastics with about 7 million tonnes p.a. accounted for 7 per cent of Municipal Solid Waste in the EC in 1986.

The following illustration shows:

(a) the composition of MSW according to materials, (b) the composition of plastics in MSW.

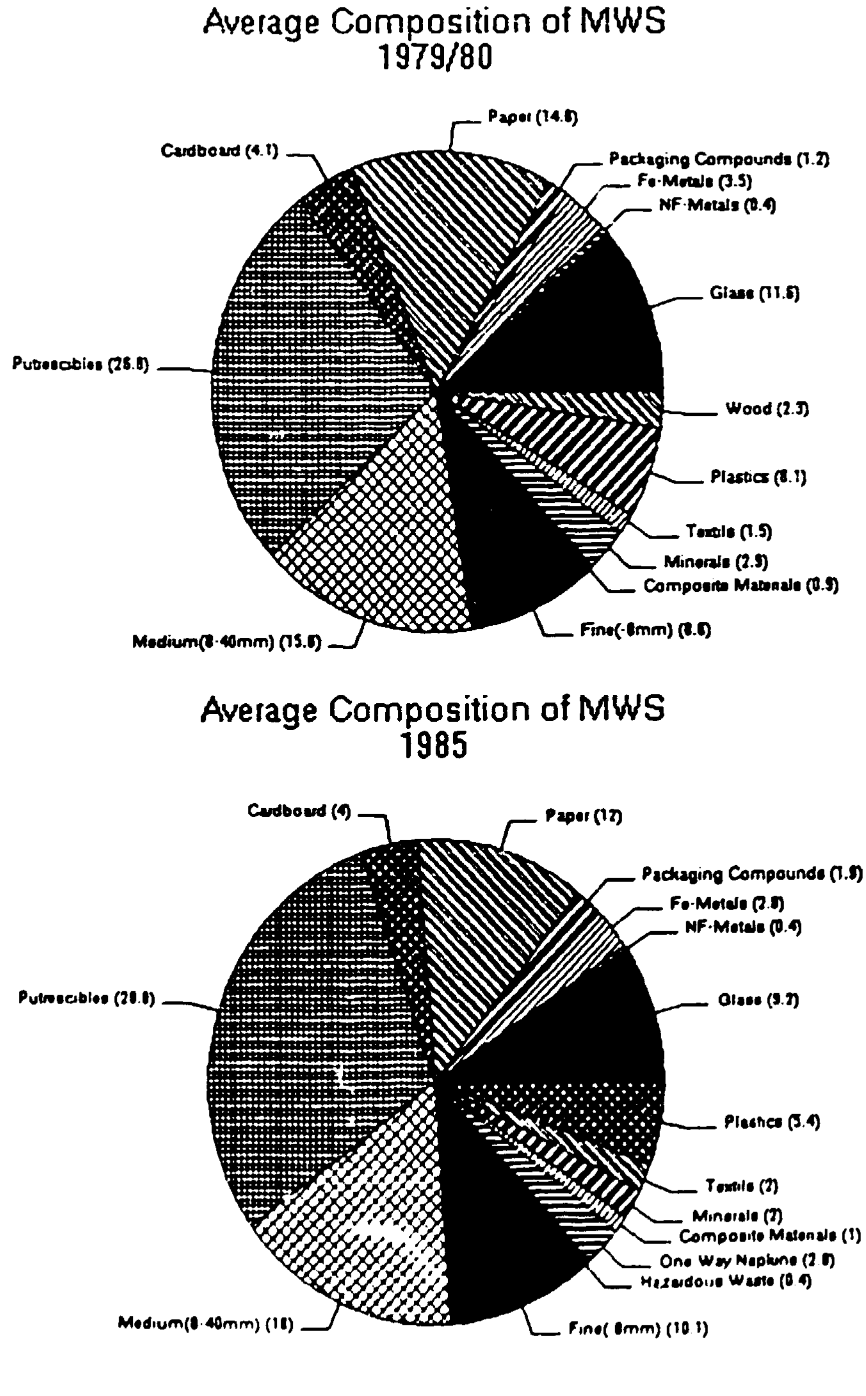


Figure:2

In general, waste management is sub-divided into four basic principles:

1. Waste reduction
2. Waste reclamation
3. Energy recovery and material-recycling
4. Waste disposal.

2. DEFINITIONS

In Austria, for example, solid waste management has been subject to standardization since the early seventies.

Apart from the Austrian Standard ÖNORM S2000, Austrian Law has its own definition of waste, but it is not very detailed.
According to ÖNORM S2000, waste is generally understood as solid refuse generated by private households, industry and public institutions. Because of its composition, it can be disposed of (by collection, transport and removal) without undertaking special measures.

Domestic refuse is waste usually originating from households, such as ash, slag, soot, kitchen refuse, food remains, textiles, leather, paper, packing materials, plastic containers, tins, beverage cans, metal goods, glass and small amounts of garden refuse. Factory waste in similar quantity and type is also called domestic refuse as opposed to street sweepings and other industrial waste, which is called special waste.

Industrial waste is refuse originating from manufacturing and processing activities caused by factories or public enterprises which is in type and quantity similar to domestic refuse. It can be liquid, solid or gaseous, vaporous or even sludgy.

Bulky refuse cannot be transported by ordinary waste collecting lorries because of its dimensions. This is generated by private households, industry and public institutions.

Special waste cannot be handled together with other waste either because of its composition or quantitity. Special safety measures or pre-treatment may be necessary.

The predominant proportion of waste is neither dangerous to mankind or the environment and is called non-hazardous special waste. After appropriate pre-treatment it can be handled together with other waste.

Hazardous special waste must be collected and treated separately. Measures concerning waste including environmental influences, are summarized under the term "waste management".

Waste removal is the deposition of waste (possibly after biological, biochemical, physical/chemical or thermal pretreatment) onto predetermined landfills.

3. FORMS OF RECYCLING

The recycling of waste is one of the oldest human activities. It may assume different forms:

1. Re-utilization of rejected articles, such as machinery, cars, appliances or clothing, often after previous examination, repair and cleaning;

2. Closed-loop recycling, i.e. the re-utilization of waste materials in applications similar to the original ones, e.g. making new steel from scrap;

3. Open-loop recycling, i.e. the re-utilization of waste materials in lower grade applications, e.g. making boards from waste paper;

4. Conversion of waste into new materials, such as fuel, compost or building materials.

The recycling potential of waste usually depends on economic factors, such as available quantites and grades, market value of the reclaimed products, available reclaiming equipment and not least, labour cost. [3]

4. COLLECTION OF PLASTICS WASTE

One of the main problems is how to organize the collection of plastics waste. The degree of contamination is determined by the mixture of the different types of plastics materials and other waste. The total amount of contamination determines the economy of the entire recycling-process.

The object of collecting plastics waste is to separate the plastics materials from the other waste already at source, i.e. at the producer. It may be worthwhile to make a distinction between the different types of plastics.

Preferably one should differentiate already waste collection at private households and industrial sites. Industrial waste is mainly generated in a form which is advantageous for recycling, while household waste is on the contrary usually mixed up with other material.

4.1 Waste stock exchanges

In many cases industrial waste recycling is complicated by the producer's ignorance, as he is not able to carry out the recovery process himself, nor does he know where to find companies who can do it for him. Waste stock exchanges are created to provide information for both the producer and the customer.

They are operated by different national and international institutions and try to obtain information on supply and demand. Their offers range from some kilograms of waste up to several tonnes per month. [4]

4.2 Plastics collection from households

Plastics waste originating from private households is principally collected together with other residual waste, contamination therefore causing a decrease in quality.

In the last few years different systems of waste collection have been introduced in order to sort out valuable material from the waste stream with little cost and high purity. There are two main systems available:

(a) Integrated collection systems (b) Additive collection systems

The integrated collection systems are sometimes called " fetch systems". The total amount of household refuse is collected in a number of dustbins (containers), each for a different type of material. The materials are collected simultaneously with the other waste.

Additive collection systems are independent from the conventional waste collection. They are based on the readiness and co-operation of the customer to transport the valuables to containers located at a central area. This system is called the "bring system".

4.2.1 The "fetch system"

To establish such a system in an area, a number of containers are used instead of a small dustbin. The number ranges from systems using two up to five or even more containers, with simultaneous or alternating removal, with combined or separated collection of different materials. One-way sacks (made of plastics or paper) can also be used.

Plastics materials are collected either together with materials such as paper, glass or metal, or separated into individual bags.

The expenditure for the customer is low, about 75 per cent of all plastics materials found in the refuse can be collected. The average composition of waste, determined by an analysis in Hamburg - Bergedorf in the Autumn of 1986 is shown in the table below: [5]

Composition of Plastics Waste	weight per cent
Polyethylene/Polypropylene	44
Polystyrene	25
Polyvinylchloride	15
Residual plastics	12
Non-plastics	04
total	100

Table:1

The total costs arise from the higher expenses of the system, determined by its type. Additional costs, extra to the basic costs, are about 45 to US$ 80 per tonne of plastics material. [6]

If only plastics are collected separately in addition to the normal municipal waste disposal, the specific cost would be about US$ 1,000 to 1,500 per tonne of plastics waste, which demonstrates that this would not be economical. [7]

4.2.2 The "bring system"

The "bring system" works on a number of containers being placed at central areas. The materials must be deposited by the consumer. The volume of the containers range from 0.5 to 5 m^3. Plastics materials are collected separately from the others.

The problem with this system is that a high motivation by the public is necessary. In practical experiments only about 3 to 8.5 per cent of the plastics materials in waste are returned. [5]

The success of this method is also influenced by the number of containers at a special area and their distance from individual households.

The results of the investigation of the composition of plastics collected in Hamburg - Bergedorf in Autumn 1986 are summarized in the following table: [5]

Composition of Plastics Waste	weight per cent
Polyethylene/Polypropylene	56
Polystyrene	19
Polyvinylchloride	13
Residual plastics	9
Non plastics	3
total	100

Table:2

The cost is reported to be approx. US$ 200 to 350 per tonne of plastics waste. [3]

4.3 Examples for the collection of plastics from household waste

In the following some examples of practical experiments are described. One was carried out in 1980 in the Federal Republic of Germany in the community of Radolfzell.

1980, Radolfzell - Böhringen, FRG

The duration of the test was three months. Bags for plastics waste were distributed to private households. The waste was collected weekly. The composition is described in the table below. [3]

Composition in per cent by weight

Plastics Material	Average	Minimum	Maximum
Film	36.0	5.0	52.3
Sheet material	8.2	1.4	19.2
[illegible] containers	7.6	6.4	10.0
Non-rolling containers	8.3	6.3	10.9
Containers 30 cm	12.3	7.8	20.8
Containers 10 cm	3.1	1.4	5.7
Margarine and Yoghourt cups	15.7	8.6	25.6
Massive parts	7.1	1.1	21.6
Foams, e.g. polystyrene	1.7	0.3	3.8

Table:3

France

Since 1970 a separate collection of plastics bottles is carried out in France. About one fourth of beverages are filled in PVC bottles, which amounts to 20,000 t/a; that is, approximately 20 per cent of the total PVC consumption in France. The PVC manufacturers are associated in a club named GREPP, which aims to recycle 40,000 tonnes of PVC (including PVC bottles) per year. At the moment 37 per cent of the waste PVC is collected and converted into products as such cable insulation and drainpipes.

Japan

Since about 1973 the separate collection of plastics materials as well as glass, metals and ceramics is practiced in the city of Tokyo, Japan. The proportion of the separately collected material is about 20 per cent of the total waste, of which 20 per cent are again plastics.

Vienna, Austria

In Vienna a test for separately collected material lasting one year was carried out in 1974/75. Special bags (refuse sacks) were distributed to 420 households and collected weekly. Thus 30 per cent of the plastics waste could be collected.

5. BASICS AND PROBLEMS

5.1 Influence of contamination

Contamination can be by three causes and can be divided into three different groups:

1. Contamination caused by contact with other waste materials 2. Defilement originating from use of the product 3. Non-plastics materials collected by mistake.

The highest external contamination (caused by other waste materials) occurs with the conventional single container collection. The degree of defilement is about 5 per cent. It can be decreased by separating the different components of waste in the households themselves. [8]

Contamination originating from the application of the product consists mainly of labels, metal closings and remains of the contents.

Because of the low density of plastics materiais (compared to the contents of the package) is only about one volume per cent of the contents, which increases the weight of the package by 10 to 35 per cent. [3]

Parameter	Einheit	Quark-becher	Joghurt-becher	Spül-mittel
Füllinhalt	g	500	150	500
Restinhalt	g	4,5	5	18
Restanteil	Gew.-%	0,9	3,3	3,3
Leergewicht	g	9	3,3	47
Verschmutzung	Gew.-%	33	60	28

Table:4

The contaminations of three typical packages make up 28 to 60 weight per cent of the total weight of the package, by drying it can be reduced to 5 to 15 per cent.
The contamination of the collected plastics material is determined by the collection system. About 5 per cent of non-plastics material is added by the consumers because of ignorance. [5]

Thus, recycled plastics from household waste for use in high-grade applications require an intensive cleansing-process and separation from non-plastics. Contaminations sticking to the plastics material can usually be removed by washing with water; the remains must be separated.

5.2 Influence of plastics mixtures in recycling

Mixtures consisting of different types of plastics can decrease the quality of the endproduct considerably. The table below shows the miscibility (1 ... miscible) and non-miscibility (6 ... non-miscible) of different types of plastics materials. The table refers to quality standards for new materials.

	Polystyrol	Styrol-Acrylnitril-Copolymer	ABS	Polyamid	Polycarbonat	Polymetylmethacrylat	Polyvinylchlorid	Polypropylen	Polyethylen
Polystyrol	-								
Styrol-Acrylnitril-Copolymer	6	-							
ABS	6	1	-						
Polyamid	4-5	6	6	-					
Polycarbonat	5-6	2	2	6	-				
Polymetylmethacrylat	4	1	1	6	1	-			
Polyvinylchlorid	6	2	3	6	5	1	-		
Polypropylen	6	6	6	6	6	6	[illegible]	-	
Polyethylen	6	6	6	6	6	6	6	6	-

Table:5

The three main fractions occuring in household waste (PE/PP, PS, PVC) are non-miscible. This prevents the application of mixed polymers for high-grade products.

If used only in low-grade applications, mixtures of plastics occuring in household waste can mainly be processed. Usually only the main-fraction, PE/PP, (50 - 65 per cent) is used for the production of plastics articles. [2]

In some cases, the separation proves to be impossible, e.g. sandwich materials are disadvantageous. This should be avoided by appropriate planning.

5.3 Additives in plastics materials

Normally the majority of plastics materials contain additives: they can be divided into those additives which increase performance, and those additives which facilitate processing. Processing additives do not exceed 5 per cent, but the proportion of fillers, reinforcing materials and plasticisers can be up to 70 per cent of the polymer, causing a severe problem:

The quantity and type of additives in recycled materials are unknown and therefore the performance of recycled plastics cannot be accurately predicted

5.4 Variations in design

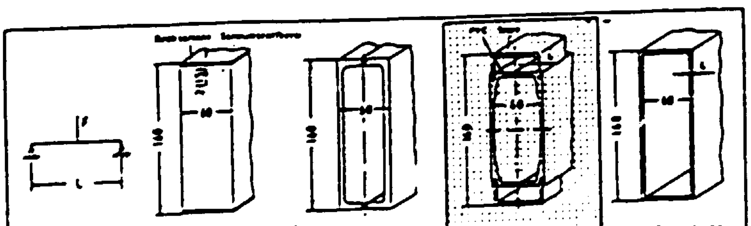
Usually consideration of the recycling process starts when the refuse should be disposed of. Thus only a small proportion of the total amount of waste can be recycled, and often only by means of expensive and complicated techniques, such as pyrolysis and hydrolysis.

It would be of advantage, if the designers would consider three points: marking of the end-product, homogeneity and appropriate assembling techniques to fit the part into the recycling process. There are two further points to consider:

1. Selection of the plastics type and the processing technique

2. Application of compounds (e.g. metal - plastics) instead of reinforcements.

The application of compounds provides a much easier recycling than glass- fibre reinforced products.



	[illegible]	[illegible]	Träger aus [illegible]	[illegible]	[illegible]	Stahl-Vierkantrohr
Recycling-aufwand	sehr groß	groß	sehr klein	groß	klein	mittel
Gewicht (kg/m)	6	5	5	4,5	7,9	13,5
Biegesteifigkeit (N·mm²·10¹¹)	2	6	0,2	2,6	9,4	11
DM/kg	5	6	2,40	11	2,60	2,70

Figure:3

The above table shows that the price/load ratio and the weight/load ratio is a minimum with a steel-thermoplast compound.

5.5 Marking of plastics articles

No perfect and economic separation method is available today. It is possible to separate the PP/PE fraction, but the PVC and PS fraction cannot be separated for economic and technical reasons. Therefore, a separation in the households by the customers themselves would be desirable. Thus it is essential to mark the plastics articles in order to give the consumer the chance of performing such a separation.

On the other hand, the chemical industry and the association of the plastics processing industry are afraid of prejudice against several types of plastics materials, especially against articles made of PVC, again because of ignorance.

5.6 Bio-degradable plastics

Basically, plastics were developed to obtain a corrosion-proof material. Therefore it would not make sense to use bio-degradable plastics for machine parts, but they would prove valuable for packaging materials. In that branch of industry the duration of the application of plastics articles is usually short. A long lifetime is not necessary.

5.6.1 Definitions

Degradable plastics are plastics materials which deteriorate under the influence of light, water, heat to macromolecules which remain biodegradable.

There are a number of advantages connected with these materials:

(a) Separation of the plastics materials from the household refuse is not necessary;

(b) landfilling needs less space;

(c) the litter problem could be solved by using such materials;

(d) medical applications: the human body is able to decompose plastics materials; and

(e) films for special applications in agriculture and food packaging can be produced.

5.6.2 Psychological reasons

Bio-degradable plastics can be decomposed by bacteria or fungii. Plastics can be disposed of without difficulty or extra cost.

5.6.3 Problems

Although bio-degradable plastics materials have many advantages, the problems listed below should be taken into consideration:

1. Bio-degradable polymers lead to an uncertainty with packages. A too early decomposition causes contamination or even loss of the product. Test and safety measures would prove necessary. Stock-keeping of products would become complicated.

2. The polymer must not contain toxic components which may migrate into the product during decomposition.

3. New technologies for recycling have to be found.

5.6.4 Assumptions

The requirements listed below are essential for this type of material:

1. Only non-toxic additives may be used.
2. The additives should not discolour the article.
3. Coloured or imprinted plastics must also decompose.
4. There should be a possibility of controlling the rate of degradation.

One way to manufacture bio-degradable plastics is by the use of bio- additives, such as starch in PP, PS or PE instead of conventional fillers.

Starch is one of the most important carbohydrates. It is produced in huge quantities, second to cellulose. A special type of enzyme fluidizises the starch and destroys the links between the macromolcules. Normally about 20 per cent of starch can be added to the polymer.

Difficulties occur in the distribution of the starch in the plastics materials, because starch is hydrophilic and most plastics used in the packageing industry are hydrophobic. A chemical treatment,such as curing, etherification or esterification proves necessary, but on the other hand these pretreatments cause decomposition problems.

A second possibility was found by Imperial Chemical Industries (ICI). They developed the bio-degradable polymer "Biopol".

Biopol is a bio-degradable thermoplast, consisting of the alipatic polyesters polyhydroxybutyrate (PHB) and polyhydroxyvalerate (PHV). [10]

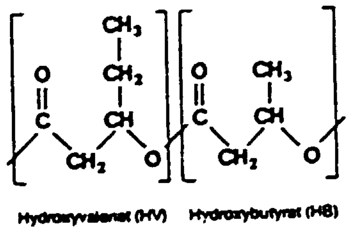


Figure:4

Polyhydroxybutyrate is manufactured by a chemical reaction caused by bacteria with sugar as basic material. The polymer can be processed by using conventional equipment. The performance of Biopol is determined by the portion of PHB and PHV and it can be reused several times.

5.6.5 Waste disposal

Biopol is manufactured from sugar and starch by a process of fermentation. It can be decomposed completely by bacteria and fungii which occur in soil. By means of hydrolysis an oligomer is formed, this acts as a food supply for the micro-organism and is decomposed. Biopol can be deposited at landfills or incinerated without causing any problems. Recycling of Biopol is possible, but not economic.

5.7 Direct reutilization of duromeric materials

Duromeric materials cannot be melted over and over again. Thus it is not possible to process them twice.

Nevertheless a technology to reutilize then has been developed based on milling and using them as filler in thermoplastic materials. The duroplastic material can substitute up to 20 per cent of the new material by improving the mechanical properties and reducing the costs. [12]

6. THE ECONOMICS OF DIFFERENT TRANSPORT SYSTEMS FOR REFUSE

6.1 Basics and problems

The major technical problems in transportation, refining, disintegration and treatment of waste, arise from differences between the mechanical, physical and chemical properties of the materials. Additional problems are caused by the collection of the waste, originating from the long distances between the waste producers and the recycling companies (landfills, power plants, etc.). Thus the waste transportation systems now used are becoming more and more uneconomic and new solutions for a wide area of waste disposition have to be found.

Instead of the dustcarts, economical and beneficial transportation systems could be used. Pneumatic tube transportation systems with suction pipes or pressure pipes could be built. For longer distances combined container traffic or other transportation systems, such as belt conveyors, could be used.

More careful planning of waste disposal systems and adoption of more purposeful and practical public cleansing systems would make it possible to use integrated refuse disposal systems. By this the entire method is meant by which refuse is transferred from the place where it originates to the place where it is finally returned to the industrial or ecological cycle. The figure below illustrates a number of different waste disposal systems.

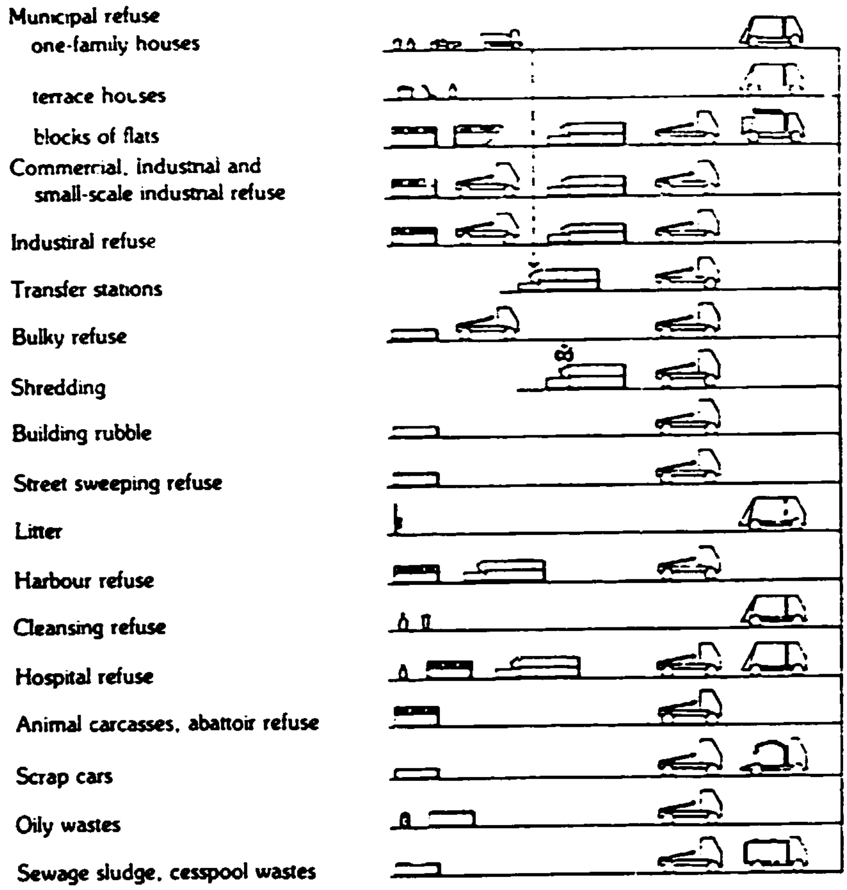


Figure:5

The refuse is taken from its place of origin to the local collection and transportation point near the house, where it is temporarily stored, then by way of the actual transport stage to the place where it is treated. Waste disposal systems can be devided into two sections, the collection (storage and transportation systems) and the treatment of the refuse. The points listed below should be considered:

1. The collection and transportation of refuse comprises a considerable part of the whole waste disposal process, since between 60 to 80 per cent of the total costs involved in waste disposal are spent on the collection and transport stages.

2. The development of refuse and collection systems and the smooth operation of these play an important part in the visible disposal of waste. The treatment of refuse and the ways in which it is finally disposed of on the other hand are not always seen as a part

of the overall urban picture. Nonetheless, they are reflected in the urban surroundings and in the total economic cost of waste disposal.

Although a waste disposal system can, in principle, be studied in two separate sectors it should nevertheless be borne in mind that the way in which refuse is treated may have a very significant effect on the choice of collection and transport methods.

6.2 Refuse collection and transport systems

Refuse collection and transport systems are integrated systems of equipment and methods by which refuse is transferred from the places where it originates to the sites where it is treated or pretreated. The ways in which refuse is collected and transported from a house or block of flats often form a separate stage from the stage where it is transported to the treatment site.

Household waste is mainly placed in bins or bags and carried from the kitchen to dustbins or refuse containers in the yards. Today newspapers and magazines are often collected separately. In large blocks there may be special chutes to facilitate the transport of refuse. Though very pleasant for the inhabitants, they are not very popular, partly for economic reasons and partly because of experiences, which have not been entirely positive with such chutes.

The collection of refuse and its transport away from homes is the most visible stage of waste disposal. Moreover, numerous systems have been developed for this stage of waste disposal.

Refuse collection and transport methods can be devided into four main classes:

1. Bin methods
2. Demountable container methods
3. Transfer loading methods
4. Pipeline methods.

Bin methods may involve the emptying of the bins or the exchange of full bins for empty ones, and the containers used may be of a permanent or disposable type, eg. sacks. Transfer loading methods are two-stage methods of transport and may be used with either bin methods or demountable container methods. Pipelines are also two-stage transport methods, the first stage being the actual pipeline system, and the second involving the use of a demountable container.

6.3 Bin methods

6.3.1 Refuse bin/truck equipped with boom crane

This method may be of the exchange type, where the full bin is exchanged for an empty bin by means of the truck crane, or it may be of the emptying method, in which the bin is hoisted onto the platform of the truck to be emptied and then returned to its original place.

This method has proven uneconomic, nonetheless, it is still in use in the Soviet Union, for example. [3]

6.3.2 Refuse bin/compacting refuse collection vehicle

The full bin, sack or small container (1 to 5 m^3) is emptied either manually or mechanically into the loading hopper of the vehicle. The refuse is then compressed by means of a compacting plate or screw device into the loading space of the vehicle. Such vehicles can transport about 50 to 80 m^3 of loose refuse at a time. This method is in general use throughout the developed world for the collection of household refuse and of industrial refuse similar to household waste.

6.3.3 Refuse sack/light collection vehicle

The full refuse sacks are collected by means of a mechanical loading device and a light vehicle equipped with a loading platform that can be tipped. Vehicles of this type can transport about 5 to 10 m^3 of loose refuse at a time. The method is used principally for the collection of household waste, mainly for transport to a nearby refuse dump or treatment site.

6.3.4 Container/compacting refuse collection vehicle with winch

The full container (usually 6 to 8 m^3) is emptied mechanically by means of a winch arrangement into the loading hopper of a compacting refuse vehicle and the refuse is compressed into the load carrying space of the vehicle. It can transport 50 to 80 m^3 of loose refuse. The method has become very widespread of late, since such a type of strong multipurpose vehicle can be used for transporting various types of refuse, even furniture and machines.

6.4 Demountable container methods

6.4.1 Refuse container/truck with demountable body equipment

The full refuse container is transported by means of a truck equipped with demountable body apparatus to the refuse treatment site or transfer station. The container is emptied by tipping. It can transport 5 to 20 m^3 of loose refuse. A very popular system is the Multilift demountable container system, even building refuse can be collected and transported with it. They are only used for household waste if 1 to 20 m^3 accumulates daily and the journey to the treatment site does not exceed 15 kms.

6.4.2 Compacting containers/truck with demountable body equipment

The refuse is collected directly or emptied from refuse containers into a certain compacting equipped apparatus. The full container is then transported by means of a truck with demountable body equipment to the refuse treatment site. Such a container can transport 40 to 80 m^3 of loose refuse. This method is widely used for collecting commercial and industrial refuse where the accumulation of refuse is 15 to 50 m^3 each day at least and the journey does not exceed 30 kms.

6.4.3 Refuse compactor/refuse container/truck with demountable body equipment

The refuse is collected directly or emptied from large containers into the loading hopper of a refuse compactor. The loose refuse is then compressed into a detachable refuse container attached to the compactor. The full container is then transported to a refuse treatment site. Such a container can transport 50 to 100 m^3 of loose refuse. The compactor/container system is mainly used for collecting commercial and industrial refuse and for collecting refuse from households producing 10 to 100 m^3 of refuse a day and where the distances are no more than 30 to 40 kms.

6.5 Transfer loading methods

Transfer loading methods involve two stages of transport where the refuse is transferred from one form of transport to another. Usually only transport by road is considered when talking of transfer loading. However, there are other methodes of transfer loading in use involving the transfer of refuse from road transport to rail or water transport. The principle of transfer loading methods is illustrated below. [3]

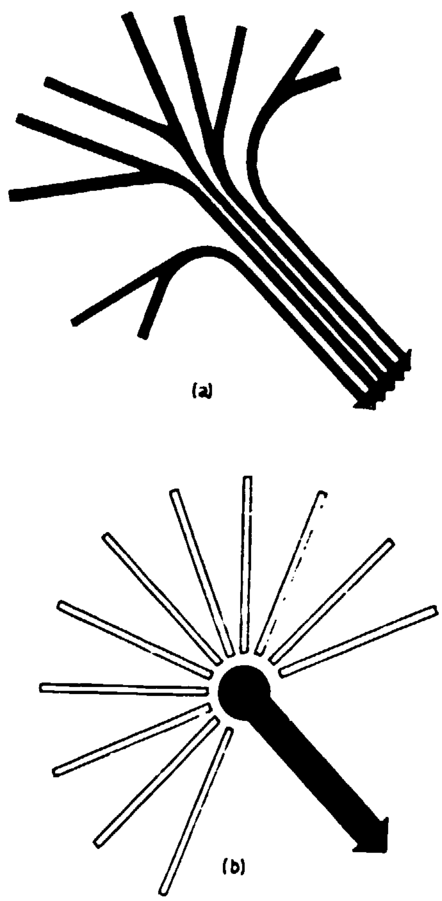


Figure:6 Diagram illustrating principle of transfer loading (a) The refuse is transported straight to the treatment plant (b) Refuse is taken first to the transfer station and then to the treatment plant

Transfer stations do not, provided they are operated properly, pollute the environment, furthermore they can be operated at relatively low cost.

The waste can be transported to the transfer station with the methods described above. In the station the waste can be put through a refuse shredder or a refuse crusher and afterwards is usually compacted by a packer plate or a screw compactor.

The transport containers used in this method are capable of transporting 100 to 150 m^3 of loose refuse at a time.

A transfer station can also be built in the centre of a large town, for example underground, as has been done in central Stockholm. Finland especially shows an increasing interest in the transport of refuse from water to land and vice versa. [3]

6.6 Pipeline methods

Pneumatic and screw methods of transport are widely used in industry for carrying different kinds of powdery and fine-grained materials. Since the early 1960's, pneumatic transport systems have also been used for municipial refuse. In addition to various collection and transport systems for household refuse, pneumatic methods have also been used for district refuse handling in residential areas where the refuse is collected and transported by means of a pipeline to a central refuse collection centre. At the centre the refuse is separated from the transportion air stream and then usually compressed into transport containers and taken away by trucks.

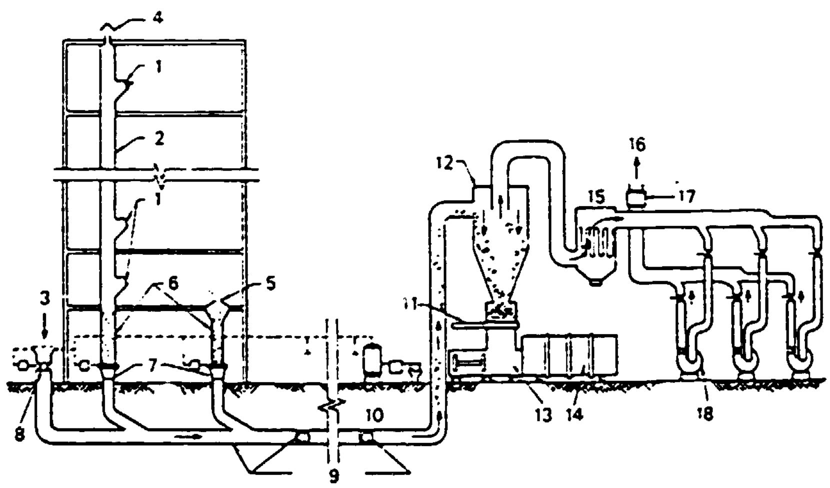


Figure:7 Pneumatic pipeline system for use in residential blocks[10]: (1) chute feed. (2) refuse chute. (3) air inlet. (4) relief inlet. (5) floor-mounted chute feed. (6) refuse storage section. (7) discharge valve. (8) air inlet control valve. (9) pipeline joints. (10) compressor. (11) slide gate. (12) cyclone separator. (13) compactor. (14) transport container. (15) air filter. (16) air outlet. (17) silencer. (18) exhaust blowers. (Reproduced from P.H. Luiten, in: *National Waste Processing Conference 1976*, by permission of The American Society of Mechanical Engineers).

The most important users of these methods are hospitals, government offices, industrial plants and heavily built-up residential areas. One considerable advantage, which has been increasingly stressed, is that the refuse does not have to be touched by human hand at any stage of the collecting process. Among the advantages of pipeline methods of transporting refuse are the absence of smells and noise, aesthetic and hygienic benefits and the reduction in traffic. Weighed against the ecological benefits are economic considerations and also technical difficulties, such as pipeline wear, and above all, the danger of blockages.

In the past years a new method, using a screw, has arisen alongside the pneumatic systems. Systems using water as a transport medium are also in use.

6.7 Transportation conditions for hazardous material

The number of transports of hazardous material has increased during the past years, up to 30 per cent of the European railway and road traffic. [2]. Industrial waste can often be classified according to several hazard classifications (eg. explosive materials, inflammable fluids, toxic, caustic or radioactive materials), thus precautionary measures have to be taken, a classification proves necessary.

6.7.1 Risk and transportation-safety

The problem in the transportation of hazardous material is mainly found in the following point: Ensuring the safety of the transport, of the transport devices and the people involved. Especially railway and road transports are performed in densely populated areas. Another important influence is pollution control. Safety measures must endure the whole lifetime of a hazardous material.

One of the most important points is the unification of the transport conditions.

There are several international regulations for:

road transport:	ADR	(Accord Europeen Relatif au Transport International des Merchandises Dangereuses en Route)
railway transportation:	RID	(Reglement International Concernant le Transport des Merchandises Dangereuses par Chemin de Fer)
shipping traffic:	IMDG	(International Maritime Dangerous Goods Code)
air traffic:	ICAO	(International Civil Aviation Organization)

These are accepted by most countries of the world. According to these regulations the classification of hazardous material is listed below:

Classification 1a:	Explosive substances and goods
Classification 1b:	Goods loaded with explosive substances
Classification 1c:	Pyrotechnics and the like
Classification 2:	Compressed, liquefied gases or gases solved under pressure
Classification 3:	Inflammable fluid substances
Classification 4a:	Inflammable solid substances
Classification 4b:	Self-igniting substances
Classification 4c:	Substances developing inflammable gases in contact with water
Classification 5a:	Flammable acting substances
Classification 5b:	Organic peroxids
Classification 6a:	Toxic substances
Classification 6b:	Disgusting substances or contagious matters
Classification 7:	Radio-active substances
Classification 8:	Caustic substances

The containers must resist against aggressive agents. Plastics materials are often used.

6.7.2 Unification of the hazard-classifications

In European rail and road traffic the international hazard classifications are valid.

For international traffic within Europe several transport conditions concerning tank cars transporting hazardous material listed in the regulations were added.

7. DISPOSAL OF WASTE-BASICS AND TECHNOLOGIES

Plastics refuse can be treated mechanically, thermally or chemically by various techniques. The goal of mechanical treatment is the recovery of a "regranulate", on the other hand chemical and thermal processes have been developed to provide the basic materials or to convert plastics refuse into energy.

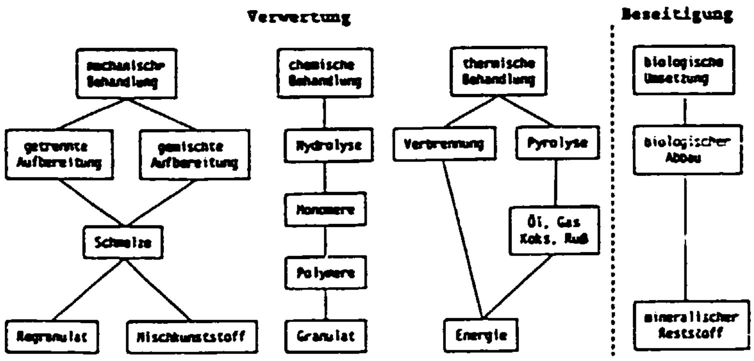


Figure:8

7.1 Material recovery by central sorting of household refuse

Material contained in household refuse can be recycled either after collection of source segregated materials or after centralized manual or automated sorting of refuse.

7.1.1 Basics and problems

The oldest simplest and most widely used sorting method is the hand-picking of valuable components from waste. Although most of these activities will meet criticism on hygienic, social and aesthetic grounds, it should also be stated that recovery on the dumpsite is an organised and basic part of developing economies all over the world. The capacity of sorting at a belt varies from a few hundred kg/h for light and bulky material to severals tonnes/h for dense material. Usually the belt moves at a speed of 10 m/min. [3]

Sorting methods can be subdivided into dry and wet methods. Dry methods are cheaper in investment and operating costs than wet methods, but they may create dust problems and explosion or fire hazards. Moreover, the recovered fractions are still contaminated with dirt or organic materials. Wet methods are more expensive, they yield a cleaner product, but give rise to a waste water treatment problem. The table shown below lists a number of dry and wet methods, with their size range of application.

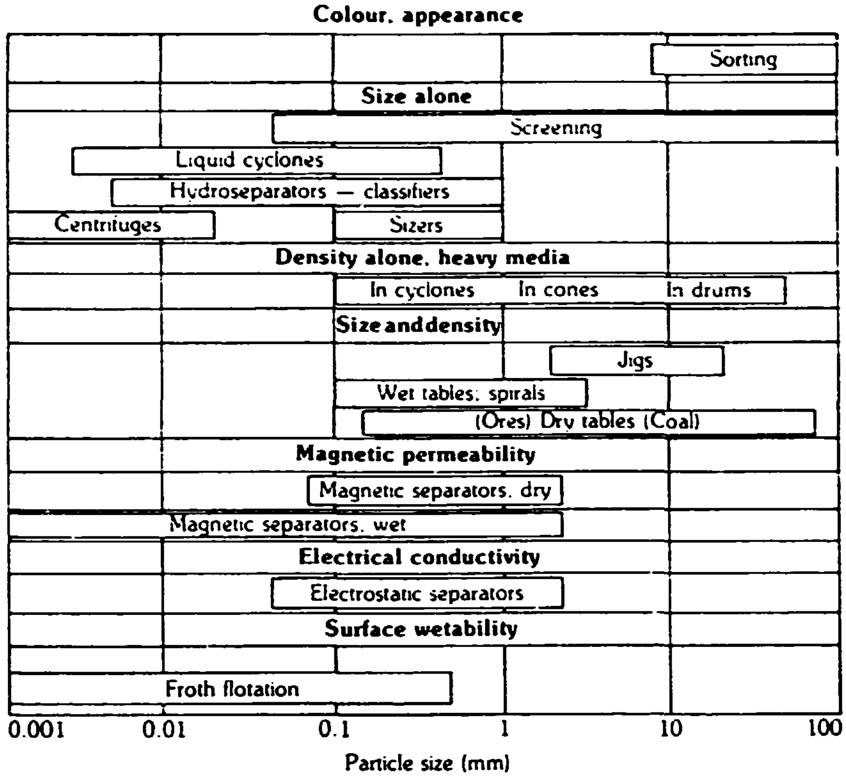


Figure:9

7.1.2 Yields and grades

Each sorting operation subdivides a feed stream into at least two fractions, between which the components of the original mixture are distributed. The performance of a sorting operation on a component can be characterized by a concentration ratio, a yield and a product grade. When a separator, for example, is used to extract plastics materials from a refuse layer, spread onto a conveyor belt, the previous factors can be defined as follows:

$$\text{Yield} = \frac{\text{Amount of plastics material in the concentrate}}{\text{Amount of plastics material in the feed stream}}$$

$$\text{Product Grade} = \frac{\text{Amount of plastics material in the concentrate}}{\text{Total amount of the concentrate}}$$

$$\text{Concentration Ratio} = \frac{\text{Flow rate of the feed material}}{\text{Flow rate of the concentrate}}$$

These factors should be as high as possible, but may be conflicting goals.

7.1.3 Size reduction

Size reduction is a basic operation for all separation methods. Hydrolysis and pyrolysis require only small size reduction, on the other hand there is a size reduction to small particles necessary for technologies such as screening and separation to remove non-plastics and separate the different types of plastics materials.

Size reduction in sorting systems can serve:

1. to make oversized materials more tractable;

2. to liberate entangled material;

3. to convert composite items to more homogenous materials; and

4. to give the feed stream an optimum, homogeneous size for a particular sorting process.

For all these reasons, shredding is the basic step for a large number of automatic refuse classification systems. But it can also be used as a selective classification method for specific feed streams:

1. Shredding of a mixture of paper and plastics films selectively tears the paper, expecially when this is moist;

2. Glass can be eliminated from plastics or metals by crushing it in an impact mill or a drum with filters. [3]

Hammer and flail mills operate on the basis of impaction and shredding.

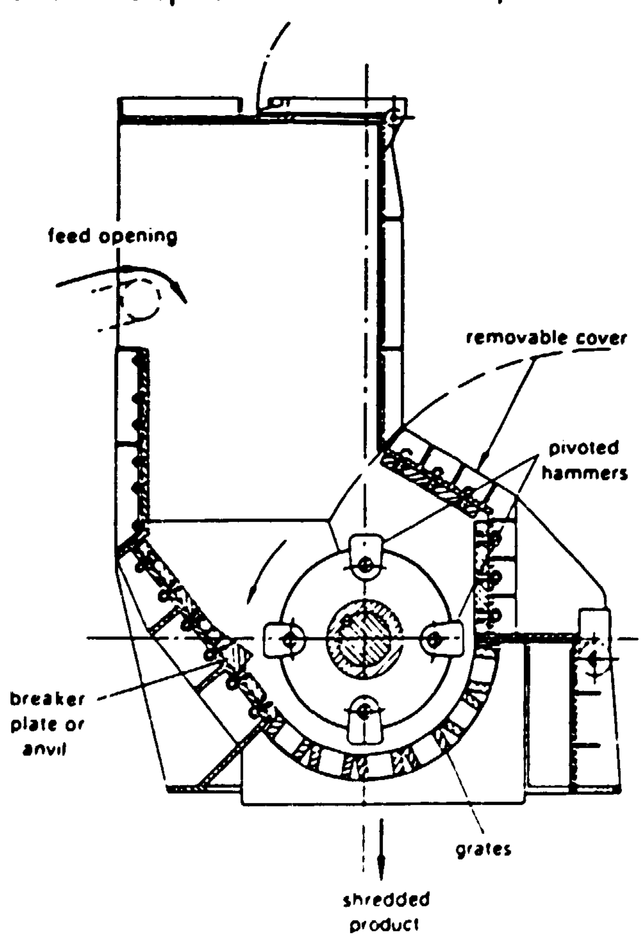


Figure:10

These consist of a heavy casing, with a single or double rotor, rotating at high speed (usually 1,000 to 2,000 rev./min.). Low speed knife or disc mills are used to reduce the size of the larger refuse components without extensive shattering of glass or cross contamination.

There are several problems forthcoming with size reduction. The equipment has higher operating and investment costs and during the shredding process the different components are cross contaminated.

Costs:

Low speed knife mills:	mass specific energy consumption:	30 - 35 kWh/t
	costs for a plant with 1,000 t/a:	35 - 45 US$/t
hammer mills:	mass specific energy consumption:	150 kWh/t

[13]

7.1.4 Screens and sieves

Screens and sieves are basic equipment used to:

1. protect downstream equipment against oversized and tramp material;

2. remove fines, which are either valueless (e.g. ash), or interfere with subsequent operations, such as the formation of slimes; and

3. prepare the feed stream for a particular sorting process which requires material in a given size range.

Raw or shredded refuse can be subdivided into several size fractions with markedly different compositions:

1. Fines (usually below 2 cm), containing ash, dirt, earth or shattered glass.

2. Middle fraction (usually 1-2 to 5-10 cm), containing a large part of kitchen and garden waste, small pieces of paper, plastics or metals.

3. Large fractions (usually 5-10 to 15-30 cm), containing a large part of reuseable paper, plastics and bottles. 4. Oversized material, consisting of large films, magazines, and miscellanous objects. [3]

For some separation processes, such as the sink/float separation process and other processing technologies, sizes of particles above 1 mm are necessary. Tests with a 6 mm screen in a hammer mill have shown that more than 45 per cent of the product was reduced to sizes smaller than 1 mm. This portion cannot be recycled. [2]

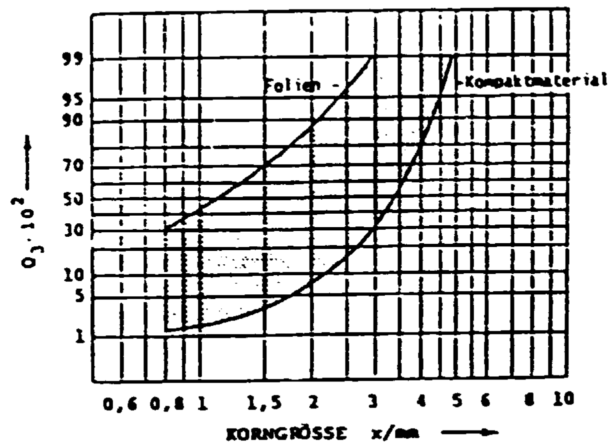


Figure:11

Drum screens, consisting of a slightly inclined, rotating cylindrical frame covered with a perforated plate, bars or wires, are mostly used in the screening of raw and shredded refuse. The most important operating problem with screens is their tendency to be blinded by wires, textiles etc..

7.1.5 Dry sorting

The success of the separation is basically determined by the particle size.

7.1.5.1 Ballistic separators

Ballistic separators are used to classify refuse according to the inertia of the individual components. The latter are dropped one by one onto a rotor and projected into a classifying chamber. The greater the mass of the particle, the greater is the travelling distance.

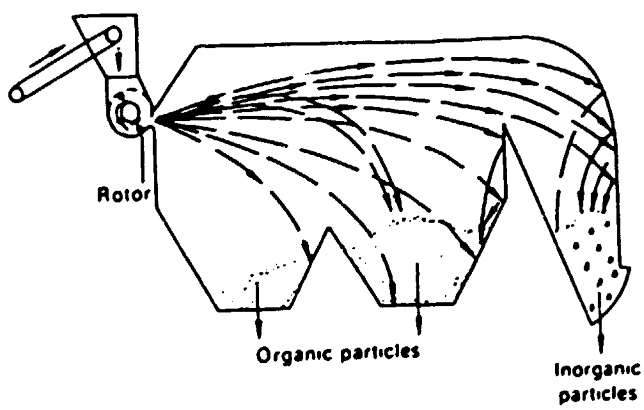


Figure:12 Ballistic separator. (Reproduced with permission from A. V. Bridgwater and C. J. Mumford *Waste Recycling and Pollution Control Handbook*, George Godwin/Van Nostrand Reinhold.)

In a sorting process developed by the Franklin Institute, refuse is shredded, screened and air classified. Material over 2.5 cm in diameter is hurled away by a rotating cogwheel in an almost horizontal direction and collected by one of three consecutive bins. [3]

7.1.5.2 Secators

The secator is used to separate hard and elastic materials from softer and lighter ones.

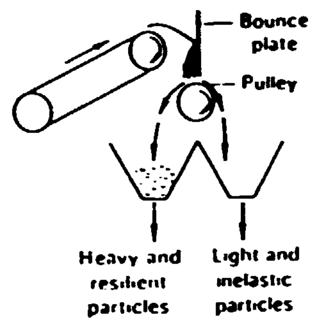


Figure:13 Secator. (Reproduced with permission from A. V. Bridgwater and C. J. Mumford *Waste Recycling and Pollution Control Handbook*. George Godwin/Van Nostrand Reinhold.)

The components to be separated are dropped onto an inclined band conveyor or onto a slowly revolving drum. The heavy, hard or elastic particles bounce up and move down by gravity, whereas the light and soft material adheres to the surface and is carried away.

7.1.5.3 Fluidized bed separators

Fluidizied bed separators have been invented for separating metal from cable sheath after chopping up electric cables.

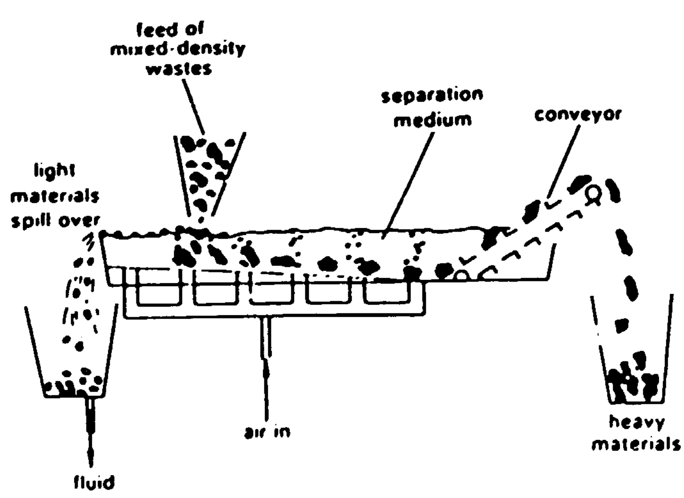


Figure:14 Fluidized bed separator. (Reproduced with permission from A. V. Bridgwater and C. J. Mumford *Waste Recycling and Pollution Control Handbook*. George Godwin/ Van Nostrand Reinhold.)

The separators are based on the sink/float principle, i.e. light particles flow atop and dense particles sink to the bottom of the bed. The separator handles material in sizes ranging from 0.2-10 cm and requires a miniumum difference of density of 0.2 g/cm^3.

7.1.5.4 Stoners

Stoners are slightly inclined perforated tables with a specific movement, so that dense particles climb faster than lighter ones. The latter are carried off downwards. An air current, rising through the perforations more or less fluidizes the mixture.

7.1.5.5 Air classifiers

Air classifiers separate waste components on the basis of falling velocity which is determined by weight and aerodynamic properties. They are major components of almost every dry sorting system.

Vertical classifiers give a sharper separation than horizontal ones. On the other hand their capacity is a factor 3-4 lower to allow the settling of particles without excessive mutual hindrance.

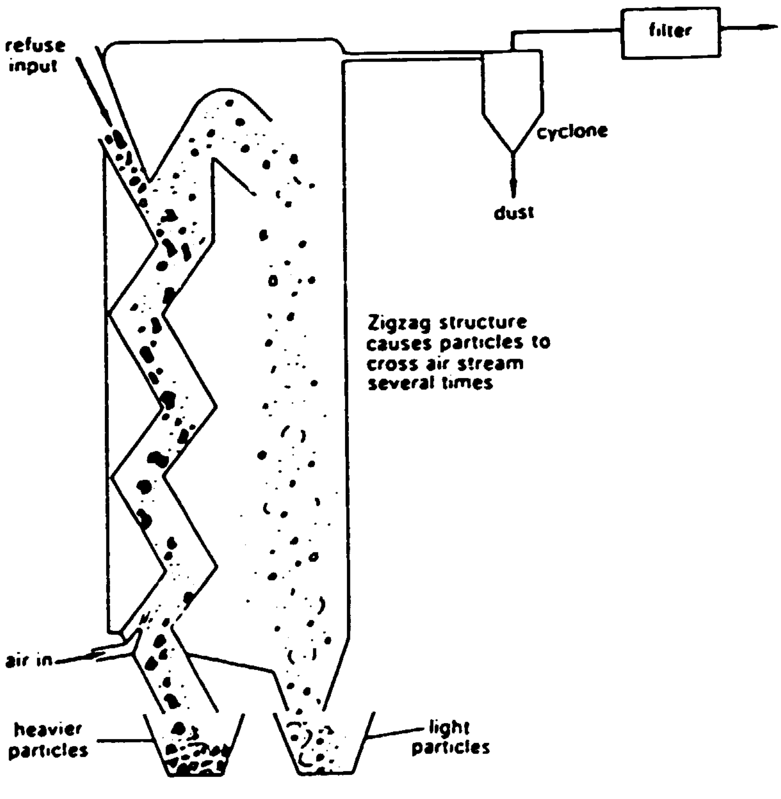


Figure:15 Zig-zag air classifier. (Reproduced with permission from A. V. Bridgwater and C. J. Mumford *Waste Recycling and Pollution Control Handbook*, George Godwin/Van Nostrand Reinhold.)

The best classification is achieved by zig-zag air classifiers.

Air classifiers can be used to reduce the portion of fines, having a size below 1 mm. A combination of screening and air classification has proven useful for high throughputs.

7.1.5.6 Vortex classifiers

Particles falling through an air vortex change their radial position under the combinded influence of gravity and aerodynamic forces and approach their equilibrium radius in a manner depending on their density and drag coefficient. Such particles can eventually be collected at convenient points. Air is used as a classifying medium; when the density is lower than one water is used for denser materials.

7.1.5.7 Optical sorters

Optical sorters have been developed to separate colour sorted glass from a concentrate of mixed cullet. They can nor be used for sorting household refuse nor for separating different types of plastics materials.

7.1.5.8 Dry magnetic separators

Dry magnetic separators are extensively used in refuse sorting, either to recover ferrous metal from shredded refuse or to remove tramp iron from various streams. The overband separator consists of a stationary electromagnet around which a rapidly moving rubber belt is fitted to capture and carry off the material lifted from the refuse.

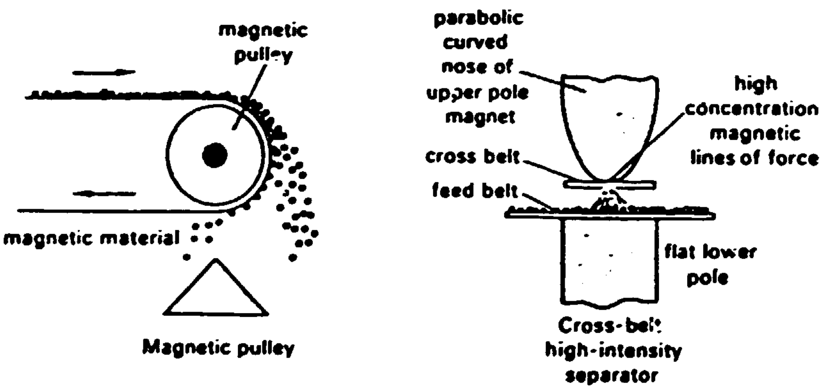


Figure:16 Magnetic separators. (Reproduced with permission from A. V. Bridgwater and C. J. Mumford *Waste Recycling and Pollution Control Handbook*, George Godwin/Van Nostrand Reinhold.)

On raw refuse, the yield of recovered material can be as low as 25 per cent; with shredded or sized refuse a yield of 50 per cent or more can be attained. The usual speed of a conveyor belt is about 1.5 m/s. The treatment cost is of the order of US$ 0.2 per tonne. [3]

This separation technique is often used after size reduction with a hammer mill, but before the knife mill in order to decrease wear.

7.1.5.9 Electrostatic separators

Electrostatic separators can be used to separate conducting from non- conducting particles, or even to separate non-conductors consisting of different materials. Typical applications include most paper/plastics, glass/aluminium, and different types of plastics.

In practice it is difficult to use electrostatic separators, because of the frequent occurance of short-circuiting.

The conductivities of polymers are very similar, therefore destaticisers have been developed to increase conductivity. This separation technology has proven uneconomic because of the lack of selective destaticisers. [2]

7.1.5.10 Metal detectors

These are used to detect small pieces of tramp metal. When a metallic particle passes through the detector, an impulse is generated. A deflection mechanism or an air jet is actuated by this signal and the metallic particle is ejected by one of these means.

7.1.5.11 Eddy current separators

Eddy current separators have been developed to separate metal particles from non-conducting ones. When a conducting particle is subjected to a variable magnetic field, an eddy current is generated which follows a closed circuit inside the particle. The induced current has its proper magnetic field which is opposed to the original field. The repellant force of the two fields can be used to deflect the metal particle from the feed stream.

7.1.6 Wet sorting

These methodes are mainly used for the purposes listed below:

1. to separate organics from inorganics by sink/float methods (e.g. for plastics recycling); and

2. to classify inorganic materials.

Wet processing virtually eliminates explosion hazards and dust problems. Fractions separated by wet classificators are generally cleaner than those obtained by dry methods. Unfortunately, they are generally more expensive in terms of both investment and operating cost.

7.1.6.1 Sink/float separation

A mixture can easily be separated into a light floating and a dense sinking fraction merely by immersing it in a fluid of intermediate density in which the individual components are insoluble. Water is a suitable fluid to separate floating organic from sinking inorganic material. Water/alcoholic mixtures of suitable density have been tested as a means for sorting plastics according to their various types (PE, PS, PVC, etc.). To separate materials denser than water, stable suspensions of very finely dispersed inorganic magnetic materials are used. The magnetism is necessary to separate them from the waste fraction later.

With the sink/float process plastics fractions with purities of over 98 per cent can be obtained. The separation of PVC-P (PVC Plasticised) is not possible. [15]

7.1.6.2 Wet classifiers

Wet classifiers are based on the differences in settling rates of dense and light particles of a constant dimension or between coarse and fine particles of a constant density. The driving force may be either gravity or centrifugal force, as in hydrocyclones and centrifuges.

7.1.6.3 Elutriators

Elutriators can be used to classify incinerator residue, car scrap, chopped electric cable or colliery waste. In an elutriator, the particles settle against a rising current (as in air classifiers), which increases the effective density of the liquid. The drag force on the particles is a complex function of size and form.

7.1.6.4 The hydrocyclone

A hydrocyclone is a vessel with a cylindrical conical shape and provided with a tangential inlet. The entering slurry whirls down along the wall of the vessel. Because of centrifugal forces, heavier particles are concentrated near the wall and are discharged through the apex. The rest of the slurry moves to the centre of the vortex and leaves the hydrocyclone through the overflow. Hydrocyclones are effective in separating solids from about 5 to 150 micrometers. [3]

The hydrocyclone has, compared with the sink/float process, a higher throughput and a simpler structure. The purity of the output can reach up to 97 or 98 per cent. The energy consumption is about 36 kWh/t. A plant with a capacity of 4,000 t/a causes costs of about US$ 20 per tonne of plastics material. [14]

7.1.6.5 The centrifuge

A centrifuge can also be used to classify solids. Since the entire body of liquid rotates at an almost uniform velocity, the shear forces between successive concentric layers of fluid are very small. Therefore the agglomeration of particles does not take place.

In nozzle bowl machines the feed enters near the axis of rotation and spreads radially between a number of closely spaced perforated disks.

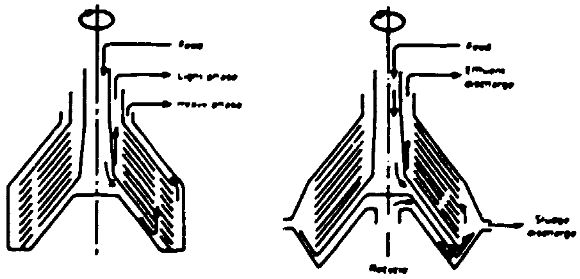


Figure: 17 Nozzle-bowl centrifuge. (From *Chemical Engineering Handbook*, by Perry and Chilton. Copyright © McGraw-Hill. Used with the permission of McGraw-Hill Book Company.)

The feed splits into a dense fraction which is collected by a discharge nozzle at the periphery of the bowl and into a light fraction which discharges near the axis of rotation. Sharp classifications are possible for particles below 10 micrometers.

7.1.6.6 Flotation

At the present flotation is probably the most important method for processing of complex ores, but can also be used for other materials such as plastics. The material is first slurried to a pulp. Chemicals are added which influence the surface properties of the material to be separated. Adsorption of collectors make particles water repellent (hydrophilic). Then a froth layer is created, either by mechanical means or by air agitation. The hydrophobic material collects in the froth and is scraped off, whereas the hydrohphilic material is retained in the pulp.

Flotation can be applied to all liberated particles that can be lifted by gas bubbles (5-800 micrometers).

The selective separation of plastics material is caused by chemical substances (5 to 150 mL/L) in the separation fluid. The purity can reach up to 99 per cent; the costs being about US$ 17 per tonne. [14]

With this technology the different PVC types can also be sorted.

7.1.7 Effects of collection

The collection method or frequency has a marked influence on the quality of the refuse to be sorted:

1. In compression vehicles the mixing and contamination of refuse components are minimal. Screw compacting systems open most refuse bags and cause a more intensive mixing. The tumbling action of rotary drum collection vehicles opens most bags and causes extensive moisture transfer and attrition.

2. The frequency of collection determines the amount of odour hindrance, flies and moisture transfer.

3. Where refuse is collected in paper or plastic bags, provisions should be made to open the bags and liberate the contents prior to or during the initial stages of sorting.

7.2 Recycling of plastics materials (material recycling)

The plastics fraction in household waste consists of more than 90 per cent of thermoplasts. These can be melted and processed over and over again (limit: decomposition). It is necessary to have at least an amount of 50 per cent of a certain type of a thermoplast to achieve sufficient mechanical strength. The compositions of thermoplastics in household waste is given in the table below: [2]

Plastics Type	weight per cent
Polyolefins	60 - 65
Polystyrene	15 - 20
Polyvinylchloride	10 - 15
Other plastics	about 5

Table:6

This way of recycling without separation into the different thermoplastics is of relatively low investment cost. It allows the manufacture of products with "new" properties, different from the "originating" thermoplasts and with mechanical strength lower than each of the mentioned commodity plastics. The processing techniques can be granuling, extrusion, foaming, injection moulding or compression moulding.

To obtain a sufficient homogeneity, the material should be processed above the melting temperature of the most stable plastics fraction.

Kunststoffart	Erweichung [°C]	Verflüssigung [°C]
PVC	100 - 150	130 - 190
PE	105 - 130	140 - 200
PS	80 - 90	140 - 160

Table:7

Because of the differences between the melting points of the various types of plastics, a partial decomposition of several fractions may occur. The crack products must be sucked off and treated properly.

Recycling has always been the desired method, when compared with the thermal disposition of plastics waste. Without the requirement of using virgin material new plastics articles can be manufactured quite economically.

Although the quality of the recycled products is poorer than of those made of virgin material, they are still valuable for applications together with new material or for parts having to meet lower requirements and quality standards. The amount of recycled material in the virgin material is determined by the mechanical properties required. As a matter of fact recycled products are predominantly of dark colours, they are usually pigmented grey, black or brown.

In spite of these disadvantages mentioned above, recycling of plastics materials should be practiced in order to save resources and energy.

Generally spoken there are two philosophies existing in the recycling of Municipal Solid Waste:

1. Recycling of waste plastics consisting of pure polyolefins or polystyrenes providing a high quality "regranulate";

2. Recycling of the plastics mixture more or less as it occurs in the household waste bins without mechanical separation and sorting.

The recycling of industrial waste, consisting mainly of one type of polymer with little contamination is in practical operation since a long time, but is not to be dealt with in this report.

7.2.1 Recycling of plastics films and sheets consisting mainly of polyolefins

To achieve pure polyolefine waste complicated and expensive separation and cleansing technologies are necessary, resulting in high - quality products, showing excellent performance (tensile stress, MFI, etc.).

In the following the recycling process by ANDRITZ-technology will be described, similar process-techniques have been developed by AKW, WAVIN and LANCE.

7.2.2 The ANDRITZ technology-recycling plant

The plant for treating waste plastics with Andritz Technology, producing roughly 1 tonne polyethylene granulate per hour, is able to process mixed plastic films and sheets (mainly LDPE and HDPE-a low amount of PP) with a maximum contamination of 20 per cent.

Foreign matters and other types of plastics, such as PVC, PS, PET etc., are separated and removed in the cleaning and separating stages.

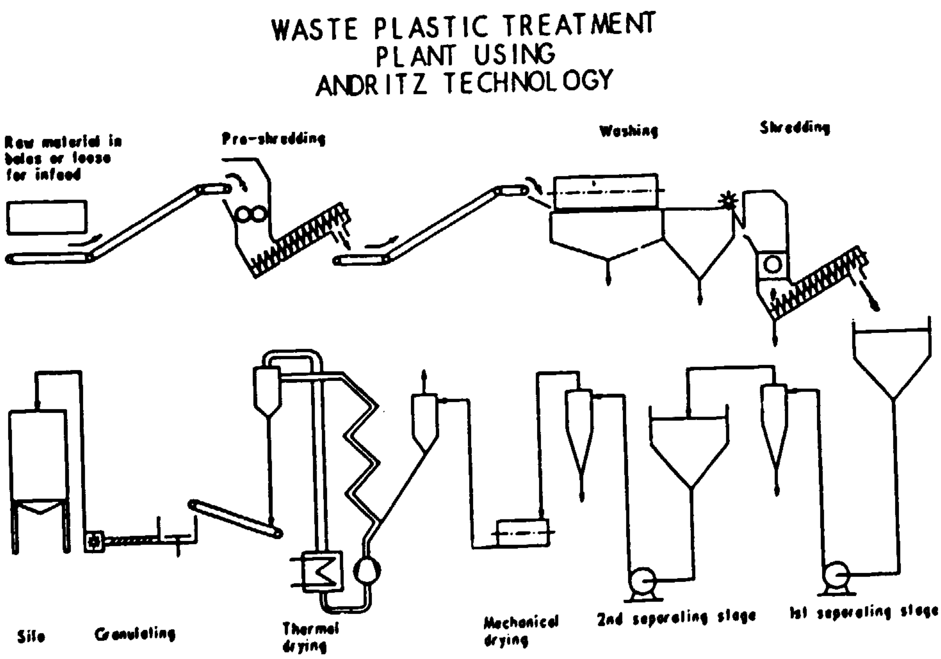


Figure:18

The process is carried out as follows:

The raw material is brought from the storage pile on a stacker truck and deposited on a belt conveyor, which brings it to the preliminary shredder.

The material coming from this shredder is transported to the preliminary washing stage on a second belt conveyor. Following this washing stage, there is a wet shredder, with rotating knives, which reduces the size of the films to pieces of about one cm in diameter.

After this second shredding stage, the plastics material enters a multi- stage separating and washing unit via a dewatering screw.

The multi-stage separating and washing unit has two highly efficient hydrocyclone stages, which remove foreign matter. The upper stream of washed material from the second stage then is put through a vibration dewatering stage.

In the low-concentration section after the separation stage, the shredded sheets are properly divided into two streams.

Since all subsequent units are in duplicate, the entire system's operating reliability is raised.

After the vibration dewatering stage, the material undergoes mechanical drying.

Now the raw material is more or less free of water, it is put through a thermal drying stage. From here it is conveyed on a specially designed storage conveyor to the granulator. Finally, the granulated material is blown into a mixing silo and filled into bags from there.

The water needed in the wet section of the plant is circulated in two loops and cleaned efficiently by mechanical means in order to keep consumption of fresh water as low as possible.

The total electric energy consumption is approximately 0.6-0.8 kWh/kg granulate and around 0.15 KWh/kg granulate for thermal drying energy in the form of hot water.

The fresh water consumption, which depends on the grade of contamination of the waste films, is about 8 kg/kg granulate.

The resulting product is high-grade PE granulate, which can be used again for processing of plastics films. [28]

7.2.3 Remoulding of mixed plastics waste

Using these technologies a great variety of waste, even copper-strands of cables, yoghourt-cups, all types of packaging materials and the like, can be recycled. A remarkable decrease in quality in comparison to the recycled products made of pure polyolefine waste, must be considered.

The determined development of energy and cost effective solutions to the re-processing of mixed (comingled) plastics waste has resulted in introducing "new" raw materials to the industrial market, which makes savings upon the use of basic energy resources and furthermore improves the environment.

The products are used for wood-replacement, EURO-palettes, palisades, fences, flower pots, noise control screens, drainage channels, marina supports and plant control constructions.

A frequently used technology was developed by GREINER, other companies with similar techniques are SUPERWOOD, ART and several Italian, Dutch and Swedish Companies all based on the basic development of the Japanese Reverzer-process which has been introduced to European countries by REHSIF SA. and modified and further developed by E. Klobbie.

7.2.4 DEKOPLAST-plastics recycling from GREINER EXTRUSIONSTECHNOLOGY COMPANY, AUSTRIA

Picture: 1

(Hollow Chamber Plastics Profiles from Mixed (Comingled) Plastics Waste)

7.2.4.1 Basic research

To establish this recycling technique several assumptions had to be met.

It was found that the most promising methods of collection and sorting were using the "Green Bin" system; in this system each household has two waste disposal bins, one "Black" for inorganic materials such as glass, paper, metals and plastics and a "Green" bin for organic materials such as food remains, wood and compostible remains. The second system involves the establishment of collection centers organised by local government. Households would be encouraged to bring their own inorganic waste and hazardous waste to the centres where this could be sorted and further transported to those recycling companies involved.

Using material gained from each method of collection trials were made with the plastics waste exactly as it was delivered. This meant that all soiling, dust, dirt and remains in plastics containers, is be attempted to be reprocessed with the plastics without further washing or sorting.

Analysis of this waste showed that this mixture was composed of the following:

weight per cent	Plastics Type
50 - 65	Polyolefines (PE, PP, Polyolefine laminates etc.)
15 - 20	Styrene polymers (PS)
8 - 14	Vinyl polymers (PVC)
0 - 5	Polyethylene terephthalate (PET)
1 - 4	Other materials, including dirt paper, aluminium etc.

Table:8

7.2.4.2 Preparation of the plastics waste

This phase involves the most appropriate methods of preparing the plastics waste into a form where this material can be processed into hollow chamber extruded profiles.

It must be realised, that the collected material can be divided into two basic types:

1. Formed parts (injection mouldings, vacuum formed mouldings, blow mouldings and injection - blow mouldings), know as hard plastics;

2. Items directly produced from plastics films (plastics sacks or bags and film wrapping), known as soft plastics.

By using conventional shredding and grinding machinery it is possible to size reduce both types of material, however the resultant granulate has obviously a relatively low bulk density. There are two reasons: The film products can only be chopped into small pieces which do not not flow easily in transport equipment and their intrinsic shapes give an uncontrolled low bulk density.

Size reduction of the hard plastics alone results in a regular granulate with a bulk density of approximately 0.35 g/cm^3, furthermore this granulate has a good flow.

Soft plastics and film products can be size reduced and densified using an agglomerator, where the film waste is processed into basically round (ball-like) granules with a regular bulk density of approximately 0.35 g/cm^3. This material also shows a good flow behaviour, which means, that the soft plastics granules and the hard plastics granulate can be remixed together and be processed in this way.

7.2.4.3 Machinery

This phase involves the development of the best suited extruder to plastify and homogenize the mixed (comingled) plastics and the design characteristics of dies and calibrators to produce extruded hollow chamber profiles.

The first trials were made with single screw, medium length machines, however the moulding material showed too much inclusion of gas. Further trials showed, that this gas comes from moisture inclusion in the waste and reaction gases from the plastifying of mixed plastics.

Experiments using relatively compact twin-screw extruders with medium length plastifying units and de-gassing units gave better results. A melt being 99 per cent free from gas inclusions can be formed.

Increased through-put (kg/hour) was further improved with the incorporation of a special agitator, compression device in the raw material hopper above the extruder barrel material inlet.

Processing temperatures range between 170 and 195 centigrades. Materials having higher melt temperature remain as "non-plasticated" fillers.

Die designs were optimized with the emphasis on providing more compression of the melt through the die flow channels.

Calibration and cooling of the formed plastics mass was achieved using a single dry cooling vacuum calibrator externly and wet calibrators under vacuum in a spray tank.

7.2.4.4 Products

The granulate size, approximately 5 mm, dictates the minimum wall thickness of profiles, 4-5 mm. Comparatively simple hollow planks, posts, pipes and single wall profiles have been produced and are now successfully competing with conventional products including items for the transport, construction and agricultural industries, such as noise control screens, drainage channels, marina supports and plant control constructions.

7.2.4.5 Cost analysis

(based upon Austrian conditions, maximum 4000 tonnes per year = 4 extrusion lines with Austrian costs, US Dollar converted at 13 ATS = 1 US$).

A. Investment:			US$ * 1000
a)	Land 5000 m^2 at US$ 23,00/m^2	115.000.-- US$	
	(approx. 54000 SQFT) development cost	15.385.-- US$	
		130.385.-- US$	
on 20 year loan with 9 per cent interest			12.46
b)	Production building 2500 m^2 a US$ 460/m^2	1.150.000.-- US$	
	(approx. 27000 SQFT) on 15 year loan with 9 per cent interest		128.23
c)	Administration building 300 m2 a US$ 1154/m^2	346.200.-- US$	
	(approx. 3230 SQFT) on 15 year loan with 9 per cent interest		38.46
d)	Office funiture + equipment	46.154.-- US$	
	on 5 year loan with 9 per cent interest		11.31
e)	Vehicles 1 car, 2 trucks, 2 fortrucks	38.462.-- US$	
	on 5 year loan with 9 per cent interest		94.24
f)	Accessory production equipment	115.385.-- US$	
	on 5 year loan with 9 per cent interest		28.23
g)	Production plant		
	on 5 year loan with 9 per cent interest		640.77
			953.70

B.	Overheads and Maintainance Costs		US$ * 1000
a)	Building and land		19.23
b)	Machinery		
	1 barrel and screw set	34.61	
	grinder knives	19.23	
	accessories	23.08	
			76.92
c)	Vehicles		
	taxes/maintainance	6.92	
	fuel	13.85	
			20.77
d)	Overheads		
	travel	23.08	
	advertising	15.38	
	service personnel	15.38	
	insurance	11.54	
	post, telephone, fax	26.92	
	office and computer	26.92	
	taxes and contrib.	15.38	
	extras (not defined)	30.77	
	working capital loan costs	15.38	
			180.75
e)	Raw material		free of charge
C.	Personnel		
	18 people a US$ 29.23		526.15
D.	Power		
	2200 Megawatt/year at 0.1 US$/kWh	US$ 220.000.--	

1200 m^3 water
at 0.65 US$/$m^3$ US$ 7.800.--

227.80

2005.32

E. Cost

without selling costs, profit, freight, additives and margin at 90 per cent efficiency = 3600.000 kg (approx. 7.637.28 thousand pounds)

manufacturing cost per pound = 0.2526 US$/LB

[29]

7.2.5 Conclusion

In the last two years several recycling plants for plastics films have been installed in Europe and the real cost per tonne of regranulate including investment, operating and maintainance costs vary between US$ 300 and 400.

7.3 Pyrolysis

Pyrolysis is the thermal decomposition of organic materials under exclusion of oxygen, air, CO_2 and the like. Fugitive substances are emitted in a temperature range between 150 and 900 centigrades.

Products obtained in this process are:

- Pyrolysis soot or coke
- Pyrolysis oil
- Pyrolysis gas

The products are either used as fuel or to process basic materials for the chemical industry.

7.3.1 Products and their properties

Plastics are cracked in C_{25}-C_{40} aliphatic materials in a temperature range between 300 and 350 centigrades. Increasing the temperature up to 700 to 800 centigrades result in a C_2-C_4-olefinic fraction. The olefinic materials combine under high temperatures to aromatics under emission of methane and hydrogen. [17]

7.3.1.1 Pyrolysis soot or coke

The solid products provided by pyrolysis of plastics materials are:

- fillers
- soot
- coke

Depending on the material cracked the solid portion can range from 1 to 43 per cent of the input material. [2]

7.3.1.2 Pyrolysis oil

The portion of the pyrolysis oil is about 40 to 60 per cent of the input material. It is a mixture of light fractions und coal tar and consists to 95 per cent of aromatics. By means of destillation, the oil can be separated into a high and a low boiling fraction.

Benzol-, Toluol-, Xylol-Aromaten	Gew.-%	60 - 70
Naphthalin + Methylnaphthaline	Gew.-%	10 - 15
Siedeverlauf:		
Siedebeginn	°C	30 - 70
Siedeende	°C	200 - 250
Dichte:	kg/m³	800 - 900
Mischoktanzahl:		80 - 100 95 - 110
Organisches Chlor:	mg/kg	0,3
Anorganisches Chlor:	mg/l	30

Table:9

Benzol, Toluol, Xylol-Aromaten	Gew.-%	5
Naphthalin + Methylnaphthaline	Gew.-%	20 - 30
Gaschromat. erfaßbare Anteile	Gew.-%	70
Extraktionsrückstand:	Gew.-%	6 - 10
Dichte:	kg/m³	1000 - 1200
Asche:	Gew.-%	10
Organisches Chlor:	mg/kg	5
Anorganisches Chlor:	mg/l	1000 - 2000

Table:10

In the low boiling fraction benzene is the main component and has a portion of 30 to 50 per cent. The high boiling fraction could be used to produce naphthalene. Pyrolysis gas is mainly used in the petrol sector to increase the Octane Number. The refinement of chemical substances such as toluene and benzene has been proven to be uneconomic. [17,18]

7.3.1.3 Pyrolysis gas

Refering to the input material 35 to 60 per cent gas is developed. Pyrolysis gas mainly consists of methane, ethane, ethyiene, propane. Its calorific value is about 35,000 kJ/m³.

Parameter	Anteil in [Gew.-%]	Anteil in [Vol.-%]
Wasserstoff	2,2	18,8
Kohlendioxid	4,3	1,9
Kohlenmonoxid	9,4	5,7
Methan	54,5	58,2
Ethan	5,2	3,0
Ethen	16,7	10,2
Propan	0,2	0,1
Propen	2,9	1,2
Butadien	1,2	0,4
Benzol-, Toluol-, Xylol-Aromaten	2,7	0,5
Mittlere Dichte:	0,764 kg/m³	
Mittlerer Heizwert:	34 554 kJ/m³ ≙ 9,6 kWh/m³	

Table:11

The gas can be used to replace natural gas.

7.3.2 Partial oxidation

The pyrolysis of plastics materials between 600 and 850 centigrades provides a mixture containing carbohydrates such as methane up to higher aromatics. A part of the input polymers is oxidized, thus the temperature is increased to 1500 centigrades. At this temperature mainly unsaturated C_2 carbohydrates and methane are formed. Synthesis gas is also developed. Unsaturated C_2 carbohydrates (ethylene) are basic materials for the plastics industry.

7.3.3 Economic considerations

7.3.3.1 Pyrolysis gas

A basic assumption is the short distance between the waste producers and the pyrolysis plant. This should not exceed 50 kms. This range would provide an annual volume of waste of about 10,000 tonnes. A cracking plant for household waste with 5,000 t/a, compared with industrial cracking plants (usually 500,000 t/a) is not economic, but can be used in combination. A price between US$ 350 and 600 per tonne pyrolysis gas could be obtained. [19,20,21]

7.3.3.2 Pyrolysis oil

The price depends on the price of crude oil. Pyrolysis oil usually costs about US$ 350 per tonne. [2]

7.3.3.3 Pyrolysis soot

Soot can be activated and used as active coal, or as pigment in varnishes and paints.

7.4 Hydrolysis

The goal of hydrolysis is to obtain monomeric basic materials from plastics refuse. A re-reaction of all plastics produced by means of polycondensation or polyaddition, such as the polyamides, polyesters and polyurethanes etc. is possible. The hydrolysis can be performed either in water or in higher alcohols.

The fluid or gaseous monomeric products can be used after special treatment to produce the respective plastics material again.

7.4.1 Hydrolysis of expanded materials

The most important material to hydrolyse is polyurethane. During the past years polyurethanes have become more and more popular and are today much in use. PUR is usually used as a foam, is expensive (US$ 15-18 per kg) and needs large transport containers.

At temperatures of 200 centigrades approximately two hours are needed for a quantitative chemical reaction. Increasing the temperature by 10 to 15 centigrades reduces the duration of the reaction by 50 per cent. [22]

By means of a twin screw extruder (reaction temperature 200-230 centigrades, pressure of hydrogen/steam: 15-30 bar) a continuous hydrolysis technique could be developed. [22]

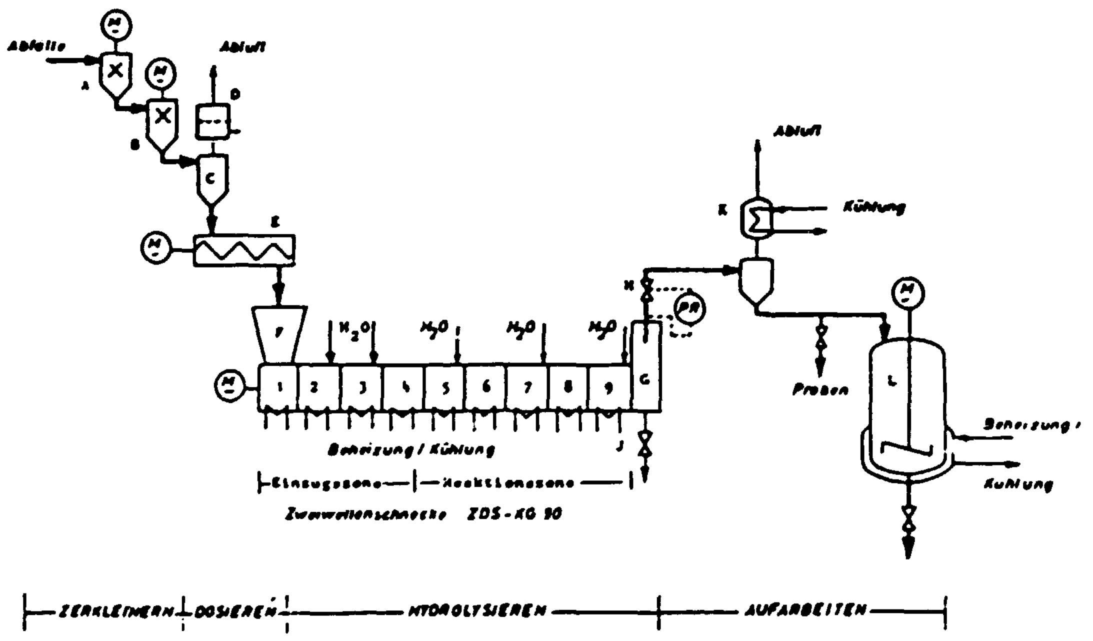


Figure:19

The expanded PUR materials are first reduced in size to flocks or powder and then fed continuously into the hydrolysis screw. In the compression section the material is compacted. The water, essential to the hydrolysis process, is pressed into the screw by dosing pumps. It vaporizes under heat and pressure. The mixture of fluid and gas is continuously carried out by the screw.

7.4.2 Products and their properties

PUR foams are usually manufactored by means of a reaction between toluylendiisocyanate and polyether. Under special conditions polyurethane can be hydrolysed to the exact preproducts. The amine is used to produce the isocyanate.

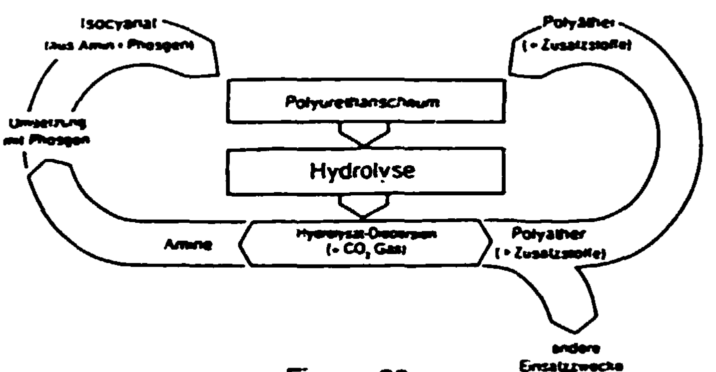


Figure:20

The amine (TDA) can be distilled. By means of a chemical reaction the amine is converted to the isocyanate. The polyether is not modified by the hydrolysis and can, after a purification, therefore be used without pretreatment.

This technology can be applied to all plastics materials which are hydrolysable. The performance of PUR produced from hydrolysed PUR foams and that of new PUR foams is similar.

7.5 Incineration

The calorific value of the plastics fraction in household refuse is about 30,300 kJ/kg. Thus polymers contribute about 15 to 20 per cent to the energy contents of the waste and a separate plastics disposal would lead to a decrease in thermal power.

Older incineration plants are designed for a calorific power of household waste without plastics (8,500 kJ/kg). These plants can only be operated with a reduced throughput, so a separate disposal of waste would prove economic for these plants. [23]

It must be considered that several types of plastics, e.g. PVC, emit HCl, heavy metals and organic substances. About 50 per cent of the HCl emissons are caused by plastics incineration. Ecologists talk of dioxins and furanes in the emissions, but this has not yet been proven.

7.6 Deposition at landfills

Plastics materials do not cause any fluid or gaseous emissions. They are completely inert and are therefore no-toxic.

Unordered disposition of household waste or industrial refuse leads to:

1.Contaminaton of subsoil water and water on the surface by extraction of toxic substances;

2.danger of contagious diseases;

3.contamination of the air in cases of uncontrolled fires; and

4.decreasing value of the nearby landscape.

Thus, an ordered deposition at landfills is required. The costs depend on the geographical position of the landfill, about US$ 10-20 per tonne, but will increase strikingly in the future. [23]

Recylcling techniques, incineration, hydrolysis and pyrolysis need an ordered landfill for the deposition of non-usable remains.

7.7 Composting

Polymers in compost behave like glass or metals, i.e. they cannot be decomposed and must be separated. The problem is not physiological, but compost made out of waste, contaminated with plastics is hard to sell.

8. CONCLUSION

The economic value of recovered plastic material depends on the quality of the products that may be made from such a material.

For replacement of relatively cheap construction material separation and cleaning need not go very far. But for more sophisticated applications the recovered material has to meet agreed specifications.

Over the past few years, consciousness in society has undergone a decisive change with regard to environmental problems. A great number of technical research and development programs in the environmental protection area, as well as numerous legal regulations, have been the manifestation of this changes. Recycling of plastics is a relatively young industry which has been developing lately, and the trend is to continue at an increased rate. Thus also applies to reclamation of plastics from discarded industrial and consumer products containing plastic components.

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2. NATIONAL AND REGIONAL EFFORTS AND PROGRAMMES

Solid waste concerns spur plastic recycling efforts

The management of solid waste is reaching a crisis in the United States and world-wide. This is illustrated by wandering garbage barges with no permission to land and by wastes washing up on beaches.

Every year the US generates about 320 billion lb of what is called municipal solid waste, or post-consumer waste. About 85 per cent of this trash is currently disposed of in landfills. Yet as the amount of solid waste increases - and the Environmental Protection Agency estimates that it will reach 380 billion lb by 2000 - a third of the landfills are expected to close in the next five years. Many people are concerned that efforts to deal with the growing quantity of garbage are not moving fast enough.

Plastics make up only about 7 per cent of solid wastes, according to figures prepared by Franklin Associates for EPA, but plastics and paper are the fastest-growing segments of such wastes. In 1987, the plastics industry produced a total of 55 billion lb of plastics, and the public discarded about 22 billion lb of that. By 2000, plastics production may reach 75 billion lb, and the public is expected to throw away about 38 billion lb of that, accounting for 10 per cent of solid municipal wastes that year. Although not a significant proportion by weight, plastics have been targeted as a waste problem since, by volume, they are a very visible 30 per cent of municipal solid waste.

Rapidly rising costs of landfilling, as high or higher than $100 per ton in some parts of the US, and of alternative waste treatment methods, such as incineration, are making it prohibitively expensive to deal with large amounts of waste. When coupled with the desire to conserve resources and have an environmentally acceptable means of reducing solid waste, recycling is often considered as an alternative. Recycling, although not inexpensive itself, can be less costly than other disposal methods because there is both a return on the re-used materials and an offset of landfill charges. Of the more than 300 billion lb of solid waste produced, only about 10 per cent is recycled annually.

The apparent lack of movement in plastics recycling has helped to make plastics a scapegoat in the battle on solid waste. In the past decade, plastics have become increasingly prevalent because of their light weight, versatility in a range of applications, and convenience. But many plastic consumer items have short life spans and quickly make their way into the waste stream. More than half of the discarded plastics are found in the form of packaging, an area frequently targeted for recycling. Packaging, about one third by weight of consumer waste, consists primarily of paper (48 per cent), glass (27 per cent), and plastics (11 per cent).

Much of the public believes that plastics cannot be recycled or safely incinerated and, because they do not decompose, that they should be removed entirely from the waste stream. One can argue as to whether plastics are in fact a major cause of the solid waste crisis, but the answer is almost irrelevant since plastics are generally perceived to be a significant problem.

Public perception and the resulting trends in legislation have led manufacturers of plastics and plastic products to realize that they either have to act and get involved with the issue or be prepared to shoulder much of the blame for the solid waste crisis and face tremendous restrictions on their industry. The companies' initial responses included the formation of both internal divisions and co-operative industry associations to approach the issues of plastics recycl'ng and solid waste management.

"Fortunately, we had some visionary people," says Wayne E. Pearson, executive director of the Plastics Recycling Foundation (PRF), an independent, non-profit organization started through the Society of the Plastics Industry in 1985 by 20 members of the plastics and allied industries. "This group recognized, before it was as apparent to most of us, that there was a solid waste crisis, that recycling was important and that [group members] needed to know more about it." The foundation now has 45 member companies, ranging from resin producers to container manufacturers to users of the containers, who are concerned about the attitudes driving today's legislation and would like to see it take a new direction.

But how and where does a group like this get its facts? In 1985, PRF made its primary objective the establishment and support of the Center for Plastics Recycling Research (CPRR) at Rutgers University. Funds totalling nearly $2.3 million in 1988-89 to support research come from PRF, Rutgers University, and other organizations such as SPI, the National Science Foundation, the New Jersey Commission on Science & Technology (which has established CPRR as one of its Advanced Technology Centers), and several state governments and universities. In the near future, Rep. Jim Courter (R.-NJ) is expected to reintroduce a proposal to fund the centre as the National Center for Plastics Recycling, the hub of a national effort with other universities.

Starting up a research programme in recycling is not an unlikely thing for plastics manufacturers to do, Pearson points out. "One of the things I do not think the public at all understands is that the pla ics industry recycles every plastic, every thermoplastic, every day." He explains that the reprocessing of in-house scrap from the manufacture of plastic products has been a common practice for as long as the industry has existed. Thus, much of the technology for re-using plastics already exists. But, he notes, the use of in-house scrap is relatively straightforward, since collecting and sorting the materials is not necessary. So the question CPRR was given regarding plastics recycling was, Pearson says: "How do you gather it back from 240 million Americans and do something with it that makes any sense?"

Under a charter to advance R&D in all aspects of plastics recycling and re-use, the job has been given to Darrell R. Morrow, director of CPRR, and his staff. The centre operates with three divisions - research, process development, and information services - that work on covering the scientific, technological, economic, environmental, and practical sides of recycling plastics. This includes defining and developing the necessary infrastructure to recycle plastics. This framework consists of four areas: collection, sorting, reclamation and re-use. Unlike other materials such as paper, metal, and glass, which have been recycled for 40 years or more, the infrastructure for plastics recycling is not yet in place.

The centre initially concentrated on reclamation and re-use and developed a technology for the reclamation of post-consumer waste plastics. After only two years, CPRR published nearly 25 reports based on its research and held conferences to provide for transferring the technology. "We want to disseminate the information as widely and in as timely a fashion as we can to help develop the infrastructure that will cause plastics to be included in the recycling stream," says Morrow.

In its first two years, CPRR also constructed and began operating what is potentially a commercial-scale pilot plant facility. "To be able to reduce the applied research to practice in a timely manner," says Morrow, "we realized that we had to have a process development and demonstration facility that was significantly larger than you would ordinarily expect to find at a university, or even in industry." He adds that this has allowed them to move along faster towards a commercially viable design.

Through this focused effort, CPRR has produced a technology transfer manual that describes in detail the set-up and operation of a plastics recycling plant. The hope of CPRR is that making the technology available will foster the commercialization of plastics recycling. There are currently 14 licensees of the CPRR process world-wide; two of them are looking into building plants in the near future.

The process developed at CPRR is said to be similar in its layout to those used in private industry. Most plastic reclamation systems are designed to work with rigid containers, such as PET beverage bottles, and HDPE milk or household product containers, because they are currently the easiest post-consumer items to collect and sort. PET beverage bottles are actually not one, but several materials: a PET body (clear or green), a pigmented high-density polyethylene (HDPE) base cup, aluminium cap, label, and adhesives. To separate these components, either a dry or wet separation method based on one or more of the different physical properties of the materials can be used.

Frank W. Dittman, project manager at the CPRR plant, describes its operation after the containers have been collected and delivered to the plant. The bottles are sorted by hand to separate out the more valuable resins. "We are looking at mechanical sorting based on optical and electrical principles," says Dittman, "but whether that is going to beat hand sorting at cost, I do not know. You can sort by hand pretty quickly." After sorting, the bottles are shredded and ground into chips for processing. The chips are then air classified, which, Dittman says, means that the lighter weight paper and other contaminants are separated in an air cyclone from the heavier plastic chips.

To remove the labels still attached to the chips, a cost-effective and efficient means of removing a waterproof adhesive had to be devised. After finally finding a detergent wash that would work, he explains, it had to be optimized with respect to temperature, washing time, concentration of detergent, power of mixing, and, of course, concentration of chips.

In the case of the multi-component PET beverage bottles, once the labels are removed, the lighter HDPE fraction is separated from the heavier PET and aluminium pieces in a hydrocyclone system. It is at this stage that other reclamation methods often differ, using a separation step based on flotation methods. Dittman suggests that the hydrocyclone system will be an improvement over the flotation methods. The HDPE chips are then dried and collected.

The PET and aluminium chips require further drying so that they can be electrostatically separated. This is the most expensive part of the entire process. "The aluminium cap is only 1 per cent by weight of the bottle," explains Dittman, "but the equipment to remove it represents about 30 per cent of the investment in the plant. It is out of balance, and we are trying to remove the aluminium more cheaply." The process - which at the CPRR plant can handle about 600 lb per hour, or a potential capacity of about 5 million lb per year - generates clean, well-separated (99.9 per cent) granulated plastic chips that can be sold to a manufacturer who uses the resins.

The chips sell for about 25 to 35 cents per lb for PET (with less than 100 ppm of aluminium), and 17 to 25 cents per lb for HDPE. In comparison, virgin PET costs about 50 to 60 cents per lb, and HDPE resins about 40 cents per lb. The centre combines these and other factors in evaluating the financial aspects of operating a plant. "In our engineering manual we analysed the economics and showed that a profitable plant should be able to process 20 million lb a year or more," says Dittman. He notes that the investment for a plant of that size would be about $2.5 million and it would pay for itself in three to five years.

Other available reclamation technologies for rigid HDPE plastics are made by Transplastek of Canada and AKW of the Federal Republic of Germany and are similar in design to the CPRR process with granulating, washing and separation steps. Transplastek uses a proprietary flotation tank method to separate plastics by density, whereas the AKW method is based on the hydrocycloning technology.

Much of the resin reclamation and reprocessing technology comes from overseas, as the Europeans and Japanese have been involved in recycling for a longer period of time. There are other reclamation processes for different resins, which have been developed by or licensed to private companies, but because these are usually proprietary the details of their operations are not known.

Morrow makes a point of calling the system designed at CPRR a "resin recovery system," to stress the fact that it will work on about five different resins. Currently PET and HDPE can be processed together and are easily separated because of their different densities. The centre hopes to add polystyrene and polyvinyl chloride to the mixed plastics stream they process. But, with the present technology, PET and PVC cannot be run together since they have similar densities.

"We have a very ambitious objective," says Morrow. "What we have challenged ourselves to is to make our resin recovery system a universal reclamation facility." Ideally, he explains, one would like to be able to feed in mixed, even granulated, plastics and have pure, generic resins come out the other end. This would remove the need for hand sorting and, for example, the separate processing of pigmented and unpigmented HDPE containers. Morrow notes that economics are driving this stage of the reclamation process: coloured HDPE is less valuable than uncoloured HDPE, which has greater flexibility in end uses.

The value of recycled materials is present only if there are available markets, and plastics have become the second most valuable recyclable material after aluminium. The greatest return on recycled plastics is gained when the resins are re-used in their original or similar applications, or by producing materials with added value, such as engineering plastics. If the properties of the resins are not compromised by the reclamation process, and if free enough of contaminants, generic resins can be sold to the manufacturers of plastic products as a replacement for virgin material. But Food & Drug Administration restrictions prohibit use of recycled resins in food applications, making one major plastics market inaccessible to recycled resins.

Mixed, or commingled, plastics must be dealt with differently to find end uses. Several technologies exist for mixed plastics, such as the ET/1 extrusion process from Advanced Recycling Technology of Belgium and a compression-moulding process from Recycloplast of the Federal Republic of Germany. At CPRR, another pilot plant with an ET/1 extruder has been installed to make plastic lumber out of mixed plastics. Lower-melting plastics in the mixture act as a matrix that carries other plastics, and even up to 40 per cent contaminants, such as paper, metal, glass, and dirt, into the mould. The resulting product can be treated and used like wood in non-construction applications such as decks, picnic tables, and park benches. Reclaimed HDPE resins are also used to make flower pots, pipe, bottle base cups, pails and drums.

A few companies make mixed plastic items commercially. About six years ago, Eaglebrook Plastics of Chicago started recycling HDPE plant scrap, developing its own technology for cleaning and reclaiming the resin to be sold back to manufacturers. Eaglebrook since has extended its technology to deal with post-consumer waste and now buys bales of bottles from community collection centres. An offshoot company, Eaglebrook Profiles, was recently opened to make plastic lumber profiles using a proprietary, continuous-extrusion process developed in-house.

Similarly, Polymer Products, a division of Plastic Recycling Inc. of Iowa, is a young company that has started buying industrial scrap and post-consumer plastics, generally commingled, to make car stops, speed bumps, traffic bollards and plastic lumber. Floyd Hammer, chairman of Plastics Recycling Inc., says that when he started the company he had in mind to manufacture value-added products with their own end-use markets, rather than deal in the more volatile commodity resins. He noted that two years ago there was not a market for mixed plastics products, but that the company has been building its market slowly, but successfully, as one of the few small companies making these types of products.

In contrast, PET end-use markets have been developing for at least 10 years. When the PET bottle was introduced in 1978 and was collected in states with deposit laws, the industry for recycling them and reusing them began to develop. PET resins can be re-used to make polyols for insulation and unsaturated resins for bathtubs, shower stalls, boat hulls, and auto panels. Reclaimed PET is also used for strapping, paint brushes, geotextiles, fibres for fibrefill and carpets, and other textile applications.

Wellman Inc. of Clark, NJ, the largest consumer of reclaimed PET, recycles PET beverage bottles and scrap to manufacture fibres, fibrefill, geotextiles, and other products. Dennis Sabourin, vice president of Wellman, indicates that the company used about two thirds of the PET bottles collected in the US, or about 100 million lb, in 1988. About 150 million lb of PET bottles were collected nation-wide and recycled in 1988, or about 20 per cent of those manufactured. This is a substantial increase over the 8 million lb collected in 1979 at a time when the return of plastic bottles was just beginning. CPRR estimates a potential market now for at least 500 million lb of reclaimed PET, increasing to more than 900 million lb in 1993. Similarly, 55 million lb of HDPE containers were recycled in 1988 and the potential market is estimated at 440 million lb, growing to 660 million lb in 1993. By most estimates the market for plastics re-use is growing.

According to an analysis of markets and economics of recycling by R. M. Kossoff and Associates of New York City, although the market for plastic resins can fluctuate widely, economic incentives are present in all aspects of the recycling chain. The firm sees the business as highly segmented, with opportunities at a variety of levels. These include collection, reclamation, selling of reclaimed resins, end-use products and equipment manufacture. But as Richard M. Kossoff, director of the study, says, "In the long run, the markets will have to lead."

Increasing costs of virgin resins and viable end-use markets are currently making the recycling business attractive, and more and more companies, both large and small, are entering the business. The 1988 Plastic Bottle Recycling Directory and Reference Guide published by the Plastic Bottle Institute of SPI currently lists 67 companies that buy bulk bottles for recycling, 47 companies that sell reprocessed plastics, 50 companies that purchase reprocessed plastic, and 54 companies that manufacture equipment for recyclers.

Most people in the plastics recycling business will tell you they can always use more plastic than is currently available, but that the bottleneck is in getting the materials collected from consumers. Sabourin indicates that Wellman could use more than twice the amount currently available and as much as three and a half times that in the next two years. That more than 200 million lb of plastic containers were recycled with no organized recycling programme, other than deposit laws in nine states, suggests that the level of plastics recycling and the requisite end-use markets will probably rise with increased collection efforts.

Having produced a working reclamation plant, CPRR is shifting its R&D emphasis to the areas of collecting and sorting plastics. The centre is in the process of publishing another manual to help communities and industry establish the infrastructure for collecting and sorting plastics as a part of a comprehensive recycling programme. In following the progress and analysing the results of several community pilot programmes, the centre has found that the success of these programmes depends on many factors. The most important factor is the careful design and planning of a programme to fit a given community.

Even though including plastics in recycling programmes is a new concept, participation rates can be as high as 70 to 90 per cent. "If you want to get serious about collecting, you make it very simple for the consumer to participate," says Pearson. This usually means kerbside pick-up programmes for trash and recyclable materials in suburban communities. In comparison, drop-off programmes only have a 10 to 30 per cent participation rate. Although mandatory recycling laws do help to directly communicate the need for recycling and enforce it, Pearson feels that with sufficient education about the solid waste problem and the value of recycling, most people are very willing to participate. And the value of education is not to be underestimated, because the most difficult initial obstacles to overcome are the previous misconceptions people hold about plastics not being recyclable.

The extent to which a community gets involved in recycling depends on the economics of collection, transportation, handling, reprocessing, the revenues from sales of recycled materials, and the offset of landfill or incineration fees. The large number of variables makes the overall economics of recycling programmes complicated. Based on current costs and market prices, the CPRR economic model predicts that an average suburban community with landfill charges of $45 per ton or more cannot afford not to recycle. Although this should encourage some communities to become involved in recycling, this does not mean that local governments must become entrepreneurs in the plastics end-use market. However, government subsidies to start programmes and stimulate market growth might be necessary.

CPRR suggests that communities work towards developing regional Material Recovery Facilities (MRFs) to handle all the recyclable materials collected. Several MRFs exist across the US, and the number being looked at is growing rapidly. These larger facilities, serving several communities, can handle sorting and densification (baling or shredding) in addition to sale and transport of recyclables to reprocessors.

Promoting recycling and collecting plastic containers has led to the development of other organizations. One of these is NAPCOR, the National Association for Plastic Container Recovery, a non-profit association of 12 major PET resin and container manufacturers. "We work with communities in recycling efforts to either encourage including PET in existing programmes or to have it included in programmes under development," says Luke B. Schmidt, president of NAPCOR. NAPCOR has a goal of achieving a 50 per cent recycling rate for PET bottles by 1992.

NAPCOR works on a project-by-project basis to encourage collection, Schmidt says. These projects are usually in demonstration programmes. Currently, they are working in at least seven states giving financial support, technical assistance and public education and promotion programmes. In addition, the member companies of NAPCOR have pledged to use a voluntary coding system developed by SPI to identify resins. The code consists of a number and letter symbol that can be imprinted on containers in the moulding process and should help in the sorting of resins.

The Plastic Bottle Institute of SPI and the Council on Plastics & Packaging in the Environment (COPPE) work to educate and provide information on plastics recycling and waste issues. The Plastic Bottle Institute, with 23 industrial members, publishes newsletters in addition to its extensive plastics recycling directory. Along with other organizations, it hopes to inform the public about the recyclability of plastics and the existence of viable end-use markets. COPPE works to communicate information to industry, the public and government about plastics recycling and waste management.

"We want to educate the public as to what can and should be done so that decisions can be made on an informed and not an emotional basis," says Connie Pitt, communications co-ordinator for COPPE. Although not a lobbying organization, it does interact on matters of public policy as an information source and in a peer review capacity. There are 42 companies in COPPE that cover a broad base in the plastics industry. Noel H. Malone, manager of marketing in Eastman Chemicals' polyester recycling division, says that the large number of groups spanning the plastics industry is beneficial. "The industry is deep and wide, and specific groups can focus in on specific problems," he says.

New Jersey Division of Solid Waste Management deputy director Sheil is encouraged that the plastics industry appears to be joining together and moving forward on recycling. "Unlike other industries [glass and paper], the plastics industry is a very diverse group, ... especially by the time you get to the end product," she says. "If the states had not put the pressure on, it would not have happened." Although the industry has come a long way towards recycling plastics, comments Sheil, recycling plastics has not yet become real on a large scale, and it will remain to be seen what happens in the next few years.

In addition to getting involved in recycling through organizations such as PRF, NAPCOR and COPPE, the plastics industry is expanding its own internal efforts. Many of the major resin manufacturers, such as Du Pont, Dow Chemical, Mobil Chemical and Eastman Chemicals, have taken positions on and responsibility for solid waste issues and established corporate divisions to focus on plastics recycling and/or solid waste management. These divisions look into the governmental, environmental and business aspects.

Of course, companies see the support and promotion of plastics recycling as vital to their positions in the market-place and the growth of their companies. As happened with the aluminium can, the promotion of a product as recyclable lets the public perceive it in a positive light and helps to maintain a market. And joint ventures, acquisitions, and the building of recycling businesses offer the plastics industry new markets and promotional opportunities.

Mobil Chemical is a producer of polyethylene and polystyrene resins and a major manufacturer of polystyrene products. In addition to recycling all in-house scrap, the company purchases 100 million lb of polyethylene film scrap to use in the production of institutional trash bags. Robert J. Barrett, general manager of Mobil's Solid Waste Management Solutions unit, expects that business opportunities will continue to arise from the solutions to solid waste problems. An example is Mobil's $4 million joint venture company, Plastics Again, with Genpak of Glens Falls, NY.

Genpak, a plastic products manufacturer, and Mobil are in the process of opening and operating one of the first plants to recycle polystyrene foam items such as food containers, cups and cutlery. The materials are being collected from Massachusetts schools and institutions by New England CR Inc., a major reclamation firm and recycled materials end-use manufacturer. The plant has a capacity to recycle 3 million lb per year of polystyrene resin, which will be re-used by the companies or sold to producers of insulation, fence posts, and flower pots. The new company is expecting a profit by 1992.

Similarly, Dow has entered into a joint venture agreement with Domtar of Canada to operate what the companies hope will be by 1990 a self-sustaining PET and HDPE recycling business. The North American company is expected to take post-consumer plastics and, using a proprietary Dow process, convert them into resins for use in Domtar's manufacturing or to be sold by Dow.

Other industry efforts to "close the loop" of product manufacture, recycling and resin re-use include Procter & Gamble's marketing of a plastic household product container made from recycled PET. Johnson Controls, a major manufacturer of PET beverage bottles and containers, is also involved in promoting recycling efforts. Internally, the company recycles in-house scrap and is working on proprietary R&D efforts in recycling. As a container manufacturer, Johnson Controls is also taking an interest in the design of packaging to make it more recyclable. A company spokesman indicates that approaches are being worked on to begin marketing non-food containers from recycled materials. Manufacturers looking to use recycled resins are concerned with getting consistent quantities and quality of the materials to make these efforts economically feasible.

Although plastics have been targeted in the battle on solid waste, and both government and industry have responded, plastics are only one part of the growing solid waste problem. The importance of investigating alternatives in waste disposal is becoming obvious to all involved. And new organizations, such as the Council on Solid Waste Solutions of the SPI, are growing out of the plastics and other industries. Unlike PRF, which emphasizes plastics recycling, the Council looks into all aspects of the solid waste problem, focusing on reaching local, state and federal governments to influence legislation and on evaluating waste treatment technologies.

Alternative solid waste treatment methods are being explored and plastics recycling will probably continue to be among them, because it does not seem likely that our society will entirely give up their plastic products. Morrow makes the important point that plastics should be integrated slowly into the recycling scheme, starting with beverage bottles and moving on to other types of packaging, to provide time for the collection, reclamation and end-use infrastructure to grow. Forcing too much, too soon, into the existing structure could do more harm than good in terms of a collapse of the effort and backlash from the apparent failure to recycle plastics. The outlook on biodegradable plastics, as generally expressed by the plastics industry, is that they may only find limited applications in agriculture or in dealing with litter.

EPA's Office of Solid Waste has proposed that an integrated system of waste reduction, recycling, incineration and landfilling be established. This view seems to be supported by most industries and many legislative and environmental groups, but with different emphasis on the different components. EPA has also set a goal for recycling 25 per cent of solid waste nation-wide.

Although the details and issues of solid waste management are both complex and controversial, it appears that after reducing the amount of waste through recycling and burning that which can be safely incinerated in waste-to-energy conversion facilities, the levels of materials left for landfills can be greatly reduced. Still left to be dealt with are the issues of safe and cost-effective incineration, air and ash toxicity levels and disposal, establishment of a nation-wide recycling infrastructure and development of efficient and environmentally safe landfilling methods.
(Extracted with permission from Chemical and Engineering News, 30 January 1989, American Chemical Society)

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Plastics recycling takes off in the USA

Part One

Households in the USA generate over 11 million tons* of plastics solid waste each year. Although this quantity represents only 7 per cent of all municipal solid waste (see table on page 70), it has received disproportionate attention from the public. Plastic containers have high visibility, particularly when discarded as roadside litter. Also, plastics are regarded as "unnatural" synthetics, not subject to the rapid breakdown in the soil that environmentalists wrongly attribute to such "natural" materials as paper. Finally, waste recovery has traditionally been seen as a low-technology, "junkman's" business.

Despite these attitudes, the US industry is now demonstrating that plastics recycling is practical, environmentally sound, cost effective and potentially profitable. Such major producers as Amoco, Dow, Du Pont and Mobil are building resin recovery units, often in collaboration with waste sources like the fast food chain, McDonalds, or waste collectors, such as Brown Ferris Industries or Waste Management, Inc., but also many small entrepreneurs are entering the business.

The driving forces

Four factors are driving the boom in recycling. First, escalating landfill costs are revolutionizing the economics of recycling. With its vast land area, the USA, unlike Europe and Japan, traditionally had large areas suitable for dumping. Such land is rapidly disappearing, particularly in the populous states of the north-east and the west coast.

Second, incineration, the most promising alternative to reduce the volume of wastes going to landfills, is also expensive. Construction costs for a 1,000 ton/day plant run around $110 million; add to this the costs of acquiring suitable sites, and financing charges. After sale to local utilities of 500 kWh of electric power per ton processed at, say, five cents a kilowatt-hour, total costs of such a plant run to $15-25 (M/a), or $40-70 per ton processed.

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* "Ton" refers to "short-ton", or 2,000 lb, throughout.

Third, landfills, incinerators, and other waste treatment facilities all suffer from the "NIMBY" reaction - "Not in my back yard". Everyone wants disposal of wastes, but not close to home. Recycling plants are environmentally and aesthetically benign. Fourth, the high current prices and shortage of capacity for virgin resins make clean, recycled plastics attractive as raw materials.

Recycling requirements

For successful recycling, a resin must meet four requirements:

- There must be a large dependable source in reasonably clean form. Industrial scrap from moulding, blowing or extruding can easily be recycled, as can post-consumer scrap from single-resin sources such as HDPE milk jugs, PS trays from school cafeterias, or PVC water jugs;

- In mixed materials, such as municipal wastes, the resins must be easy to sort and separate. Soft drink bottles and milk or water jugs already meet this requirement. Equipment now under development will separate other plastics items into reusable streams;

- The recycled resins must be relatively high in value, as PET and HDPE are today;

- Recycled plastics must have acceptable end uses, generally in non-food applications.

Polyethylene terephthalate

PET is the most commonly recycled resin. It is widely used in soft drink bottles; in the USA, an estimated 895 million lb went into these bottles in 1988.

The USA recycled over 150 Mlb of PET in 1988. Major end uses for the recycled product include: fibrefill for ski jackets and sleeping bags; geotextiles for control of soil movement; strapping; carpet fibres and non-food containers.

A half-dozen firms reprocess PET, but most of them are small. The entry of Dow and Du Pont into the resin recycling business represents a major change. Dow has announced plans to recycle 75 Mlb/a in a joint venture with Domtar of Canada, which will supply the feedstock, initially from bottle-deposit jurisdictions, and later from kerbside collection. The plant is scheduled to start up in early 1991.

Du Pont, like other resin producers, has been reprocessing large quantities of clean factory scrap for some time. It is now looking to post-consumer scrap as a new source of resin. In a joint venture with Waste Management, a large waste hauler and processor, the company plans to establish a number of recycling centres in the USA and Europe. The first location will process 40 Mlb/a. Additional centres will be built as the infrastructure for collection becomes established.

For PET bottles, the process developed at the Centre for Plastics Recycling Research has six steps: 1. grinding the whole bottle to $^1/4$ in. in size; 2. air separation to blow off label paper; 3. washing in warm detergent solution to remove soluble glues and any residues; 4. removal of HDPE by flotation; 5. drying the residual PET; and 6. electrostatic separation of aluminium (from bottle caps). The reclaimed resin will replace virgin resin in many uses.

High-density polyethylene

HDPE is the second most widely recycled resin reclaimed from post-consumer scrap; 72 Mlb were processed in 1988. One-gallon milk jugs are the principal source of HDPE feedstock. The base cups from PET soft drink bottles, mentioned earlier, provide a second source. Since these items are made solely from HDPE, recovery primarily involves cleaning, baling and grinding. Currently, baled milk jugs sell for about 17 cents/lb versus 40-45 cents/lb for virgin resin. Major end uses for recycled HDPE include pipe, pails, drums, crates and new base cups for soft drink bottles.

Polystyrene

Foamed PS is a favourite target for environmentalists. They claim that even the new blowing agents, like HCFC-22, damage the ozone layer, that styrene and its combustion products are toxic, and that paper is a preferable material for disposables because of its rapid biodegradability. Although scientific studies refute these claims, the environmentalists' argument is aided by the high visibility of discarded PS litter in parks and along highways.

To combat these claims, and to establish new economic sources of resin, Amoco and Mobil are beginning to recycle PS; Dow and others in the industry also are actively investigating the possibility. Amoco has a new recovery plant in Brooklyn, New York to process total wastes from the McDonald's fast-food chain and segregated material from other sources. Although the plant is billed as a demonstration unit, it may later be converted to a commercial operation.

Wastes enter the unit in plastic bags. The bags are shredded and release their contents to a rotating, sloping trommel, which allows small fragments to fall into reject bins. An inclined air classifier then separates the larger pieces into a light fraction containing the PS and paper, and a heavy reject fraction. The light fraction moves to a pulper, where water is added and the pieces are broken to smaller size.

The PS foam floats off in fragments of $^1/4$ to $^1/2$ in, which are dried and hauled to a central plant for repelletizing. The clean recovered pellets, priced somewhat below virgin resin, are sold for conversion to insulation board, household utility items, or other non-food uses. Material rejected at various stages is blended and compressed to densified refuse-derived fuel pellets, and shipped elsewhere for burning.

Mobil has recently opened a reprocessing plant in Leominister, Massachusetts, in a joint venture with Genpak, a large packaging company. New England CR Inc, the waste processing firm described below, delivers a stream of used PS trays and utensils, rough cleaned and stacked, from school cafeterias in Massachusetts and Connecticut. A cafeteria serving lunch to 1,000 students generates about 35 lb of PS every day. This high grade PS stream is sorted by hand, chipped, washed, dried and repelletized.

Mobil's objective is to make the recycled pellets virtually indistinguishable from virgin resin. The plant is expected to run profitably by its third year; if it does, Mobil may later build other plants around the country to recycle PS from various sources, perhaps including fast-food outlets.

Dow is participating in a development project in Akron, Ohio with the waste management firm wTe Corp. Recyclables from kerbside collection will be separated in a Materials Recycling Facility, and Dow and wTe will recover and reprocess PS and other resins from the mixed plastics stream.

In a new development, Amoco, Dow and Mobil joined four other producers, Atlantic Richfield, Fina Oil & Chemical, Huntsman Chemical and Polysar to form a National Polystyrene Recycling Corp. Total initial investment of the seven member companies is $14 million. The new company will build and operate five PS recycling centres around the country, including the existing Mobil/Genpak plant in Massachusetts. All plants will be running by late 1990, and the goal is to recycle 25 per cent of PS consumption by 1995. At first the centres will process streams high in PS from institutions like schools, hospitals and fast-food restaurants. Eventually they will also treat household scrap collected at the kerbside.

<u>Polycarbonates and other thermoplastics</u>

General Electric Plastics is heavily promoting the concept of recycling PC and other high-valued engineering resins. For such resins, GE envisions multiple uses over a long lifetime that would justify the resin's high initial cost. For example, PC might go first into clear packaging, say, as one-gallon jugs for spring water. It could then be recycled for conversion to bumpers, wheel covers, distributor caps and other automotive parts, and finally recovered from scrap cars and recycled again into construction materials. The initial customers would in effect "rent" the resin rather than buy it.

GE already buys back empty five-gallon PC water jugs from suppliers of spring water to offices and factories. It is now conducting pilot-plant work on automotive parts recycling, and has an agreement with Luria Brothers, an automobile junk yards operator, to supply selected scrap auto parts, as demand develops. The company recently organized a subsidiary, Polymer Land, to distribute smaller lots of resin to customers, and to buy back and resell their factory scrap.

<u>Other single resins</u>

Low-density polyethylene. A large volume of LDPE is recycled from clean factory scrap. Mobil alone buys 100 Mlb/a from small converters to reprocess into waste bags. Some companies on the west coast are recovering LDPE film from shopping mall wastes, separating out the corrugated paperboard for resale, and reprocessing the LDPE to agricultural film (mulch) and other low-valued uses. However, the industry has only just begun to evaluate the recycle of household LDPE waste. The initial economics appear unfavourable for its recovery as a single resin.

Polypropylene. PP is also recycled from clean factory scrap and storage battery cases but, since it has limited use in containers, not yet from post-consumer waste.

Polyvinyl chloride. PVC is readily recycled, from factory scrap, such as insulated wire and cable, with little or no further addition of stabilizers. One producer of clear one-gallon jugs for spring water is buying back ground resin from his customers. If the application of PVC in such jugs increases, it will provide an easily sorted source for further recycling.

B. F. Goodrich, a large vinyl producer, is co-operating in the Dow/wTe PS demonstration project in Akron, taking the sorted vinyl stream for experimental recycling. The company is seeking sophisticated separation techniques for automated sorting.

Because vinyls have only limited use in bottles, not much post-consumer scrap is recovered as yet. Large-scale recycling to a single resin may become practical only when blinds, shower curtains and other household items are collected at the kerbside, as well as containers. Pipe for waste drainage and irrigation would provide a ready market for these recycled resins. (Extracted from <u>Chemistry & Industry</u>, 17 July 1989, article written by Charles H. Kline, PanGraphion, Inc., 389 Ski Trail, Kinnelon, NJ 07405-2247, USA)

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<u>**Part Two**</u>

High prices and easy sortability make recovery of polyethylene terephthalate (PET) and high density polyethylene (HDPE) profitable even today. Recycling polystyrene (PS) foam also appears economical, at least from selected sources. But mixed streams of low density polyethylene, polypropylene, PS and vinyls are difficult to sort, particularly in the form of film, low-volume containers, or other household items. Considerable research is under way at the Center for Plastics Recycling Research at Rutgers University, in New Brunswick, New Jersey and Rensselear Polytechnic Institute in Troy, New York.

Meanwhile, a few companies are already converting commingled plastics, a blend consisting primarily of industrial scrap, with some post-consumer scrap. Hammers Plastics Recycling in Iowa Falls, Iowa, produces car stops in black, blue, brown, silver-grey and yellow, speed stops, bollards and thick-wall mouldings. The company also makes 12-ft plastic profiles in 3, 4 and 6 in rounds and in flats sized 2 x 2, 2 x 4, 6 x 6 and 6 x 8 in. End uses for these profiles include decks, marinas, landscaping timbers and fence posts. Announced production at the Iowa Falls plant is 15,000 lb/day, but actual throughput may run to twice this amount. The company plans satellite plants in other locations as demand develops.

The chief problems in commingled plastics recycling are developing markets for the end products, maintaining a suitable mix of feedstocks, and mechanically processing the mix.

Most of the processing equipment comes from Europe. Hammers Plastics Recycling employs a British unit, for which it has now acquired US patent rights. Other firms and universities are evaluating, and in a few cases using, low-temperature, low-shear extruders like the ET-1 unit of Advanced Recycling Technology of Belgium. Compression moulding devices, such as those sold by Recycloplast GmbH in the Federal Republic of Germany, also find some use. However, there is still no agreement on processing methods.

<u>Integrated disposal system</u>

Universal recycling of post-consumer plastics will come only after municipal and state governments install the necessary infrastructure to collect, sort and process all household wastes. In cities and towns householders must separate all refuse into three streams set out at the kerbside for weekly pick-up:

- Newspapers, stacked and tied or bundled;
- All recyclable containers, placed in special bins provided free by the state;
- Food wastes and other garbage, in a separate container.

In rural areas householders must take these materials to drop-off centres.

Scavengers take the garbage separately and truck it to a landfill or incinerator. Specially designed trucks pick up and load the recyclables into two compartments, one for newspapers and one for containers. Both are hauled to a state-owned Materials Recovery Facility (MRF) with a capacity of 140 tons/day. A private firm, New England CR Inc., designed and operates this facility. The company, established in 1982 by 12 beer wholesalers in Massachusetts, already runs an MRF in that state, and has contracts to build similar units elsewhere.

At the MRF, automated sorting equipment, designed by Maschinenfabrik Bezner of the Federal Republic of Germany, separates all recyclables into marketable commodities. Newspapers, unloaded separately from the collection truck, are baled and sold, as are corrugated container board and high-quality papers from businesses.

The mixed container stream is conveyed to an electromagnetic belt separator to remove steel cans, which are shredded, baled and sold. The other containers then pass to inclined gravity sorters to separate out the heavier glass bottles. An optical scanner inspects these bottles and divides them into clear, amber and green fractions, each of which is crushed and sold.

The lighter stream passes through an eddy current separator, which removes aluminium cans for flattening, baling and sale. The remaining plastics containers are sorted by hand into HDPE bottles and jugs, which are granulated and sold, and PET bottles, which are perforated, baled and sold. The system provides for inspection of the wastes and removal of fines. Other resin containers are now discarded, but pilot programmes for their recovery, and that of household batteries, will begin this year. Leaf and yard wastes will also be added to the list this year.

Studies by the Center for Plastics Recycling Research demonstrate that the most effective method of collecting recyclables is kerbside collection. This procedure captures 70-90 per cent of the recyclable containers, <u>versus</u> 15-20 per cent recovered through buy-back methods, such as bottle deposits, and 10 per cent reclaimed by collection centres. The centre recommends giving each household a 20-gallon bin for weekly collection of containers; newspapers are bundled separately, and placed next to or on top of the bin.

<u>The plastics industry's response</u>

Across the country, proposed new legislation threatens to further restrict the use of plastics, particularly in containers. The plastics industry has responded through individual actions by major resin suppliers, such as those described in this article, and by group action through industry associations. These associations will spend over $20 million on solid waste problems in 1989. Among them are the Council for Solid Waste Solutions, the National Association for Plastic Container Recovery, the Council on Plastics and Packaging in the Environment, and the Plastics Recycling Foundation.

This Foundation operates the Center for Plastics Recycling Research at Rutgers University, a technical centre also supported by resin producers, equipment suppliers, consumer goods packagers, recyclers, the National Science Foundation, the New Jersey Commission on Science and Technology and the States of Michigan, New York and Ohio. The Center conducts research on collection, sorting and processing of individual resins and commingled plastics.

To help increase the recycling of all plastics containers, particularly by making sorting easier, the Society of the Plastics Industry has developed a resin coding system for bottles 16 oz and up, and for tubs and trays 8 oz and up. The system is being widely adopted by industry (see figure on page 70). When most bottles are coded in mid-1991, sorting and recycling PVC and other lower-valued resins will become easier.

<u>The outlook</u>

The US Environmental Protection Agency has set a national goal of recycling 25 per cent of all solid wastes. In plastics the combination of governmental action, pressure from environmentalists, the current heavy demand and high prices for thermoplastics, and the entry of both large resin suppliers and smaller entrepreneurs seems likely to push recycling far beyond this goal. Plastics are moving from junk for discard to resources valuable for recovery. (Extracted from <u>Chemistry & Industry</u>, 7 August 1989, article written by Charles H. Kline, PanGraphion, Inc., 389 Ski Trail, Kinnelon, NJ 07405-2247, USA)

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<u>Society of Automotive Engineers (SAE) Conference, March 1989; Detroit</u>

Discussions highlighted many of the unique issues facing producers of plastic automotive parts. While big car makers have been slow to join the battle, processors such as Davidson Instrument Panel, a subsidiary of Textron, Inc., have already begun instituting solid-waste control programmes of their own. These efforts have resulted in a 25 per cent waste reduction and increased profits for Davidson. Together with its suppliers, the company continually looks for ways to further reduce waste and improve recycling.

<u>Recycling companies threatened</u>

While industry is just now beginning to set up structures for coping with household waste, an efficient mechanism - the network of automotive dismantlers and scrapyards - already exists for removing and recycling automotive part and components. But ironically, the very companies most able to deal with post-consumer auto scrap could face serious economic difficulties with the increased use of plastic in cars.

Numbering over 12,000 in the US and Canada, automotive dismantlers and recyclers take in "junked" cars, dismantle them bolt by bolt, then rebuild and resell the usable parts including the scrap metal. Scrap recyclers and shredders take what is left, remove the remaining saleable fractions and dispose of the shredded remains.

While there will probably always be a market for select, used, automotive parts, as the portion of recyclable metal decreases and plastic increases, the economic incentives for dismantling and recycling diminishes and we are likely to see less of the car salvaged.

And if disposing of the recycling residue, or "fluff", becomes too costly, the process of obtaining the valuable and recyclable components of automobiles, such as metals, may no longer justify the effort. Should that happen, there will be even more automotive waste for disposal. One answer is to design recyclability into the part in the first place. Just as strength, appearance and cost are factors in material choice today, recyclability - a real, but hidden cost - must be included as well.

Assuming automotive plastic is removed and sent to plastics recyclers for processing, a different concern emerges - the move towards degradable plastics in consumer products and packaging.

Where does Detroit come in?

Automobile dismantlers represent a mechanism for removing plastic components from junked cars, which then can be shipped to recyclers for reprocessing. One need, pointed out by the director of field services for ADRA: Automotive Dismantlers & Recyclers of America, is a means of determining what plastic was used in moulding a given part. The SAE, in its recommended practice, SAE J1344, provides that tool.

Co-authored by the product materials engineer for Ford, J1344 provides a guideline for identification marking of plastic components. The codes, used to identify the type or class of plastic, are intended to facilitate recycling and the repair and repainting of plastic parts. Despite its simplicity, there is little enforcement of the code requirements by the auto industry. In fact, of the nine divisions within Ford, only one, the engine division, uses identification codes as a matter of course. It was unclear as to whether the record of other auto makers is any better.

Since it will take about 10 years before dismantlers and recyclers start seeing the results of initiatives taken today, the longer it takes for the automobile industry to start enforcing code requirements, the longer it will be before any benefit is realized. In the meantime, if recycling of automotive plastic is to be attempted, an interim identification technique will be needed. One such suggestion is for dismantlers to have access to a catalogue which will provide plastic composition of parts, by make, model and year of the automobile.

But coding, enforced or not, is not the answer unless there is a substantial market for recycled automobile plastic, which seems to be the crux of the problem. Sending recycled plastic back to car makers will not work since the replacement of metal in the car body and under the hood often requires highly engineered and virgin resins to achieve the necessary physical properties. And many of the plastics being designed into the automobile today are composites or materials, such as thermosets, which do not lend themselves to recycling.

None the less, everyone seemed to agree that the industry can ill afford to have the Government regulate solutions and that the preferred approach to the issue must be a voluntary one. (Extracted from Plastics World, May 1989)

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The nine lives of plastic

Plastics last forever. That is their curse, but it may also be their blessing, as new uses are steadily being found for old plastic. Americans will soon be able to buy Spic-and-Span floor cleaner in a bottle made entirely of recycled plastic. Another fixture of American life, Chrysler vans, may be outfitted with fenders made from recycled soda bottles as early as the 1992 model year.

These are only two of the many products that will soon be made of reclaimed plastics if the current boom in plastics recycling continues. The rush of activity is the result of forces as disparate as the rising cost of ingredients for high-technology plastic and people at the grass roots worried about the garbage problem.

While plastics account for only slightly more than 7 per cent of municipal solid waste by weight, because of their bulkiness they take up a surprising 20 to 30 per cent of landfill space. A rising tide of throwaway plastic containers combined with ebbing landfill space has turned public opinion against the long-lived plastics to such an extent that several communities around the country have banned certain plastics from their landfills.

Alarmed, the plastics industry began a campaign to promote recycling as an alternative to disposal. It has spearheaded research on new techniques for processing reclaimed plastics and, in an unlikely alliance, has worked side-by-side with recycling advocates to convince communities that collecting and reusing plastics is feasible.

Coincidentally, large price hikes for the resins used in making plastics have turned makers of plastic products to recycled resins, which are very competitive in some uses, costing about half as much as the virgin material.

Almost all of the current recycling activity is centred on two plastics used by certain manufacturers: PET (polyethylene teraphthalate), the material found in soft drink bottles, and HDPE (high-density polyethylene), found in milk jugs and motor oil bottles. Right now one in five plastic soft drink bottles and one in 20 milk jugs is recycled.

Overall, only 3 per cent of waste plastics, or about one billion lbs, was recycled in 1988, according to a New York consulting firm. This is hardly impressive, but a definite improvement on a recycling rate of less than 1 per cent recorded just two years earlier.

These low rates are destined to rise, however, as the economics of recycling, research within the plastics industry, and the concerns of waste managers create further pressure and demand to do something other than discard the material.

In the last year alone, several companies announced plans for opening plastics recycling plants, joining the ranks of nearly 70 firms already in business nation-wide. The entrants include two enterprises that plan to recycle the polystyrene foam plastic used in fast-food containers and a joint venture between Dow Chemical and Domtar, a Canadian firm, that will recycle PET and HDPE into roof shingles and other high-priced products.

Manufacturers' demand for plastic is running high, but not enough plastic is being collected to meet it. Right now, the largest sources of second-hand plastic today are the bottle-deposit systems operating in 10 states. By placing a redemption value of five or 10 cents on beverage containers, these states retrieve almost all of the aluminium cans and glass and plastic bottles emptied by beer and soft drink consumers. The problem with such "bottle bills" is that they do not collect a wide range of other products and containers made from aluminium, glass and plastic.

A more comprehensive range of amassing plastic is to collect it along with aluminium, glass and newspaper in suburban and urban recycling programmes.

Few communities pick up plastic now because the unwieldy containers complicate the collection process. When a recycling truck makes its rounds, the section for plastic typically fills up faster than the glass and aluminium compartments. More trips to the depot means less efficiency and higher costs.

Equipment firms are busy designing and testing devices that can be installed on trucks to reduce the volume of plastics by shredding or compacting them as they are collected. The results of on-going tests in Ontario will establish whether these solutions are commercially viable.

Towns and cities that pick up unsorted household recyclables avoid this problem altogether but face another - separating the materials after collection. Until now, the tedious and time-consuming task of hand-sorting was the only option. However, fully automated plants like the one built in Billerica, Massachusetts, Inc., prove that glass, metals and plastic can be sorted mechanically. As of March, the $4 million facility began handling 160 tons of recyclables brought in daily from Rhode Island's mandatory kerbside collection programme.

Once plastic is culled from the waste stream, though, the sorting does not stop. Processors must separate plastics into the five most commonly found types to maintain the purity of the melted-down resins. Each plastic has different properties of strength and flexibility that suit it to particular tasks; most manufacturers cannot use anything less than pure strains.

Distinguishing one plastic from another is more difficult than it sounds. The Society of the Plastics Industry (SPI) is trying to help by pushing its members to stamp codes on their containers identifying the composite resins. Six states have legislated use of such a code, although not necessarily SPIs, and others are expected to follow suit. More sophisticated coding methods may soon be developed. A Cincinnati plastic maker, Quantum Chemical, has suggested adding fluorescent dye "tags" to plastics so their resin content can be identified under ultra-violet light.

Until a more effective system is introduced, plastic collectors will continue to sort scrap the old-fashioned way: in water. The process takes advantage of the different densities of PET and HDPE resins - HDPE floats and the heavier PET sinks.

The uses of pure, recycled PET and HDPE are many - carpet and rope fibres, fibrefill stuffing, car stops for parking lots, piping, planters, plastic lumber and highway markers, to name a few - but the real recycling challenge comes in finding economically attractive uses for mixed plastics. A substantial portion of plastic waste cannot be melted into pure resin, either because it is made from a combination of resins technically infeasible to separate or because it is contaminated with paper, dirt or other materials. However, reclaiming this low-value plastic mixture of resins is essential if plastics are to be eliminated from the waste stream.

Mixed plastic waste is usually turned into plastic lumber or other construction material. Europeans have been recycling mixed plastics since the late 1970s (their solid-waste crisis predates the US's by about a decade) and their technology is starting to cross the Atlantic. Four plants in the US now make plastic lumber with a simple system that melts mixed plastic and feeds it into moulds. A more versatile process called "Recyclinplas" will soon be used for the first time in North America by Innovative Plastic Products, Inc., an Atlanta-based firm. The patented West German technology puts hot plastic into compression moulds to form pallets, drainage troughs and similar items.

Like their purer cousins, mixed plastic products will sell only if they have a demonstrated utility that gives them value in the market-place. In the early stages, governments may need to give the industry a boost as it experiments with techniques and products.

While the current economics of plastic and the threat of more regulation bring new developments almost daily in the plastics recycling industry, governments and citizens alike should recognize that money will have to be spent to get rid of plastics, one way or the other. It is far more sensible to subsidize plastic recycling through government purchasing requirements or tax incentives than it is to consign plastic to only one life and, in the process, pay for yet another landfill in which to give it a proper burial. (Source: <u>World-Watch</u>, Vol. 2, No. 3, May-June 1989)

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<u>Excerpt from an article which appeared in Mike Hyde's Chemical Insight 409, early March 1989</u>:

....Like Denmark, Germany and Italy, many US states have made the return of bottles obligatory. The European countries have adopted laws which APME, the Association of Plastics Manufacturers in Europe, rightly sees as causing serious barriers to trade.

Danish bottle law inhibits free trade. Since 1981, Denmark has had a mandatory deposit and return system for beverage bottles which has stopped the import of foreign beers and soft drinks, but without inhibiting Danish exports.

The European Commission contested the Danish "case" before the European Court which, while favouring the Commission, ruled that it had not been able to present a practical alternative that would secure the control of empty bottles without limiting imports. The decision has weakened the Commission's authority to query the laws of any member State that may distort trade.

Plastics waste now one of APME's main concerns. It is the first case in which environmental protection has taken precedence over the protection of free trade. APME concludes that the ruling also implies that, when contesting official measures which affect trade, industry will have to present alternative solutions. The association has, in fact, recently appointed two executives dedicated to the question of post-consumer plastics waste management which is now one of its main activities.

This year, plastics bottles in the Federal Republic of Germany will be subject to a 50 pfennig mandatory deposit, while imports will be subject to the same rule from the end of 1990. The aim is to control the use of polyethylene terephthalate (PET), the Government refusing to accept Coca Cola's own promise to collect and reprocess 80 per cent of all empties. The deposit now imposed exceeds the cost of the bottle and is the subject of protests from French mineral water exporters.

Italy to tax plastics bags, bottles. The Italian decree of 9 November 1988 says that the cost of collecting and processing plastics packaging waste will be financed by a combination of taxes on retail bags (up to 100 lire a piece), on imports of plastics packs and on plastics materials sold for packaging (10 per cent of the sales price). Unlike Denmark and the Federal Republic of Germany, Italy has "delegated" the responsibility and cost of selective waste collection and handling to the industry.

Plastics seen as presenting more of waste problem than natural products. It is worth looking at some of the solid waste options, starting with the knowledge that plastics materials are perceived as presenting more of a litter problem than the natural products they have replaced. They are so visible that they seem to account for more litter than their tonnage justifies. In fact, they represent only 7 per cent of landfills by weight and about 30 per cent of the waste mass by volume. They can, however, be incinerated or recycled.

Much plastics waste is already being recycled, either by producers and processors within their own factories or by specialist companies. Polyethylene terephthalate (PET) bottles, for instance, often use base cups made from recycled high-density polyethylene and both materials can be recycled.

All main thermoplastics for packaging can be recycled. All the major thermoplastics, which account for about 87 per cent of the total, can be recycled, the main problem lying with the smaller quantities of more exotic materials that can be involved in domestic waste.

This could be overcome if each container were coded to indicate the resin, or resins, used. This would be costly, as would any scheme designed to collect and sort domestic waste. In some respects, producers of the traditional materials which compete with plastics are better served, many having been involved in waste recycling for 50 years or more. The problems, real and imaginary, associated with the recycling of plastics waste have led to other approaches, such as incineration or the supply of products that are biodegradable.

Incineration recovers heat "borrowed" from crude oil. The modern high-temperature incinerator could be a more cost-effective means of disposal. It also has the advantage that it recovers the heat "borrowed" from the crude oil which formed the original starting material. The energy in polyolefins is at least as good as heating oil and better than coal. The average BTU/kg contained in polyolefins, 43,600, compares with 41,700 for heating oil and 25,400 for coal.

Although incineration is considered both efficient and scientifically sound, it is not popular with environmentalists who believe that it creates more problems than it is likely to solve. However, if it were to put the case for this method of treating difficult wastes with more vigour, the industry would be able to influence decision-makers.

Recycling offers economic incentives all along chain. In the long term, recycling is likely to prove more acceptable than incineration, offering economic incentives to all involved in the chain of collection, reclamation and re-use. A US consulting firm estimates that 907,000 tonnes of recycled plastics were used last year, representing 2.2 per cent of the total volume consumed throughout the world. It is expected that this will increase to 4.3 million tonnes, or 7 per cent of the total, by 1998.

Just over half the 1998 total will be accounted for by the USA. Packaging offers the largest and most immediate potential and is expected to account for 50 per cent of the total 10 years from now.

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Plastics problem

Are plastics really a problem? This question cannot just be looked at from a technical or economic point of view, it must also be considered from the point of view of increasing environmental awareness in society. An area of conflict has arisen here, with, on the one hand, the advantages of plastics as a modern material, and, on the other hand, their disadvantages above all where their disposal is concerned.

The current method of avoiding waste when manufacturing goods made from plastics is for the producing company to recycle it. In addition, production waste is also recycled by specialized firms outside of the producing firm.

The general principle for recycling materials is that it is easiest and most economic to re-use the materials when the plastics have been sorted out into the various types. Therefore, particularly in the car industry, cars are already being built from plastics suitable for recycling, so that they can be dismantled much more easily. An additional labelling of the parts makes the task of sorting the various materials out after they have been separated much easier. This gives the recycling firm a much wider choice of materials to work on. Bayer supports the production of plastics suitable for recycling, as well as the labelling of the various parts, and is working on such projects, or is offering technical advice on applying the knowledge and on its experience in manufacture.

Chemical recycling means the recycling of plastic waste into its basic chemical components.

In the course of a research programme set up by the VKE, Bayer hydrolysed PU flexible foam waste in the 1970s. But up to now the knowledge could not be used in the market, because homogeneous production waste could only be produced with homogeneous recycled materials.

Bayer also supports the project aided by the BMFT (Federal Ministry for Research and Technology), VDA (Association of car manufacturers) and the VKE for the glycolysis of complete car seat cushions from Ford. However, it is at the moment not possible to foretell whether the standardization of the recycled polyols produced by this method is enough to enable them to be re-used for PU applications such as rigid foams.

The third largest use for plastic waste is its use as a source of energy, which is comparable with that of petroleum. This means that plastics are a valuable source of heating value of household rubbish, as they make up approximately 7 per cent of it. Bayer is convinced that the present utilization of energy value of household waste is too low, as at least two thirds of household waste is still dumped without being utilized.

Bayer sees a way of environmentally compatible waste disposal in "energy recycling", with suitably designed plants, which must be developed further along with material recycling. Modern waste-fuelled power stations with the necessary flue gas purification are, according to the standards of the "TA Luft" (technical instructions on air emissions), among the cleanest incineration plants in Germany. Along with the regeneration of energy, this technique ensures a considerable reduction in volume of the disposable waste, thereby saving valuable dumping space. Moreover, the dumped residue from the incineration is much less of a danger to the environment than the unburned waste. In addition, the waste that exists after the flue gas has been scrubbed and dedusted must be disposed of in an environmentally friendly way. Here development work is being carried out to use the common salt which results from the scrubbing of the flue gas in chloralkali electrolysis.

If all household waste were to be used to create energy in waste-fueled power stations, it would correspond to approximately 7 billion kilowatt hours. This is about the same as two 600 MW power stations burning fossilized fuels. The energy content of the plastics can therefore be used to protect our resources. This means that we replace the energy that we have "borrowed". The plastics which are now being used have already performed a valuable service, in particular by saving us energy.

Burning to produce energy is the ideal technical solution, when it can be used to convert and dispose of hazardous waste. (Extracted from Chemical Marketing Reporter, 11 September 1989, address by Dr. Gunter Oertel, Manager of Applications Technology in the Polyurethanes Business Group of Bayer AG, at the Pre-K'89 press conference in Cologne, Federal Republic of Germany)

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Recycling in Italy: Legislation almost required all packaging be degradable

Italian manufacturers of recycling equipment have become extremely active. By the end of 1987, the amount of recycled thermoplastic reached 400,000 million tons, about 15 per cent of all thermoplastic made in Italy and worth 400 billion lire. The Italian plastic and rubber machinery industry ranks second in the world in exports and third in production capacity.

And exciting developments are coming. Interesting results have come from trial collection programmes in several cities. The three principal packaging associations have joined together in a programme called "Plastica Amica" (Plastic, Our Friend) to promote the benefits of plastic and influence governmental decision-makers.

The three main associations for plastic materials manufacturers, processors and machine-tool producers initiated the "Plastica Amica" programme with four objectives:

1. Make authorities aware that plastic packaging contributes only 7 per cent to urban waste and that plastic bags represent 0.7 per cent;
2. Invite authorities to begin "anti-litter" campaigns;
3. Create a federation for the recycling of plastics which would study and verify uses for recycled plastic products and energy savings;
4. Work hand-in-hand with Italian municipalities and ministries to initiate programmes for separating plastic in concert with what is being done in other countries over the years with glass bottles (and recently, with smaller success with metal cans).

Italian experiences

Recycling's most difficult task is recovering containers. Several experiments were performed in Italy worth describing.

In Parma last year, 19 collection bins (with 3 m^3 capacity) were located in key areas such as the parking lot of a supermarket. A strong advertising programme was begun in Parma's newspapers and radio stations to deliver clean plastic waste to the bins.

In five months, 20 million tons were collected. The experiment was declared a success based on a quick extrapolation: if the bins had been placed throughout Parma, 8 per cent of the plastic produced in Italy per year could be collected, a decent percentage.

The collected plastic was shredded and used for extrusion tests in the laboratory. The results showed it was possible to obtain good quality extrudate using twin-screw technology, opening a path to the economical recovery of mixed plastics.

Another interesting experiment was carried out in Tuscany. A society was formed, jointly managed by a public administration and an association of plastic manufacturers, to settle plans for a recycling plant. Plastic wastes are collected separately in coloured bags.

Once collected, materials will be delivered to the recycling plant. There, they will be used to manufacture by-products.

And in July 1987, a separate collection of plastic containers for beverages was organized by Plastica Amica. It took place at three supermarkets in the Milan area. Posters throughout the stores asked customers to return their bottles.

The result was unexpectedly good. By the end of January 1988, some 21 million tons of bottles were collected, or about 400,000. (Extracted from Food Engineering International, December 1988, based on a talk presented to the Plastics Institute of America, 25-26 May 1989, by Mr. Claudio Grignaschi of Assocomaplast, the Italian Plastics and Rubber Processing Machinery Manufacturers Association)

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UNIDO's activities in plastics recycling

A Workshop on Plastics Waste Recycling Technology, organized under the joint auspices of the United Nations Industrial Development Organization and the Ministry of Foreign Economic Relations and Trade (People's Republic of China), was held at the Shanghai Resource Recovery and Utilization Company, Shanghai, People's Republic of China, from 10 to 12 April 1989.

1. Background

Since 1971 intensive research has been carried out in Belgium on polymer alloys, which are essentially very finely developed emulsions obtained by intensive and thorough mixing of polymers in the molten state and stabilized by cooling to obtain a high quality mix of a very viscous polymeric liquid. To achieve this it is necessary to have a very short residence time.

When the energy crisis started, concentrated study on the use and fabrication of these polymeric alloys from mixed plastics waste was highly emphasized. In 1977 Fabrique Nationale Herstal SA, Herstal, Belgium, obtained a licence for the process and developed a complete plastics recycling line with the main piece of equipment being a short-screw plastifier.

In May 1983 a Chinese delegation from the municipality of Shanghai visited Belgium, the Federal Republic of Germany and the United Kingdom to study various plastics recycling systems including the municipal waste recovery plant at Liège, designed to be the EEC pilot unit to be copied in other EEC countries, and a factory for industrial waste recovery, where all types of plastics waste were recycled using the above system.

In compliance with a request from the Government of the People's Republic of China, two Belgian experts were fielded to China in August 1985. Their mission was to survey the plastics waste situation in China and the technology used and to discuss with the Chinese counterpart institution, the Shanghai Resource Recovery and Utilization Company (SRRUC) the possibility of establishing a pilot plant for the recycling and utilization of plastics waste. The SRRUC recovers 16 categories of waste materials, including more than a thousand sub-grades. This includes ferrous metals, non-ferrous metals, rubber, paper, rags, cotton, chemical fibre and animal bones, human hair, broken glass, glass bottles, old machine parts and accessories, chemical residues, waste oil, and of course plastics. The total amount of waste material collected in 1983 was 1,660,000 tons, of which industrial wastes accounted for 85 per cent and post-consumer waste for 15 per cent, with plastics waste being 12,000 tons and rubber waste 8,600 tons.

Following this mission the SRRUC expressed a strong interest in establishing such a pilot plant and in using this plant as a demonstration unit not only for the People's Republic of China but also for other Far East countries. According to the SRRUC, there is a potential need in China for the erection of about 200 similar plants.

Based on the recommendations which emerged from the preparatory phase, a project "Recycling of plastics waste" (financed through a special-purpose contribution from the Government of Belgium to the UNIDF) was designed to establish a complete pilot unit for the recycling of plastics waste adapted to the technological and economic conditions and needs of the People's Republic of China. A pilot plant was built at the Xinguang Plastics Recycling Factory to upgrade the properties of the plastics waste and increase the yield of the plastics recycled materials. This recycling factory is a suburban division of the SRRUC, covering an area of 10,000 m^2 and mainly recycling waste PVC, PMMA and nylon with a total annual output of 2,000 tons, of which approximately 800 tons are recycled PVC.

For the establishment of the pilot plant, a subcontract was awarded to RHEO SA, a subsidiary of Fabrique National Herstal producing short-screw plastifiers, the most important item of equipment in the recycling line, and under world-wide patent. This subcontract provided for the supply of the technical know-how, drawings and specifications as well as a plastifier and a micronizer required for the pilot unit. The rest of the recycling line including crushing, compacting, washing equipment, etc. has been provided by the Chinese, as this equipment is already available locally and the complete line was assembled by experts from the subcontractor.

Experiments showed that the extruder is highly efficient in treating pure PE or PVC material of different specifications and is specially adapted for recycling PVC. Experiments on granulating mixed plastics containing 90 per cent PVC and 10 per cent PE were conducted. The resulting mixed granules demonstrated that production of better quality granules is possible only with minor adjustments of technology parameters. The reclaimed plastics granules produced by the extruder are much better in quality than those produced by ordinary extruders due to its specific design, which ensure sufficient homogeneity, short residence time, and no obvious property degradation of the plastics in the granulation process.

The patent and know-how, however, remain the property of the subcontractor. This means that, if the People's Republic of China produces this system for sale within China and in the Far East, an agreement has to be reached on the future know-how payments to the subcontractor.

UNIDO is organizing an International Conference on Plastics Recycling in September 1990, to be held in the People's Republic of China.

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Following are two articles which were presented to the Workshop:

<u>Establishment and implementation of UNIDO project for waste plastics recycling:</u>
<u>Zhu Kexi, Deputy Manager, SRRUC</u>

Introduction

Of all the projects set up for the benefit of our company with the support of UNDP and UNIDO this project is meant more for us, as it provides an effective solution to the technical problem of recycling mixed plastics waste. The project helps us establish a complete new system wholly adapted to the specific circumstances of China. With this new recycling system, upgrading of working efficiency, improvement in product quality, and elimination of environmental pollution have been realized. RHEO SA of Belgium, subcontractor of the project, undertakes to supply the Xinguang Plastics Factory of our company with a complete waste plastics processing and production line, which comprises chiefly the extrusion machine, granulator and micronizer as the main equipment. The UNIDO contribution to the project totals US $429,965 and the government input in kind US $903,000 (for the workshop, premises and subsidiary equipment). Implementation of the project starts from 1987 and ends in 1989. And now this waste plastics recycling system has been put into normal production, which proves that what we originally expected to acquire from the project, i.e. upturn of production capacity, improvement in product quality and elimination of environmental pollution, have been successfully achieved. It is envisaged that this recycling system will expand its positive influence to other industrial cities in China, and possibly some other developing countries.

Background

In the three-year span from initiation to the establishment of this project we have noticed such mutual confidence and good co-operation has existed between our Government and UNDP as well as UNIDO.

Shanghai Resource Recovery and Utilization Company (SRRUC) is one of the large-scale State enterprises specializing in waste recycling in China. Plastics waste takes 7.7 per cent of the recyclable waste total our company collects. Apart from a portion of such scrap directly supplied to the market as raw material for industrial production, the remaining part is to be processed and utilized by Xinguang Plastics Factory, a subsidiary of SRRUC.

At present, plastics waste treated by the Xinguang Factory comprises chiefly PVC, PE films and PA6 filaments. Products made of such processed material are regenerated plastics pellets. The original process adopted by the Xinguang Factory can be briefly illustrated as follows:

Plastics waste ⟶ Sorting and washing ⟶ Plastifying in-2 roll
↑
adding in plasticizer, stabilizer, colourant

mills ⟶ extruding ⟶ filtering ⟶ granulating ⟶ quality checking up and packaging

The above process actually resulted from a careful study of the characteristics of the plastics waste allocated to the Xinguang Factory and the simple equipment available on the domestic market. For a small factory with limited investment and limited time to achieve production capacity, such a process was considered feasible and rational then. But before long the Xinguang Factory faced up to some serious technological problems. Plastifying and densification of the films by 2-roll mills with electric heating in an unsealed state led to disintegration of a portion of PVC with evaporated gaseous hydrochloride pervading the working surroundings, thus gravely affecting the workers' health.

The material repeatedly heated in the course of plastifying, filtering, extrusion and granulating inevitably resulted in property degradation, thus impairing the quality of the product. Besides, inadequate material pre-treatment was an added disadvantage to the entire process.

All these negative factors cropped up to prevent the growth of production capacity, and even stagnated the normal operation. For our company, the only way out was to turn to technological reform with the introduction of more advanced state-of-the-art facilities.

Thanks to the UNDP/World Bank global project 80/004 for integrated resource recovery and utilization enforced in Shanghai in 1983, in the frame of the project, a representative of our company, Mr. Guo Yongkang, participated in an expert team touring Belgium and other countries to study their waste recycling practices. In Belgium the team visited the FN Industry Company (the parent company of RHEO SA) and the Centre de Recherches Plastiques (Liège), where they observed a PRH 120 C type short-screw plastifier invented by Professor Georges A. Patfoort of the Vrije Universiteit Brussel. The creative design and structural novelty of the machine invited deep interest from the study team. In demonstrative operation, the machine displayed its superiority in productivity, product quality and exclusion of environmental contamination.

With an expectation of remoulding the existing process of plastics scrap recycling in the Xinguang Factory, our representative, together with other experts, initiated a discussion with the top officials of UNIDO at its headquarters in Vienna, during which the study team was told that the Belgian Government had an idea of using its special contribution to UNIDO to finance the introduction of the above equipment and technology to our company in Shanghai.

In August 1983 the Deputy Head of the Division of Industrial Operations, UNIDO, visited Shanghai and inspected the Xinguang Plastics Factory. Two months later, the Ministry of Foreign Economic Relations and Trade in China officially requested UNIDO to set up a project in this connection. In August 1985 UNIDO experts, Professor G. A. Patfoort and Dr. A. Buekens visited Shanghai to conduct a feasibility study in the Xinguang Factory. Along with their positive mission report, they submitted a project proposal to UNIDO and our Government. In March 1986, Professor Patfoort came to Shanghai to hold detailed talks with the leadership of SRRUC regarding concrete steps to be taken to set up a waste plastics recycling pilot plant and to support the introduced equipment with all necessary subsidiaries. In April a Senior Interregional Adviser from the Chemical Industries Branch of UNIDO and a representative of the Belgian Government in UNIDO for project assessment visited Shanghai to inquire of our company how to proceed with the proposed project and to hear the work report prepared by Professor G. A. Patfoort.

Implementation of the project

In February 1987 related UNIDO authorities signed an agreement with the project subcontractor RHEO SA of Belgium to provide SRRUC with the technology and the complete set of equipment for plastics waste recycling.

In April 1987 a decision was reached between Professor Patfoort and SRRUC with regard to training of Chinese technical personnel in Belgium, delivery of equipment, and mapping out the engineering programme for complementing the imported equipment with necessary subsidiaries.

In October 1987 a three-person technical team headed by Mr. Zhu Kexi, Deputy Manager of SRRUC, went to Belgium for systematic training.

In November 1987 Mr. Georges Micheels, Counseiller of the Research and Development Centre, and designer of PRH 120 C type extrusion line, visited Shanghai as UNIDO expert to investigate preparations under way for setting up the pilot plant in the Xinguang Factory. He expressed satisfaction with our engineering programme for complementing the imported equipment with necessary subsidiaries.

At the end of May 1988 waste plastics recycling equipment reached Shanghai, and immediately afterwards Mr. Vincenzo Sciascia, Industrial

Manager, and Mr. A. Noirhomme, Production Manager of RHEO SA, came to Shanghai to execute their expert mission at SRRUC to guide and supervise the installation of the delivered machinery, and help start up the recycling line with necessary adjustment for test-running and production operation.

In the course of trial production, the machine line has run well and yielded a good result in processing PVC films. Of course, for the sake of further improvement some work has to be done to well compact the films first but, for the present, an effective densificator is not available on the domestic market.

Far-reaching significance of the project

Following the rapid development of industry and the growing shortage of natural resources, exploitation and utilization of recyclable waste material is an important policy for extending the function of potential resources, alleviating environmental contamination and protecting the ecological balance as a whole.

The project manifests a fruitful co-operation between UNIDO, the Belgian Government and our country in the field of waste recycling, and the successful implementation of the project results in such benefits our company now acquires as envisaged in our original plan, which might invite interests of other Asian Pacific countries having an intention to promote their waste plastics recycling activities. Shanghai, as an industrial city with a population of more than 12 million, is eager to introduce advanced technology adapted to its local conditions to develop resource recovery and utilization. As such, we are willing enough to share with you any kind of good experience, and sincerely expect technical exchange and co-operation with you, especially in the field of waste plastics recycling.

* * * * *

Plastics Waste Recycling Industry in India

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This paper is in two sections - one that refers to general comments/contemporary end-use application examples, and the other on the scenario in India

SECTION I: General comments and contemporary end-use applications

The subject of plastic recycling is of utmost importance on account of two basic factors - first and foremost being environment preservation and protection, and secondly the very important aspect of cost benefit economics, particularly with the high cost of plastics (owing to high base price or high fiscal levies or both) and the human endeavour to attain maximum advantage out of it.

As to the matter of environmental protection, plastics being non-biodegradable in general, require handling with careful selectivity in their application so as to ease the subsequent retrieval for recycling and re-use to achieve maximum advantage from its technological use and further to negate any ill-effects to the environment.

As to the cost benefit economics, the maximum beneficial use must be achieved so as to mitigate its high cost over multiple stage applications for which appropriate R&D in industry must be encouraged.

For a long time, recycling of plastic waste has aroused world-wide curiosity and interest. It is time to talk of promoting plastics recycling keeping in view a number of reasons why a more efficient recycling industry would make sense both in industry terms and for the whole economy. Plastics recycling generally takes one of the three forms: (i) in-house process waste recycling; (ii) specialist plastics waste recycling; and (iii) mixed plastics recycling. High density/low density polyethylene (which constitutes half of plastics packaging by weight) is the most common type of material recycled, others being PVC, polypropylene, polyamides, etc.

To sustain ecological balance and to take advantage of the thermoplastics' polymeric life, efforts to develop economical and beneficial technology of recycling plastic wastes and products therefrom must be encouraged to utilize the product which is generated from (i) factories, (ii) collectors of industrial waste from large generators/extruders, and (iii) packaging from commercial and agricultural sectors, etc. This step imparts efficiency and economy to the use of recycled plastics from the point of view of environmental pollution control, energy conservation and overall economy, besides maximizing material utilization efficiency.

A very high proportion of virgin material comes under recycling for use in various areas including non-critical applications for different end-users in the shape of sheets, utensils, toys, temporary civil structures, auto parts, electric gadgets and so on. But the foremost point which sometimes remains unnoticed that standardized consumer products often also open the door to introduction of recycled plastic must be approached with caution. Indiscriminate use of recycled plastic invariably will bring a product application into disrepute. It is, therefore, necessary to resort to maintaining standards and quality control of products which incorporate the use of such recycled thermoplastics. We therefore must put thrust on end-use specifications, economic usefulness coupled with employment orientation. Necessary technology and development must be taken up to usher in specialized processing of low cost yet acceptable products from recycled materials.

Generally, common purpose consumer articles are aimed for. However, an effort must be made to use the recycled materials for products aimed at industrial applications so that they can contribute meaningfully in overall industrial development.

Various end applications can be conceived and engineered for effective introduction. Two major examples that have been developed are:

(i) Pallets for dunnage in storage/material handling; and

(ii) Boxes/cases for fruit/vegetables, soft drinks and general packages made from waste LDPE/HDPE and rice husk combinations.

A unique example which has recently been introduced after development in our country is pallets from recycled HDPE/LDPE, for use as dunnage in storage and material handling, in substitution for wooden pallets.

This development replaces the use of wood which otherwise is scarce and thus needs to be preserved, more particularly for environmental protection reasons.

For sourcing the recycled plastic for this application, the development has been dovetailed to the CAP (Cover and Plinth) storage concept and programme in our country.

The scientific CAP storage requires extensive use of poly covers made from virgin LDPE/HDPE film/sheets for protection of foodgrains during storage from acclamatic conditions and rodent wastage. This is used on an extensive scale in India in the Foodgrain Storage and Protection Programme. This in turn generates substantial volume of obsolete poly scrap which has good polymeric life but is otherwise of limited value. On the other hand, wood becoming increasingly scarce day by day, the development of substitute pallets and the need to use this waste was taken up with foresight. Research on non-exploitative ways of using obsolete scrap was taken up, which led to development of poly pallets manufactured out of the low value scrap. LDPE/HDPE scrap, otherwise of good polymerics life but low value, thus could be recycled for a second generation application of economic value and contributes to environment preservation through conservation of wood as also, yet on the other hand, consumption of plastic waste.

Thus plastic scrap is brought into profitable use in the shape of poly pallets which serve the multi-purpose applications in storage as dunnage, having quality and acceptable standard of product, specially designed and fabricated for its long life. These pallets can be used with fork-lifts for industrial use, and ordinary poly pallets for dunnage for storage applications.

The particular characteristics of plastic pallets are that they:

(i) Need no fumigation;

(ii) Need no specialized handling, being able to withstand rough and tough handling;

(iii) Need hardly any repairs although of light weight;

(iv) Do not damage lower layer of gunny bags in a stack;

(v) Are chemically inert;

(vi) Are odourless, physiologically harmless;

(vii) Help in containing pollution; and

(viii) Advance ecological balance by conserving precious wood for other uses.

Each wooden pallet when substituted by a poly pallet saves 2 cu ft (0.056 cu m) of wood.

With the vast number of pallets in use, the potential saving of wood can be immeasurable. This in turn carries an immeasurable value in terms of its environmental contribution in ecological balance preservation.

Another application, viz. boxes for fruit/vegetable handling/packaging, has been developed from LDPE/HDPE and rice husk compounded material where a thick sheet of 2 mm is made and then cut and assembled into containers of convenient sizes.

SECTION II: Situation on plastic waste recycling industry in India

Polymers in commercial parlance primarily comprise thermoplastics, thermo-sets, synthetic rubbers and engineering plastics. The major thermoplastics are LDPE (Low Density Polyethylene), PVC (Polyvinyl Chloride) and PS (Polystyrene). Other thermoplastics, viz. Acrylonitrile Butadine-Styrene (ABS), Styrene Acrylonitrite (SAN) and Poly Methyl Metha Acrylate (PMMA), though not engineering plastics in the true sense of the term, have been included in this category of plastics. We shall call these general commodity plastics and shall deal with the scenario in India.

Before we go into the subject of the reprocessing industry of plastics, it would be pertinent to understand the size of the polymer market in the country for virgin material and consequent developments to augment further capacities, as the size of the RP industry among other factors also depends on the virgin material availability in the market.

In this context, it would be important to understand the past consumption and growth trends in plastics, the polymer availability scenario and demand projections for commodity plastics. The details pertaining to the above have been reflected in annexures.

The figures reflect considerable growth over the past few years. This growth was 12.5 per cent on the basis of compound annual rate of growth up to the year 1984-85. At the same time, the polymer availability scenario, though showing considerable improvement, is still far below the demand projections, as reflected in table 3 of annexure. This reflects the demand potential to the extent of 796,000 MT per annum for commodity plastics with per capita consumption of 1 kg, which is likely to increase to 1.6 kg towards the end of the VIIIth Plan to 2.16 kg by the end of the IXth Plan or by the turn of the century.

The annexure also reflects the pattern of consumption. However, another very vital factor which is taking predominance is the cost of polymers, which has been rising steadily either owing to high base cost or fiscal levies/taxes by the Government.

The indigenous availability of virgin commodity plastics has been significantly lagging behind demand for most of the time. The demand for commodity plastics is dependent on a number of factors, like price, supply, consumption characteristics, etc. The degree of influence of each of these factors is again governed by the product/market characteristics. In the Indian context, the demand for plastics is observed to be more influenced by the supply and to a relatively lesser degree by the real price of the product. The reason for such an over-dependence on the supply factor is owing to the nascent status of the industry which is growing at a very fast pace. The untapped potential is high and the future scope quite substantial. The influence of supply, therefore, predominates consumption, overshadowing the marginal changes in the price.

Currently as the production of commodity plastics in the country does not even meet 50 per cent of the total demand, the domestic requirement therefore has to be put most of the polymers under OGL scheme envisaging liberalized imports whereby actual users can meet their requirement through imports. There was a relative lull in between as the global price of the plastics had shot up considerably during the year 1986-87. However, despite the above, the demand has bounced back. Another factor which otherwise restricts imports is the high level of import duty on all the polymers imposed by the Indian Government, which can vary between 100 to 340 per cent for different polymers. The import duty structure has given the domestic manufacturers leverage to jack up the price in consonance to landed prices of imports. Therefore the polymer prices in India are amongst the highest in the world today.

Reprocessing industry - the scenario

By their very nature, thermoplastics can be shaped and reshaped many times by the application of heat/pressure/shear. However, at each processing step, the polymer undergoes degradation due to breakage of the molecular chain. The extent of degradation increases in geometric progression at each processing step. Therefore, the upper limit of useful reprocessed goods is not more than three times for all practical purposes.

The scenario with high polymer price with substantial increase in consumption has brought a lot of consciousness to the reprocessed polymer trade.

The reprocessed industry in India during the early 1960s was confined to relatively small operations - at tiny cottage industry levels - the convertor was relatively ignorant about various properties of different polymers and would ultimately mix different polymers having different characteristics. These reprocessed plastics found applications where appearance and properties were of no consequence, viz. cheap toy industries, tarpaulins for shelters, etc. It was estimated that in the year 1984-85 industry had grown to a position where 23 per cent of total virgin polymer consumption went back into the reprocessed sector; currently this has approached 50 per cent.

Trade practices in the reprocessed industry

The reprocessing industry began in the early 1960s and over the years attained reasonable status. The major aspects that influence this particular trade are:

(a) The reprocessing industry is located closer to the scrap generating industry and consumption markets. This is because the industry has to thrive on economical access to the availability of the discarded virgin processed goods, and it was observed that over 85 per cent of the reprocessors are located in the metropolis and large towns;

(b) The major reprocessing activities are carried out against cash transactions. The major quantity of inputs to the reprocessing sector come from the household, which sells packaging films and damaged/broken houseware to scrap buyers. Some inputs also come from garbage sources where discarded plastic products are thrown. The other significant source of inputs is auction/tender disposal of packaging materials by the industrial sector;

(c) The output of the reprocessing sector is also predominantly sold in the retail markets in cash;

(d) The reprocessed plastic goods, under the normal situation of steady virgin raw material prices and supplies, find specific outlets based on their price and functional requirement of end use. The textile industry is reported to be a large user of reprocessed packaging films as well as moulded bobbin cones, etc. The agricultural sector also is a large user of reprocessed goods in the form of black films and pallets. The presence of reprocessed injection- and blow-moulded houseware and toys is quite conspicuous in the rural markets as well as urban markets directed at the low-income groups. Reprocessed packaging films are extensively used by retailers for protective packaging of industrial and consumer products;

(e) From the mere appearance of reprocessed goods, the trade is in a position to classify these goods into:

(i) Once-reprocessed goods,
(ii) Twice-reprocessed goods,
(iii) Goods reprocessed more than twice;

(f) The wholesale price of virgin and reprocessed goods depends on various factors, viz. once-reprocessed, twice-reprocessed and more than twice reprocessed. Once-reprocessed polymer may cost up to 60 to 65 per cent of the virgin material; twice-reprocessed may cost between 45 to 50 per cent of the virgin material; and more than twice-reprocessed material may cost up to 40 per cent.

This therefore shows the wide scope of the reprocessed industry. In the context on average costs of thermoplastics in India can be taken as Rs 35 per kg (US $2 per kg);

(g) Some products in the household as well as the industrial sector have good re-use potential. Such products become available for reprocessing to a small extent after the purpose of re-use has been served. Typical products in the household are vanaspati, container carrier bags, etc., heavy duty plastic sacks, and HDPE woven sacks also find extensive re-use among farmers and industrial users.

It would now be pertinent to evaluate prime application of various virgin commodity plastics which form the source point for the reprocessing industry.

These are:

LDPE

Food packaging: This includes liquid milk packaging, cereals, salts and processed foods.

Non-food packaging: Fertilizer and bitumen laminate, textiles, detergents, industrial products and consumer products, including toys and garments.

Non-packaging applications of film: CAP covers, nursery bags, carrier bags.

Extrusion coatings: Fertilizer and industrial packaging.

Wires and cables: For telecommunication sheathing compound.

Injection mouldings: This includes rotational moulding, blow mouldings of various consumer products and profiles.

HDPE: The prime application for the use of HDPE - woven sacks, monofilaments, HM HDPE for packaging, pipes, injection mouldings, blow mouldings, extrusion and others.

Polypropylene: TQ film, BOPP film, woven sacks, monofilaments and ropes, sheets and pipes, strapping/sutli, injection moulding, blow moulding, fibre/filaments.

PVC (rigid): Pipes, conduits, fittings, film and foils, bottles and profiles.

PVC (flexible): Wires and cables, calendared sheets, leather cloth by spread coating, footwear, garden and discharge hose, etc.

Scrap collection: The prime factor that determines the scrap value is the grade, quality and condition of the scrap. Thereafter, the next important factor is the colour. If the scrap is of virgin material and in natural colour, it demands the highest value, followed by scraps in different colours, and the last being scrap in black colour, the prime reason being that natural colour scrap can be coloured by the consumer according to his requirements, plus the addition of colour gives a fresh look to the material; whereas other colours have to be used as such with only minor modifications. Earlier the scrap industry was predominantly in the unorganized sector but with increased consumption and also the rising prices of polymers. This scenario is now gradually changing, with the emergence of large consumers who have consequently larger scrap generations, a different kind of activity that has emerged whereby scrap collection is now more organized. The scrap is disposed of either through tenders or through annual rate contract. Considering that the total consumption of commodity plastics of 1989-90 is in the order of 955,000 tonnes, it can safely be estimated that the market for the reprocessed industry would be in the region of 400,000 tonnes, estimating first-time reprocessed, second-time reprocessed and third-time reprocessed material.

It would now be pertinent to identify sectors which utilize reprocessed material and also applications to the extent to which it could possibly be utilized. We shall take the case example of LDPE. The estimated consumption of virgin LDPE during the year 1985-86 was of the order of 144,000 tonnes, a detailed end use analysis is available bifurcating each end use.

Based on this analysis, possible segments of each virgin processed goods which became available to the reprocessing sector during 1985-86, have been estimated.

(i) Canal/reservoir lining

By the very nature of this application, there is no possibility of lined film becoming available for reprocessing.

(ii) CAP covers

CAP covers are auctioned by FCI and State government agencies after two to three seasons of use. About 5 to 10 per cent of these CAP covers are retained for re-use as dunnage. There is a time-lag of $1^1/2$ to 2 years when the material becomes available through auction for reprocessing. The consumption of LDPE in this sector was in the region of about 30,000 tonnes, out of which approximately 20,000 tonnes were available for reprocessing. The prime application for this material, as the film is black in colour, was suited to make black LDPE pipes for farm and water distribution, black tarpaulins and film for shelter and protection and poly pallets for dunnage. (This application is relatively new but is gaining acceptance as an alternative to the existing pallets made of wood, a measure that the Government wants to encourage to conserve use of wood.)

Milk packaging

This is one area where there is maximum demand for reprocessing. The bulk of milk packaging is in natural colour or white colour, both of which are in high demand. The total consumption of this segment is estimated to be around 20,000 tonnes, out of which about 75 per cent is expected to be used for reprocessing. As milk pouches have some fat adherence, this film has to be washed with detergents to remove the fat. Prime applications of this film are tarpaulins and shopping bags, nursery bags and grocery bags, which are in good demand in India.

Fertiliser packaging

LDPE film is laminated with jute or extrusion coated on LDPE/PP raffia. As such it is not possible to extract the film from the discarded sacks.

Wires and cables

LDPE film/compound is used for insulation and sheathing of power cables and communication cables. This sector is gradually emerging as a large source of LDPE scrap. This sector consumes approximately 25,000 tonnes of sheathing compound annually. This material has superior mechanical properties, there is fairly good demand for scrap generated from this industry and thus demands a high premium. The scrap from this application, as the bulk of it is in black colour, is used for plastic containers, films and sheets and blends for other plastic injection-moulded materials.

Carrier bags

These bags are extensively used in the household and only after damage are they discarded. A very small segment may get salvaged from the garbage stream for reprocessing.

Industrial packaging

This segment consumes a large quantity of LDPE film for packaging of industrial intermediates; in the year 1985-86 this segment was expected to consume 33,000 to 34,000 tonnes of material and about 20 per cent of this quantity is estimated to have entered for reprocessing through auctioning/tender disposal. Only large-sized liners, sheets, etc. are disposed of where small bags and rolls find either re-use or get discarded in the garbage.

Packaging of consumer products

The consumer of LDPE in this sector is estimated to be in the order of 40,000 MT annually. Ultimately, LDPE bags and pouches reach households as bags for cereals, salt, sugar and retail bags for snack food, processed food and consumer products. Bags of different sizes and printed overlaps are also used in this sector. As such, discarded packaging material from the household does not reach the reprocessed sector to the extent as mentioned for milk pouches. A large quantity is discarded in the waste stream and the quantity salvaged for reprocessing is only 20 per cent.

Miscellaneous applications

In this segment, the immediate application of LDPE are injection-moulded houseware, shopping baskets, ropes, half-wound canes, roto-moulded containers, colour concentrates, etc. Out of the estimated 35,000 tonnes, the input available to the reprocessed sector is in the order of 6,000 tonnes approximately through waste collection channels from the household.

In addition, there are some significant sectors where reprocessing is reported several times. This is possible only when the user keeps returning damaged reprocessed goods directly to the reprocessor. This practice is known to be prevalent on products such as tarpaulins, sheets, films and agricultural pipes and hoses. Some virgin LDPE may be used at each reprocessing stage to marginally improve the product quality. The estimated outlet for such goods is in the order of 20,000 tonnes for tarpaulin sheets and about 10,000 to 12,000 tonnes for black agricultural pipes, hoses and tubings.

The availability of reprocessed goods at prices much lower than virgin goods find market in the economically lower segment of our society. After the urban market, these goods will necessarily go to the rural market. Thereafter collection becomes uneconomic to bring the goods back to the reprocessing sector. Only in cases of specific products discussed earlier, where there is a close link between the users of reprocessed goods and reprocessors, is it possible to achieve more cycles of reprocessing. In this sector again, some virgin consumption will always exist due to drastic deterioration in the quality of reprocessed goods and the need to arrest the deterioration to some extent by using virgin material at appropriate level.

The aspect of LDPE was taken up only as an example. Similar demands exist for HDPE, PP and PVC. These four polymers alone account for 80 per cent of the reprocessing trade in the country. It is also estimated that the pace at which demand for polymers is growing (also considering that India has amongst the lowest per capita consumption) of plastics, we do expect the emergence of a much more organized sector to undertake reprocessing to cater to the second level of demand which is highly price-sensitive.

Note: Much of the information in this report has been obtained based on the Report of the Committee for Prospective Planning of Petrochemicals Industry, published by the Government of India, Ministry of Industry, Department of Chemicals and Petrochemicals, for the year 1986-2000.

End-use analysis

End-use analysis is an important and a reliable method where demand is a derived demand. In this, major end-uses are studied for their current usage and an assessment made for the foreseeable future based on an intimate knowledge of the end-use sector. Using this approach, the demand estimates for 1989-90 are arrived at for major applications for thermoplastics. The total demand estimates so arrived at are used as the base for 1989-90 and growth rates are applied for projecting the figures for the 1994-95 and the year 2000.

Acknowledgments may be recorded to Mr. G. K. Dang, General Manager (Marketing), Shivalik Agro-Poly Products Ltd., for assistance in collection of statistical data and other relevant materials for this paper.
(See tables 1, 2, 3 and 4 on pages 72-73)

* * *

UNIDO has also received a report from Argentina, and Brazil has also expressed their strong interest in plastics recycling programmes.

* * *

Table Materials discarded into the municipal waste stream

Material	Mtons 1970	Mtons 1986	per cent 1970	per cent 1986
Paper and paperboard	36.5	50.1	32.4	35.6
Glass	12.5	11.8	11.1	8.4
Metals	13.5	12.6	12.0	8.9
Plastics	**3.0**	**10.3**	**2.7**	**7.3**
Rubber and leather	3.0	3.9	2.7	2.8
Textiles	2.0	2.8	1.8	2.0
Wood	4.0	5.8	3.6	4.1
Other	0.1	0.1	—	—
Food wastes	12.8	12.5	11.4	8.9
Yard wastes	23.2	28.3	20.6	20.1
Miscellaneous inorganics	1.9	2.6	1.7	1.8
TOTAL	112.5	140.8	100.0	100.0

(Extracted from Chemistry & Industry, 17 July 1989,)

Code	Material	Per cent of total bottles
1 PETE	Polyethylene terephthalate (PET)*	20–30
2 HDPE	High density polyethylene	50–60
3 V	Vinyl polyvinyl chloride (PVC)*	5–10
4 LDPE	Low density polyethylene	5–10
5 PP	Polypropylene	5–10
6 PS	Polystyrene	5–10
7 OTHER	All other resins and layered multi-material	5–10

* Stand alone bottle code is different from standard industry identification to avoid confusion with registered trademarks.

Figure SPI resin codes for plastic containers

(Extracted from Chemistry & Industry, 7 August 1989,

Where Recycling Saves Energy

Material	% By Weight	% Moisture	% Ash	% BTU's
Paper				
Newspaper	6.7	.40	.10	534
Office Paper	3.2	.16	.04	258
Corrugated	9.0	.47	.46	634
Other	19.4	1.55	1.16	1415
Glass				
Bottles/Jars	8.0	.16	8.0	---
Other	0.8	.02	0.8	---
Metals				
Ferrous	6.0	.12	6.0	---
Cans	1.8	.04	1.8	---
Al. Cans	0.5	.01	0.5	---
Aluminum	0.9	.02	0.9	---
Other	0.2	---	0.2	---
Plastics				
HDPE/PET**	0.2	0.0	0.2	30
Other	8.1	.16	.73	1212
Rubber	2.5	.19	.53	181
Textiles	2.2	.22	.07	177
Wood	3.7	.56	.15	279
Food Wastes	7.7	6.44	.58	105
Yard	17.0	12.17	3.11	156
Org. Wastes	2.0	.42	.14	115
Other	0.1	.01	.03	6
TOTALS	100	23.12	25.32	5102

**Milk and soft drink containers only.

[Source: New Jersey Institute of Technology]

A typical waste collection shows why plastic recycling is fast becoming a priority. Although plastics make up a small percentage of bulk waste (8.3% total), they represent 23% of the "reclaimable" BTU's.

(Source: Food Engineering Int'l, December 1988)

Annexure

Table 1

Commodity plastic consumption and growth trends

Polymer	1975-76	1979-80	1984-85	CARG* (%) in VI Plan	CARG (%) in V + VI Plan
Polyolefins					
LDPE	35	70.6	134	13	15
HDPE	21.5	62.8	90	8	15
PP	0.6	15.5	36	18	18
Sub-total	57.1	148.9	260	12	17
PVC	44.2	82	156	14	12.5
PS/HIPS	9.6	12.4	19.6	10	7
Total	110.9	234.3	435.6	12.5	14.5

* CARG: Compound Annual Rate of Growth.

Table 2

Polymers: availability scenario
('000 tonnes)

	1985-86	1986-87	1987-88	1988-89	1989-90
Expected production plus imports					
LDPE	140	145	160	170	180
Linear LDPE	4	12	20	30	45
HDPE	115	125	140	165	190
PP	40	47	56	66	77
PVC	165	165	202	232	267
PS	26	29	32	35	38
Total	490	523	610	698	797

Table 3

('000 tonnes)

Polymer	Terminal Year VI Plan 1984-85 (actual)	VII Plan 1985-86	1986-87	1989-90 1/ Terminal year	VIII Plan CARG %	Terminal year	IX Plan CARG %	Terminal year 2000 AD
LDPE/LLDPE	134	144	157 (165)	225 2/ (245)	11	(413)	8	(607)
HDPE	90	115	125	190	13	350	8	514
PP	36	40	47	77	18	176	8	259
PVC	156	165	165 3/	267	11	450	8	661
PS	19.6	26	29	38	10	61	8	90
Total	435.6	490	523 (531)	797 (817)	12	1 450	8	2 131
Per capita %	0.64			1.0		1.6		2.16

Notes:

1/ The demand figures for 1989-90 are based on estimates of domestic production plus imports as shown in Table 1; on this basis of availability, the CARG % during the VIIth Plan works out to:

LDPE/LLDPE (as, e.g., LDPE)	14%
HDPE	16%
PP	18%
PVC	11.5%
PS	12.5%

2/ The figures in the brackets are for equivalent LDPE markets based on LDPE plus LLDPE tonnage. The satisfaction of the demand in future would depend on the tonnage break-up between LDPE and LLDPE.

3/ PVC consumption during 1986-87 is expected to be stagnant because of continued non-availability of material from preferred sources. This position is expected to improve from the following year.

Table 4

Kilo tonnes

Product	Demand 1989-90*
LDPE/LLDPE	290
HDPE	200
PP	125
PVC	290
PS	50

* Figures are rounded to nearest 10.

3. RESEARCH AND DEVELOPMENT

Plastics and solid waste

Introduction

Over the past 50 years, plastics have been developing into a broad and ever-extending range of materials used in most everyday items as well as in specialized articles. Following their introduction as economic alternatives for existing materials in existing uses, plastics are now a class of materials which have established themselves in their own right in many applications previously impossible with other materials.

Man-made polymers, compounds and composites have a bright future with the continued development of new materials, uses and processing methods. An emerging constraint to growth, however, may well be the handling of wastes arising from plastics applications. This is the main concern and activity of the Association of Plastics Manufacturers in Europe (APME).

Plastics today and tomorrow

Plastics materials range from commodity grades used in volume applications such as packaging and construction, to engineering and composite materials used in technical and physically demanding applications such as aeroplane equipment and telecommunications. Total consumption of plastics in Europe is currently nearly 20 million tonnes, of which more than 86 per cent consists of the "major plastics" (see table 1 on page 78).

World-wide consumption of the major plastics is growing at an average rate of 3-5 per cent annually, which is higher than general economic growth. Thermosetting resins, with established positions in special applications, tend to be more static; but many engineering plastics and speciality resins have growth rates above 10 per cent, thus showing faster growth than any other plastics in new technology fields.

The biggest part of plastics consumption (see table 2 on page 78) lies in uses with average lifetimes of several years, which shows that plastics are well accepted as reliable materials for long-term service as well as for short-term, disposable use. This fact, and the expectation that plastics consumption will continue to grow faster than the general economy, indicates that the amount of plastics will keep increasing in the post-consumer waste stream. The industry has been and still is seriously assessing the consequences for solid waste management and for the public acceptance of plastics.

Solid waste issues

In some European countries, as in other developed areas, plastics are accused of inflating solid waste streams, thus embarrassing waste disposal agencies and harming the environment. Ecologist pressure groups, politicians in need of votes, and local governments have been calling for restrictions on plastics in a variety of ways, all on waste management grounds.

Polyvinyl chloride (PVC) in particular has been criticized, on the allegation that PVC in municipal solid waste (MSW) incineration causes the formation of toxic dioxins as well as hydrochloric acid emissions and is thus a major contributor to acid rain. However, laboratory and field investigations have shown that dioxin formation is not related to the amount of PVC present and is mainly caused by poor MSW incineration techniques. Hydrochloric acid in incinerator fumes is caused only in part by PVC and is more readily separated from the fumes in properly equipped incinerators than are other acid gases present. The anti-PVC allegations have been scientifically discredited but they keep turning up as uncontrolled political arguments.

Litter is uncontrolled waste, including plastics articles, discarded by careless consumers, causing unsightly pollution and inconvenience. Some authorities, in their fight against litter, are considering restrictions on plastics uses or mandatory material specifications for such properties as degradability. However, these approaches are irrelevant and discriminatory. Litter ought not to be a plastics issue, but a question of civic responsibility and corresponding education and regulations. Although a matter of concern to APME, litter is not considered a solid waste issue in which plastics play a special role.

Occurrence of waste

Waste generated in plastics manufacture and processing is mostly recycled or reprocessed in plant, or is handled by the outside waste trade for secondary use. Post-consumer waste is mostly collected as part of the MSW stream, except in a few cases of separate collection where economic recycling is possible.

Recycled plastics waste can be used as reprocessed materials for structural use (material recycling), as raw materials for processing into chemical compounds that can be used as a feedstock for new plastics production or for other types of products (chemical recycling), or as a fuel in combustion processes. It can be used either as a separate fuel (such as refuse-derived fuel made from the light conbustible fraction separated from the waste) or as a component in MSW incineration with heat recovery (energy recycling).

Decisions to recycle or to dispose of waste will depend on the quality of the waste, economic uses for it and appropriate recycling facilities.

Pressure on the plastics industry and trade to reduce waste and to develop plastics recycling, if not for economic reasons, comes mainly from the public sect - and political groups concerned with municipal waste disposal. Separate collection of plastics waste from households has not been successful because of the lack of recycling outlets for the resulting mixture. Nor has the separation of the plastics fraction from MSW for material recycling been successful, for similar reasons.

Industries in which plastics are widely used may also need to improve their waste management. The car industry is a case in point: cars taken out of service would clutter a large part of the world if they were not taken apart by ar shredders who reclaim the metal parts and dispose of the rest.

Recently, however, polymeric components replacing metals have increased the effort and cost of dismantling a car wreck while diminishing the return of remunerative metal. Car shredders claim economic hardship; car manufacturers and the plastics industry are seeking ways to resolve the shredders' problem and to secure junk car disposal without losing the many benefits of plastics during the active period of a car's life. This now happens in the Fed. Rep. of Germany and is being taken up by APME at a European level.

Municipal solid waste

It is estimated that, in the EEC, 100 million tonnes of MSW arise each year - less than 5 per cent of total solid waste. If there is a solid waste disposal problem, it will not be solved by improving municipal waste disposal alone. None the less, MSW operators must deal with their contribution to the problem. Local MSW responsibilities are not set up to organize and finance modern large-scale solutions, which involve controlled incineration with energy recovery.

Public suspicion of incinerators, based on perceptions from earlier experiences with out-dated, ill-equipped and poorly operated plants, has caused political pressure against waste incineration and in favour of material recycling. Both options have their merits, but, in the absence of affordable landfill, the most practical solution is incineration with heat recovery.

Recycling projects

Plastics have been described as a solid form of natural energy resources that go through a phase of material use before their intended energy use. The plastics industry may think more highly of its performance products than as retarded bits of fuel, but the above view sheds light on the fact that energy use made of plastics waste is at least as respectable as using petrol in your car or heating oil in your home. The question is whether other uses of plastics waste are even better.

A second use of plastics before fuel energy use can make commercial sense, provided that recycling does not cost more than it saves. Recycling must be economic and generate financial savings or a profit compared with existing practice or competitive products being replaced.

The plastics industry has been active in studying and developing recycling options and technology.

Material recycling projects have been tested in Western Europe for years, typically based on "clean" plastics waste supplied by the industry and trade, or collected separately from households. Successful developments are typically local, low-investment, low-overhead manufacturing of one or two simple products.

In the hands of entrepreneurs, this type of business may flourish within limits. It deserves support from the plastics industry and its customers: good projects ought to be - and increasingly are - promoted and publicized. However, within the foreseeable future, material recycling is not expected to offer a significant volume outlet for plastics wastes.

Chemical recycling is a different approach, requiring more sophisticated technology and higher capital investment. The recycled products are specification chemicals that may be sold as they are or re-used as a feedstock for chemicals (including plastics) manufacture. Chemical recycling processes for plastics and other polymeric waste are still being researched but are expected to become commercial in the near future. Examples of chemical recycling are:

- Pyrolysis - thermal cracking of polymers into hydrocarbon fractions (gas, oil, carbon black);
- Hydrocracking - thermal treatment in the presence of hydrogen providing different types of hydrocarbon fractions;
- Hydrolysis, alcoholysis - methods for processing poly-condensation-type polymers into their starting materials for re-use in polymer production.

The economics of chemical recycling will depend on the market value of the resulting chemicals compared with the costs of connecting the waste material and operating the recycling plant. In general, the higher the crude oil and petrochemicals market prices are, the more favourable are the economics. Chemical recycling could be a volume outlet for plastics waste when there is sufficient demand for the resulting chemicals.

The energy use option

Incineration with heat recovery is the most reasonable option for MSW handling at the moment. However, some environmentalists oppose this on principle as being unacceptable compared with material recycling.

Justifiable criticism against the pollution from early incinerators is no longer valid for modern installations with high combustion temperatures and heat recovery efficiency, and with emission control well within requirements. Waste disposal authorities and operators do need, however, to invest in up-to-date incinerator technology.

As for the philosophical question of whether energy use is less worthwhile than material use, finite resources should be used as effectively as possible. Plastics are among the most resource-effective materials available. From production, processing and use to disposal by incineration with energy use, plastics save many times their own energy content, thus really "stretching" the oil and gas from which they are made.

Finding a second useful lifetime for plastics as material may further stretch the original resources, but product quality and economic constraints limit that option, however laudable. It is only realistic to accept the considerable benefit of plastics in single lifetime uses and make sold waste disposal more attractive through combustion.

Regulations and industry attitude

As far as plastics are concerned, recent solid waste regulations and proposed legislation in various European countries have been concerned more with reduction at source and with labelling potential waste components than with promoting adequate waste handling technology and capacity. Such developments are unduly discriminatory and are being opposed by the plastics industry with facts and arguments collected and verified through APME.

The EEC plays a constructive role in two ways. Council directives establishing common criteria and objectives aim to harmonize national laws. The directive on one-way containers for liquid foodstuffs (85/339/EEC) requires Member States to define programmes for waste containment and recycling and for consultation between all parties concerned, which include energy use as a recycling option. These programmes must be submitted to the European Commission for assessment of any technical barriers to international trade they might imply.

The second way is the obligation on Member States to notify the Commission of any new regulations that may affect free trade, and this includes matters relating to solid waste management. This requirement extends to third countries with a free trade agreement within the EEC, and thus covers practically all of Western Europe, for which APME represents the polymer manufacturing industry.

Currently, both the European Commission and the European Parliament are studying the question of plastics waste. The plastics manufacturers of Europe, through their Association, are involved and are contributing to the discussion on the rational management of solid waste.

They have offered to co-operate with the EEC authorities on the commitment of technical and marketing resources and financial support to promote recycling and other methods of reducing the import of plastics on the waste stream. The plastics manufacturers will also help in the proposed creation of a joint institution which would supervise research into waste management options and assist in the use of dissemination of the results of such research. (Source: Popular Plastics, October 1988. Article written by P. G. Claus, Director, Association of Plastics Manufacturers in Europe, Avenue Louise 250, B-1050 Brussels, Belgium)

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Chemical recycling of plastics is alternative to mechanical methods

In addition to mechanical methods of re-using plastics, such as moulding or extruding, polyester resins also can be reclaimed through chemical means and used to produce new polymer compositions. Eastman Chemicals (a division of Eastman Kodak) and Freeman Chemical Corp., have led in developing the chemical recycling of polyester resins. By one of three reaction paths, polyethylene terephthalate (PET) can be used to produce polyols (for polyurethane foams) and unsaturated resins, or it can be broken down into its original starting components and repolymerized. Eastman Chemicals, through the Plastic Bottle Institute of the Society of the Plastics Industry, has provided detailed discussions of these reactions.

PET consists of repeating ethylene glycol and terephthalic acid (TPA) units joined together by ester linkages. Aromatic polyols, hydroxyl-terminated short-chain molecules consisting of TPA and glycol units, can be produced from PET in a one-step glycolysis reaction. The idea behind the reaction is very simple: high-molecular-weight PET is broken down into short-chain pieces through a catalytic reaction of PET and diethylene glycol. By heating a mixture of PET and diethylene glycol in the presence of a manganese catalyst, the polymer chain is cut into short fragments, and the ethylene glycol portions undergo exchange with the free diethylene glycol. This reaction is allowed to proceed until an equilibrium between the two glycols is reached and the PET has been reduced to short-chain polyols.

The aromatic polyols resulting from the reaction can be mixed with commercial polyols, blowing agents, surfactants, catalysts, and polymeric isocyanates to produce a rigid polyurethane foam. When compared with control foams produced from commercially available polyester polyols, the foams produced from reclaimed materials were found to have essentially the same properties.

Freeman Chemical uses about 25 million pounds of postconsumer PET bottles and film scrap to make polyols for the production of rigid foams. The company estimates that more than 50 per cent of the laminate foam insulation used for construction is made from recycled material.

PET resins also can be re-used to produce new unsaturated polyester resins. This takes a two-step reaction. The first reaction is similar to that used to make the polyols but, instead of ethylene glycol, propylene glycol is used in the glycol exchange. The end products of this reaction include bis(hydroxyethyl)-terephthalate and bis(hydroxypropyl)terephthalate diesters, mixed ethylene glycol and propylene glycol terephthalate diesters, and free ethylene glycol and propylene glycol. Since all of the products are hydroxyl-terminated, reacting them with a dibasic acid like maleic anhydride produces new unsaturated polyester condensates.

This synthetic method has been successfully tested on PET from beverage bottles (a 2-L bottle, for instance, consists of about 50 to 60 g of PET). Producing unsaturated resins from reclaimed PET takes about half the time as other methods and produces materials of equal molecular weight, acid value, and viscosity. Glass fibre-reinforced laminates and unreinforced castings prepared from the reclaimed PET material test favourably with other materials.

Although Eastman Chemicals does not currently use the unsaturated resin synthesis from reclaimed PET in its production, it does frequently use a methanolysis reaction, which breaks down PET into its original starting materials, to reprocess large amounts (tens of millions of pounds) of Kodak film scrap. As David Cornell, manager of technology and manufacturing in Eastman Chemicals' polyester recycling business unit, says, "It makes good sense for us at Eastman Kodak to recycle our scrap as it helps treat the solid waste problem and saves on our disposal cost".

The methanolysis begins with reasonably clean PET scrap to which a catalyst and methanol are added. This mixture is heated under pressure to force the PET to depolymerize. The end products are ethylene glycol and dimethyl terephthalate (DMT). Pure DMT and ethylene glycol are obtained through recrystallization and distillation, respectively. These pure materials can be used as feedstocks for the synthesis of new polyesters.

A few special considerations must be dealt with when re-using PET from consumer sources in chemical recycling. For example, the PET must be clean and free of contaminating materials. Using plant scrap assures the manufacturers of both the identity of the resin and its purity. Using mixed coloured resins may pose a problem, although when they are used in products that are not visible to the consumer, such as foam insulation, colour is not a factor.

Whether an economic advantage is realized when using reclaimed materials depends on several factors, ranging from the relative costs of obtaining and reprocessing the materials to the cost of virgin materials or feedstocks. In addition, the supply of materials and the scale of the reprocessing effort may play a significant role. (Extracted with permission from Chemical and Engineering News, 30 January 1989, American Chemical Society)

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Automobile plastics waste yields high energy returns

A high temperature gasification process that disposes of non-metallic residues from automobile shredders by using them as feedstock for fuel is highly energy-efficient, causes no atmospheric pollution, and produces only a small amount of waste for disposal in toxic waste landfill. Voest-Alpine's HTV high temperature gasification process, is claimed to be the safest, most environmentally friendly, and in the long term, most economical way of disposing of shredder residues.

Voest-Alpine has tested the system on a pilot plant in Linz, Austria, and is now carrying out further trials on a demonstration plant. Dow Europe has supported test runs on around 40 t of car shredder waste. Voest-Alpine is working with potential customers on designs for a full-scale commercial plant. Dow has not ruled out the possibility of an active involvement in the commercialized technology.

Shredder waste comprises up to 30 per cent plastics, the remainder being paint dust, glass, cables, fluids, and dirt. In tests, Voest-Alpine has mixed this with virgin plastics - thermoplastics, PUR foam, glass-filled thermosets - supplied by Dow. The research and development director at Dow Europe says this is done in order to make the feedstock representative of waste from cars being built today, and which will not reach scrap yards in any large numbers for several years.

The waste is fed continuously to a primary reactor chamber. Primary fuel - waste oil, contaminated solvents, deposit gas, coal dust - is fed with preheated air to a burner in the chamber, bringing the temperature to 1600°C. At this temperature, carbon in the solid waste reacts with carbon dioxide from primary combustion, and, in a second reaction, with water from an integral water bath, forming carbon monoxide and hydrogen. Slag from the process falls into the water bath and forms glassy granules 1 to 2 mm in diameter. Carbon content of the granules is less than 0.1 per cent. They have very high leaching resistance, and are suitable for blending into road asphalt or concrete.

The hot gases pass through various cooling and cleaning stages. The final clean gas has a thermal value of around 3,200 kJ/m^3. Voest-Alpine says only 1 per cent of filter cake from the plant has to be deposited in toxic waste landfills.

Combustion of the clean gas produces atmospheric emissions well below permitted levels: for instance, dioxin and furane equivalent levels are less than 0.1 mg/m^3, and dust emission is less than 1 mg/m^3.

Thermal efficiency of the HTV plant during the Dow-supported test was 83 per cent, and the figure should be even higher for a fully commercial unit; by comparison, the efficiency of rotary kilns is about 60 per cent.

Dumping or thermal treatment are the only two viable ways of handling plastics waste from automobiles, given the current state of recycling technology. Legislation has already been introduced in various countries to enforce the clean-up of gas and drain water from landfills.

Legislators will limit landfills to materials that contain only a few per cent of organic substances. The further requirement to completely seal future landfills will make the costs of dumping equal to those of thermal treatment. Dow Europe SA, CH-8810 Horgen, Switzerland. Voest-Alpine Industrieanlagebau, Postfach 4, A-4031 Linz, Austria. (Source: Modern Plastics International, April 1989)

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Recycling domestic waste: a process engineering challenge

Plastics/paper

The recycling of plastics is an extremely complex business, particulars as there are so many types of plastic, and consequently there are numerous processes involved. The recovery of clean, segregated production scrap is already efficiently carried out by the plastics processing industry. However, the majority of post-consumer scrap still goes to landfill.

Plastics recovery from domestic refuse is usually considered together with paper recovery. Although plastics, in film form, are not always recovered as a saleable product, the recycling potential of fibre concentrates is enhanced by plastics removal. Unless a total wet process route is used (i.e., the raw refuse is digested and pulped), the main starting point for paper/plastics recovery is either the light (low density) fraction from the primary processing core of a mechanical refuse sorting plant or coarse oversize material from screening operations (usually + 200 mm in particle size).

In processes designed to recover both paper and refuse-derived fuel, only coarse Kraft-type material is of interest for paper/plastic recovery. There are problems associated with other contaminants, e.g., textiles and putrescibles, but these tend to be process-specific, and also tend to be dealt with to a greater extent by upstream core operational procedures.

For example, significant proportions of textile and dense plastics may be separated from paper and plastic film by using low primary air separation velocities. However, the separations are not clean enough to meet product requirements for re-use of paper or plastic. Therefore, methods of modifying the properties of either one or both constituents in order to increase the difference in response to air separation have been developed.

The Flakt process, for example, developed in Sweden, uses the application of heat in a pneumatic dryer which causes the plastics film to shrink, and reduces its response to air separation, whilst at the same time enhancing the paper response by removing moisture. Thus, in this process, the natural difference in properties is reversed.

Specific surface reduction of plastics, followed by separation by sizing, has also been reported in the USA. In contrast, the Esmil/TNO process, developed in Holland, decreases the response of paper to air separation by addition of water to the feedstock. Water is adsorbed by paper but not the plastics, and in this case plastics film is removed to the light fraction.

Many more processes have been tried, with varying degrees of success. Generally, however, the plastics film fraction separated at refuse sorting plants has not normally been of sufficiently high quality to be acceptable to the plastics conversion industry. Not only must contraries such as paper and textiles be removed, but also mixtures of different polymers are in the main unacceptable.

A more viable proposition is the use of household waste, an estimated 5 to 7 per cent (by weight) of which is plastics materials in the UK. An average typical value for polymers found commonly in household waste is 38 MJ/kg, which compares favourably to the 31 MJ/kg for coal. Successful ventures for producing electricity from waste include a major incinerator in Edmonton, north London, which produces steam to power an electricity turbine. (Extracted from an article which appeared first in Process Engineering, Spring EPS 1989)

Table 1: Plastics consumption in Western Europe, 1986

Type of plastics	Consumption (million tonnes)	Consumption (percentage)
Major plastics *	15.9	86%
Engineering plastics and speciality resins	0.6	3%
Thermosetting resins	2	11%
Total plastics	18.5	100%

* Including acrylonitrile butadiene styrene (ABS), expanded polystyrene (EPS) and polyurethane resin (PUR).

Table 2: Plastics consumption by end-use in Western Europe

End-use	Share	Lifetime group
Packaging and containers	39%	Short-lifetime use (less than one year) 20 %
Construction	19 %	
Electrical/electronic	7 %	
Transportation	7 %	Medium-lifetime use (1-10 years) 35 %
Domestic appliances	5 %	
Furniture	3 %	
Clothing	3 %	
Houseware and toys	3 %	
Mechanical equipment	2 %	Long-lifetime use (more than ten years) 45 %
Agriculture	1 %	
Leisure and health	1 %	
Others	10 %	
Total	100 %	

(Source: Popular Plastics, October 1988)

4. INDUSTRY NEWS

New cushion material made of waste PET plastic

Polyethylene terephthalate resin (PET), by virtue of its excellent properties. is widely used in synthetic fibres, films, and soft drink containers; but disposal of these non-reusable products poses a serious social problem.

The main use of waste PET until now has been limited to that of recycled fibre, and various methods are under study for its recovery and re-use. Takagi Chemicals, Inc., has developed a new use for waste PET. Processed to a three-dimensional cubic spring construction, it is used as a monofilament cushion material by changing the molecular configuration and increasing its repellency and deformation curve. Once formed in the desired shape by heat, the monofilaments are not deformed. The company calls this Curl Lock and is diligently continuing research to find other uses for the material.

The new material has better heat retention and humidity releasing properties than conventional cushion materials, so it is ideal for producing hospital beds and automobile seats.

The manufacturing process of Curl Lock is as follows: make heavy denier monofilaments from PET waste, then curl the monofilaments in three dimensions freely. At this stage the company calls the material Most Organic (MO) Curl. Then, make Curl Lock by twisting the curled monofilaments, adjusting the density and space, gluing and drying. The glue plays an important role in forming this product.

Tests conducted by the company show the differences between Curl Lock, Urethane Foam, Palm Lock and Spring. The results showed that Urethane Foam provides good cushioning at a hardness of 8-15 kg/314 cm^2, but less cushioning at a higher hardness such as 20 kg/314 cm^2. Curl Lock provides good cushioning at a hardness of 20-30 kg/314 cm^2, is superior to Urethane Foam in air permeability, and low humidity retention due to its comparatively low density.

With a higher deformation curve, higher air permeability, and less hysteresis loss than Urethane Foam, Curl Lock showed excellent results in hospitals. Urethane Foam mattresses must be changed every 6 years, where as Curl Lock mattresses show no damage after more than 10 years. Moreover, Curl Lock does not have a rust problem like a spring mattress and is not damaged by various bed movements by patients such as turning and twisting. The company reported that monitoring hospitals for the aged shows that Curl Lock mattresses prevent lumbago and reduce bedsores.

With these advantages, the company is currently studying uses other than for mattresses. For example, it is also good for vehicle cushion seats that are exposed to the elements, such as motorcycles, motor boats, etc.

As another example of outdoor use, Curl Lock used as a root bed can also supply agitated fresh water, oxygen, and fertilizer to accelerate plant growth. It is also good for fish-breeding beds.

In May 1988, a plant having a floor space of 7,500 m^2 in a 20,000 m^2 compound began production of 1 m wide, 6 cm thick Curl Lock mattresses at a monthly rate of 10,000 m per day (8-hour shift).
(See diagramme on page 84)

(Takagi Chemicals, Inc., 21-1 Horita, Obata cho, Okazaki City, Japan). (Source: JETRO, March 1989)

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As recycling gains momentum, more resins suppliers get in on the action

Three major resin suppliers have announced plans for entering the recycling business. Du Pont, Goodyear and Amoco have developed new technologies and programmes that show promise in alleviating plastics solid waste. In another development, Procter & Gamble is using recycled HDPE in its laundry detergent bottles.

PET gets back to basics. Among the more significant developments affecting polyethylene terephthalate reclamation is Goodyear Polyester Division's announcement that it has a system to "close the loop" in one recycling effort. "We have the capability, which we fully intend to apply, to re use the PET beverage bottle," says Goodyear's PET recycling co-ordinator. He reports that Goodyear has developed a chemical recycling process that can be used to depolymerize PET flake, converting it back into the basic monomers from which it is made, namely ethylene glycol and terephthalic acid. This implies that bottle-grade PET scrap can be returned to its original use. It is too early to determine when or how a commercial-scale plant will be built, but this move would assure a continual market for reclaimed PET.

Temperature and other conditions created in-reactor are sufficiently harsh to ensure destruction of contaminants, Goodyear asserts. This appears to open up avenues for food-related use of reclaimed PET. It means that PET can match the claims of aluminium recyclers, whose materials can be re-used repeatedly in aluminium cans after high-temperature smelting. Goodyear research is concentrating on how far back the breakdown of PET must be carried to satisfy concerns about contamination.

It is expected that PET derived from recycled sources will prove cost-effective enough to help stabilize resin pricing. Recently introduced PET drinking cups, lids, and deli packaging are being designed for easy recyclability.

Du Pont and Waste Management Inc. (WMI), Oak Brook, IL, USA, have entered into a joint venture to recycle curbside-collected plastics. The move marries the polymer technology clout and marketing prowess of perhaps the most diverse of US resin suppliers with the sort-and-collect potential of one of the nation's top waste management companies.

The partners plan to build a plant in North America by mid-1990 at a site not yet determined. Capacity for sorting, separating, and re-use is set at 18,200 tonnes, with initial efforts on PET and HDPE containers.

Under the joint venture, WMI will provide feedstocks by drawing on reclaim from the 90 US communities (representing about one million households) whose waste streams it currently manages. WMI already has pilot programmes in place in 10 communities for the removal and capture of plastics. The thrust is to reclaim PET in states that do not have deposit laws and where, consequently, reclaim rates are relatively low. WMI also has acquired a Swedish company with advanced technology for mechanical separation of plastics in waste.

Du Pont's role is to provide the technologies (compatibilizer and modifier being identified) for regeneration of resin properties. The company then plans to take 100 per cent of the reclaimed materials for use in already identified internal markets, or co-operative programmes with customers. Strong potential is seen in automotive and construction markets now served by engineering resins.

M.A. Industries Polymers Division, has completed the first stage of its post-consumer plastics recycling facility in Peachtree City, GA, USA. It is designed to accept mixed household plastics bottles in baled form. Recyclers need not separate by material type or colour. Three additional lines are scheduled for completion within the next six months. Annual capacity by the end of this year is expected to exceed 23,000 tonnes.

The company is currently receiving shipments of mixed bottles. The reprocessed material is sold into the manufacturing market with recycled material content identified.

Post-consumer PS foam recycling. Polystyrene Recycling Inc., a subsidiary of Amoco Foam Products, has opened a facility in Brooklyn, NY, USA, for products used in restaurants and cafeterias (food containers and coffee cups, for example). The facility uses a process developed by wTe Corp., Bedford, MA, USA, in which PS products are separated from other mixed wastes, shredded, cleaned, sent to an off-site facility, and converted into pellet form. Reclaimed pellets are then transported to Amoco's Winchester, VA, USA, plant to be manufactured into foundation protection board for commercial buildings.

Rubbermaid Commercial Products Inc., also of Winchester, plans to convert a portion of the reclaimed PS into office accessories, food-serving trays, trash receptacles, etc.

Markets for recycled HDPE. Procter & Gamble has joined three bottle manufacturers in developing high density polyethylene bottles that include 20 to 30 per cent post-consumer HDPE. Plastipak Packaging, Plymouth, MI, USA; Owens-Brockway Plastic Bottles, Toledo, OH, USA; and Continental Can's Plastic Containers Division, Norwalk, CT, USA, worked independently towards the joint objective - producing bottles for Cheer and Tide brands laundry detergent and Downy brand fabric softner. P&G says the bottles themselves are recyclable and are coded with SPI's recycling symbol.

Last fall, P&G introduced Spic and Span Pine Cleaner in a bottle made of 100 per cent recycled PET. Limited source supply and unsatisfactory cleaning processes made doing the same with HDPE impossible, says the associate director of corporate packaging. Colour was an additional complication, he notes.

The bottlers developed a three-layer extruding process (unpigmented virgin HDPE on the inside, coloured HDPE on the outside, and post-consumer and reground HDPE scrap in the centre layer).

It is the first milestone in what will be a long, lengthy development process. One of the biggest hurdles the project will face is in getting adequate supply of post-consumer HDPE, which will require industry to work in partnership with government. (Source: Modern Plastics International, July 1989)

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Du Pont joint venture claims at high value recycled plastics

In the US, Du Pont is making a major move to expand its plastics recycling business through a planned joint venture with Waste Management Inc. The venture will link one of the world's largest plastic polymer producers with one of the biggest waste collectors.

Within five years the two companies expect to be recycling over 90,000 ton/year of plastics in the US. Expansion outside the US is also likely with in one to three years.

According to the Du Pont's recycling business development manager expansion will depend on the success of the refuse collection system and the development of markets for recycled products. The firms say the joint venture provides the entire infrastructure for plastics recycling including collection, separation, sorting, reclamation and upgrading.

Du Pont's strategy is to develop technology to upgrade recycled plastics to high value products. Key products for the venture are fibres and high density plastics with applications in cars, containers and buildings.

Initially the venture will concentrate on polyester used in carbonated drink bottles and high density plastics. In the US 90,000 ton/year, or some 20 per cent, of polyester bottles are recycled. Yet total plastics recycling in the country is less than 1 per cent.

Du Pont says the recycled material will be a significant feedstock source. By developing technology to give high value products, the company believes plastics reclamation makes economic sense and fits in with the environmental pressure to reduce waste volumes. Polyester in carbonated drink bottles has an average life cycle of two months, in automotive parts it is extended to seven years and in building products to 20 years. (Extracted from European Chemical News, 8 May 1989)

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Polystyrene producers forming recycling group

Seven polystyrene manufacturers last week unveiled a $14 million plan to form the National Polystyrene Recycling Company (NPRC) with a goal of recycling 25 per cent of all disposable polystyrene products by 1995, more than the current rate of paper and glass recycling.

The seven corporations involved are Amoco Chemical Company, Arco Chemical Company, Dow Chemical USA, Fina Oil & Chemical Company, Huntsman Chemical Corporation, Mobil Chemical Company and Polysar Inc.

Each company will contribute $2 million to the venture, which will begin developing a national programme for recycling polystyrene, a moldable plastic resin typically used in packaging and food service items. It will establish five regional reprocessing recycling facilities over the next year.

The number of available landfills for solid waste disposal has plummeted from 18,000 in 1979 to just 9,000 in 1985, and half of these will be filled to capacity by next year and closed down. Experts agree that recycling post-consumer waste is a preferred method of decreasing reliance on landfills. But the US presently recycles only 10 per cent of its waste.

NPRC will be "a model for all of business", predicts the chairman of Law Environmental Inc., the overall project engineer and project manager for NPRC. "These companies will be pooling their resources to tackle every step of the recycling process from beginning to end. They will be developing real infrastructure and building an on-going enterprise."

NPRC's first task is to site the initial five recycling facilities. One is tentatively set under the name Plastics Again, a plant built in Leominister, Mass., by Genpak Corporation and Mobil Chemical. It is scheduled to go on line soon and collect post-consumer wastes from communities in New England, New York, New Jersey, Delaware, and Pennsylvania.

A second recycling centre will be located in the Southeast, serving Maryland, Virginia, North and South Carolina, Georgia, Florida, Tennessee, Alabama and Mississippi.

A Midwest plant, collecting polystyrene from Ohio, Indiana, Michigan, Illinois, Wisconsin, Minnesota, and Missouri, and a West Coast recycling centre will be built to cover California, Oregon and Washington.

While NPRC plans to finance the recycling plants, they will be operated by independent businesses. Companies such as Dart Container, Fort Howard, James River, Scott, Genpak and others that convert polystyrene resins into final products have expressed interest in running the recycling centres.

The recycling plants will produce polystyrene resins which will be used by product manufacturers, such as Rubbermaid Commercial Products Inc., to make items like office accessories, fast food trays and refuse containers.

In-plant wastes recycled

The polystyrene industry already recycles virtually all in-plant wastes. Efforts are underway to apply existing and new technologies to post-consumer wastes.

Polystyrene also is compatible with modern systems for waste-to energy combustion of solid waste, and also is a safe material for landfill disposal.

The polystyrene recycling process involves taking foam food service (cups and clamshells) and packaging materials, plastic food utensils, clear plastic food containers, and other materials and breaking them down into small pieces called fluff. These are heated and then the molten polystyrene is reformed into new solid pellets of polystyrene resin. This recycled resin is then shipped from the recycling plant to companies such as Rubbermaid that turn the resins into final products, such as childrens' toys, office equipment and videotape cassettes. (Extracted from Chemical Marketing Reporter, 19 June 1989)

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Plastics recycle deal set

Wellman Inc. and Browning-Ferris Industries Inc. have signed an agreement in principle that will establish Wellman as the market for "post-consumer plastics" collected by BFI's various recycling programmes.

The agreement links one of the world's largest waste service companies and the country's largest plastic recycler and follows close on the heels of a similar venture announced by E.I. Du Pont de Nemours & Co. and Waste Management Inc.

While the Du Pont-WMI venture joins two bigger companies, this will be the first between a major waste firm and a large recycling company. Under it, BFI will direct the plastics from its curbside collection programmes, buyback and processing centres to Wellman's plants in South Carolina and Pennsylvania.

Wellman's president says his company's interest in the plan is simple: "We want more pounds of waste plastics right now to meet our current needs and to continue to expand our existing fibres and engineering resins business, and also to develop additional end use products".

Wellman has a PET bottle recycling capacity of 180 million pounds per year, but last year recycled only 110 million pounds, mainly for lack of additional material.

The venture partners say, as do Du Pont and WMI, that they will initially target PET and high-density polyethylene, in the form of soft drink bottles and milk jugs, respectively. They estimate these two sources account for 51 per cent of the total rigid bottle waste stream and approximately two thirds of the plastics recycling stream.

BFI currently serves about 560,000 households as recycling customers through its "RecycleNOW" curbside programme, but does not as yet collect plastic waste from any of them. By contrast, WMI serves 860,000 households, collecting plastics from about 10 per cent of them. BFI does, however, collect plastics from industrial customers and from drop-off centres, and expects to initiate curbside programmes shortly.

By Wellman's analysis, of the 870 million pounds of PET bottles made last year, about 150 million pounds were recycled, with Wellman accounting for about three quarters of that.

The firm estimates 55 million pounds of HDPE were recycled in 1988 from all sources. About half of this was from industrial sources and the balance from base cups used on PET beverage bottles. Wellman recycled 20.5 million pounds, of 75 per cent of HDPE base cup material.

Worldwide, Wellman has 460 million pounds of recycling capacity: 260 million of PET and nylon fibre capacity in the US and 130 million in Europe, plus about 25 million pounds of mostly nylon engineering-type resin capacity and its HDPE capacity.

Wellman consumes most of its output internally, for the production of fibres and engineering resins for automotive, electronics and consumer applications. As its new resins supply grows, it expects to develop other fibre end uses as well as other plastics applications, such as sheeting, film, packaging and strapping.

In the US, it estimates 2.1 billion pounds of HDPE rigid bottles were produced last year, 800 million of which were milk jugs. PVC rigid bottle production was 174 million pounds; polypropylene, 122 million; and others, 43 million, for a total of 3.3 billion pounds of rigid plastic bottle output. (Source: Chemical Marketing Reporter, 8 May 1989)

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Du Pont to recycle polymer residues

Du Pont is planning to build a plant for recycling waste from its production processes in Europe. The unit will be built in Born, Limburg, the Netherlands.

Waste processed at the facility will come from four Du Pont plants: the polyester yarns mill at Hamm, Uentropp, Federal Republic of Germany; the polyester film plant in Luxembourg; and two resin facilities in Mechelen, Belgium and Dordrecht, the Netherlands.

The US major comments that while the recycling capacity is not huge, the activity is economically viable, with polymers valued between $5,000-10,000 per ton.

Currently, Du Pont sells polymer waste from its European processes for other companies to recycle. It already operates a unit in the US, and says the planned Dutch facility will use in-house technology. (Source: Chemical Business, India, 20 February - 4 March 1989)

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GE Plastics venture

GE Plastics last week announced the formation of a joint venture company, Polymer Solutions Inc., with London-based Fitch Richardson Smith (FRS), a strategic design consultancy.

The venture will provide innovative product commercialization through design, materials and process specification, engineering and marketing services.

Polymer Solutions Inc. will offer clients a complete and seamless package from concept to commercialization and will give customers access to leading-edge designers with materials and engineering expertise.

This will enable them to go to market much faster and more cost-effectively than if they were to develop products on their own. In addition, it represents an opportunity to reduce fixed in-house development costs and, thus, increase the financial agility of the enterprise.

A priority for the new company will be design for disassembly, or designing and developing products with future recycling in mind.

A wide variety of markets will be targeted by the joint venture, including housewares, major appliances, electrical equipment, computer and business equipment and consumer electronics.

Polymer Solutions will be located in Worthington, Ohio, near the US headquarters of FRS, with a staff of about six people. (Source: Chemical Marketing Reporter, 2 October 1989)

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Du Pont putting recycled plastic to road test

E.I. Du Pont de Nemours & Co. is using a trial recycling programme in Illinois, USA to determine if it can develop commercially viable highway traffic guidance equipment that meets that state's DOT standard.

The company hopes to develop the products - the cones, highway dividers, and other traffic re-routers that appear to be made of concrete but actually are light-weight plastics or rubbers - from recycled plastics.

The trial programme is aimed at developing a strong commercial market for products made of recyclable plastics and encouraging recycling on a broad scale.

The company's initial development will be based on use of reclaimed polyethylene terephthalate or PET and high-density polyethylene or HDPE bottles. Du Pont is developing its products without the benefit of any specific Illinois recycling programme. (Extracted from Chemical Engineering Progress, June 1989)

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Dow Chemical and wTe will test plastics recycling technology in Akron, OH, USA

Akron will start a curbside pick-up of bundled recyclables, and 12,000 households are expected to participate. Some 2 tpd of mixed plastics are expected to be recovered in the programme. wTe will separate the recyclables and will process all the wastes except for the plastics. Dow and wTe will jointly operate a plant to process the recycled plastics. The Akron project will be the first to include waste polystyrene products such as foam containers and cups, packaging materials and cutlery. wTe has been involved in operating Akron's waste-to-energy plant since late 1985. (Source: Chemical Marketing Reporter, 20 March 1989)

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Amoco starts up recycling plant

Polystyrene Recycling Inc., a unit of Amoco Foam Products (Chicago), opened up a polystyrene (PS) foam recycling facility for consumer products in Brooklyn, NY, to demonstrate the recyclability of PS and to further recycling technology. Initially, the facility will handle about 6,000 pounds of refuse per day from nearby schools, businesses, and McDonald's restaurants. Amoco's Winchester, VA, plant will use reclaimed PS pellets to manufacture foundation-protection boards for commercial buildings. Rubbermaid Commercial Products, also of Winchester, VA, intends to turn the reclaimed PS into such products as office accessories, food serving trays, and trash receptacles. The technology, developed by WTE Corp. (Bedford, MA), takes mixed-stream waste, says an Amoco spokesman, and extracts PS from the stream to make PS pellets. The rest of the waste is made into fuel pellets, which are used to generate heat or electricity in industrial applications, says the spokesman. (Source: Chemical Week, 26 April 1989)

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Franchising has come to the recycling business

IPPI (Innovative Plastic Products, Inc.) has opened a 63,000 square ft. plant in Greensboro, GA., to show how to turn mixed plastic scrap into useful moulded products. The plant uses a patented German process to make plastic trash, including any mixed-in wood, paper, and metal, into a homogenized melt. The resulting "glob" is compression moulded into finished parts like flat sheet, drainage troughs, pallets, and cable spools. While IPPI plans to open 15 more plants over the next five years, it also has rights to franchise the process to interested parties. (Source: Plastics World, May 1989)

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The most technologically advanced recycling plant

The Rhode Island Governor opened what is said to be the most technologically advanced recycling plant in the United States. The $5 million, 3717-square metres (40,000-square feet) Materials Recycling Facility (MRF) can process 168 tons per day of newsprint and 210 tons per day of mixed recyclables. The MRF, which is based on the German Benzer technology, accepts polyethylene terephthalate, high-density polyethylene and glass bottles; aluminium and steel-coated tin cans; and newspaper. Currently about 33 per cent of the state's residential population is "on line" to send 550 tons per week of recyclable trash to the MRF. All residents and businesses in Rhode Island will be participating by the end of 1990. In 1986 Rhode Island became the first state to legislate mandatory recycling. (Source: Environmental Science & Technology, Vol. 23, No. 7, 1989)

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UK to recycle

For the first time in the UK, comprehensive pilot schemes for the recycling of plastics from domestic waste will be operating in two major cities. In Sheffield, the project is part of the "recycling city" initiative launched by UK 2000 and Friends of the Earth. A scheme for separating plastics from municipal waste is to be started also in Manchester, by the British Plastics Federation, and Warren Spring Laboratory.

The Sheffield scheme, which covers all materials, involves the collection of domestic waste in separate bins, making sorting much easier. Similar schemes are already operating in several European countries.

A different approach is being taken in Manchester, where all plastics will remain part of the municipal waste stream. The BPF is to invest 300,000 pounds sterling in the scheme, which will develop methods for the separation of plastics from the collected domestic waste. The Warren Spring Laboratory is to conduct an initial evaluation phase, to determine the composition of the waste plastics, and the best way to separate them. (Source: Chemistry and Industry, 5 June 1989)

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CFC recovery and recycling programme extended

ICI Chemicals and Polymers recently announced the launch of a major extension to the recovery and recycling services currently offered to CFC customers. The new facility will be available, free of charge, throughout the UK and Europe.

In closed refrigeration systems, CFCs become contaminated over a period of time and less efficient as a result. For a number of years, ICI has taken used CFCs from major customers for recycling. By removing impurities, it is possible to restore them to their original quality and specification. The new scheme substantially increases the availability of this service.

The extended ICI scheme will apply to CFCs 11, 12, 22 and 502. ICI will provide customers with drums and cylinders, colour coded by CFC grade, for storage of contaminated CFCs. Once filled, these containers will be collected by ICI and the CFCs recycled for sale and re-use. CFC mixtures which cannot be recycled will still be accepted by ICI and disposed of safely at a small charge to the customer.

The new recovery and recycling operation will be co-ordinated from ICI Chemicals and Polymers' UK Headquarters in Runcorn, Cheshire, UK. (Source: Pollution, March 1989)

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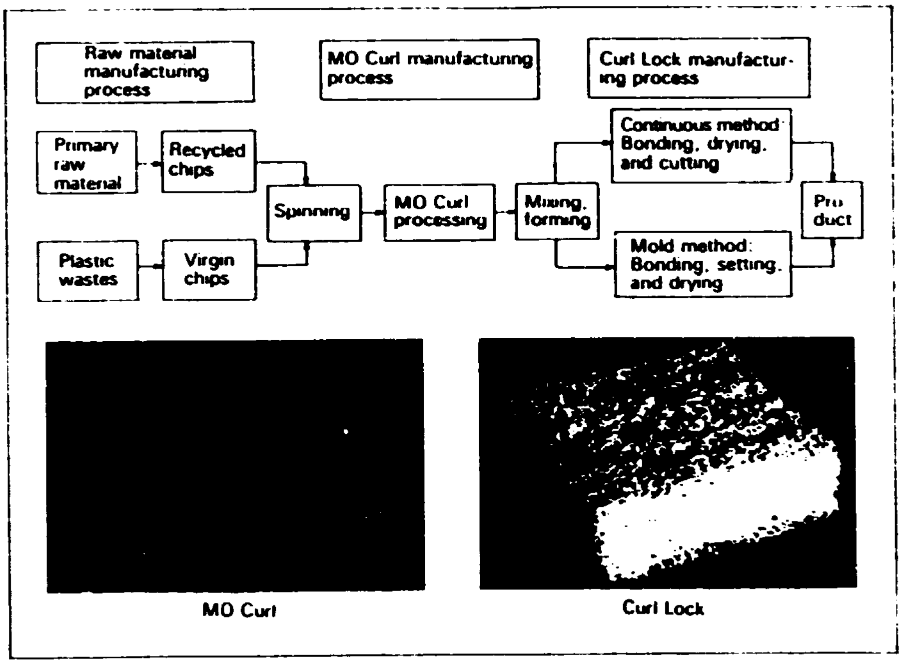

Curl Lock manufacturing process

(Source: <u>JETRO</u>, March 1989)

5. TRENDS

Plastics industry calling for more PET recycling

The plastics industry in the United States is asking for increased recycling of polyethylene terphthalate resin to keep the country's top PET suppliers operating. Many people in the industry feel that a mandatory recycling policy may be the only way to achieve this. Some success is also reported with consumer awareness, voluntary recycling programmes, and bottle deposit laws.

The head of PET recycling programmes at Goodyear Tyre & Rubber Co., a leading PET producer, said "There is a critical need to supply recyclers with PET bottles". In addition he sees the need to separate PET from other plastics in order to maintain the resin's integrity. "The beauty of PET is that it has the industry support and the customer base to make it a marketable product in its afterlife by achieving 20 per cent recycle rate," he adds, according to a report in Chemicals Press. However it seems the support and customer base is not being wholly complemented by actual recycling. The Vice-President at Wellman Inc., says "If the industry does not get its act together on recycling, it won't realize the projected 10 to 13 per cent growth forecasting." Wellman is the nation's largest PET recycler, with about 100 million pounds of capacity in Johnsonville, S.C. It recently agreed to purchase Envipco's plastics' division, which runs a 24-million pound PET recycler in Allentown, with the goal of increasing its feedstock of post-consumer PET bottles.

Currently, Wellman gets all of its PET from bottle deposit states, where the supply of post-consumer PET bottles is high. Others see the situation as more severe than just unfulfilled growth projections. "We feel there is going to be a real shortage within 90 days", says the Vice-President at Star Plastics in Albany. Star, which recycles about 20 to 30 million pounds of PET bottles per year has gone to the extent of collecting PET soft drink bottles by removing them from municipal waste headed for landfills in New York. "Someone is going to have to decide what the best system of collection is going to be for the PET bottles. Possibly the only answer is a Federally-mandated recycling policy".

Another recycler counting on mandatory recycling laws is the president of St. Jude Polymer. St. Jude is the only recycler currently getting post-consumer PET bottles from voluntary collection programmes. These programmes are in small Pennsylvania communities and two areas in Rhode Island that have initiated a pilot curbside collection programme. St. Jude recycles the resin at its 25-million pound plant in Frackville, PA. St. Jude is adding new recycling capacity every four months, and expected to be at 150 million pounds per annum by 1995, provided the material is available.

Another voluntary collection programme is being started up in West Palm Beach in Florida, according to the National Association for Plastic Container Recovery (NAPCOR). "The non-profit organization, whose members are the major manufacturers of polyester resin and bottles, will split the cost of purchasing a collection vehicle for Palm Beach country's curbside recycling programme with the country's Solid Waste Authority.

The plastic containers collected in the country will be sorted and processed through the Florida Beverage Industry Recycling Program (BIRP) facility in West Palm Beach, operated by Goodwill Industries. The President of the National Association for Plastic Container Recovery (NAPCOR) says that the Palm Beach Country has taken a giant step towards comprehensive waste management by integrating convenient curbside recycling with the resource recovery facility due to open next year."

NAPCOR is working in eight other states to institute similar programmes. Also far along are neighbourhood drop-off centres organized in Dallas this year, and a curbside collection programme in Mecklenburg Country, N.C. where NAPCOR is headquartered. St. Jude agrees that curbside collection is a viable solution. It is the way of the future, with an industry projected recycle rate of 50 per cent or better and by using their technology, it is planned to build additional recycling plants across the country as more states adopt mandatory recycling laws. (Source: Popular Plastics, November 1988)

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Plastics recycling moves ahead

A full-scale plan for plastics recycling in Guelph, Ontario, has been announced by the Canadian company, Domtar (Montreal). In a joint venture with Dow Chemical, Domtar will be responsible for collection of post-consumer plastics for recycling and re-use in such products as building and construction materials and industrial packaging.

The joint venture, named Dow-Domtar, will use Dow technology to process polyethylene terephthalate (PET) and high density polyethylene (HDPE). Curbside collection and storage of a wide variety of plastics began in March 1989. It is the first recycling programme for mixed plastics to get under way in North America.

Initially, Domtar will purchase the bulk of the recycled material for internal use in the company's packaging and construction-materials divisions. As the scheme grows, Dow will offer recycled material to its customers. It estimates the project may ultimately yield 50-100 million lbs/year of recycled plastics. The agreement allows each company to purchase up to 50 per cent of the recycled plastics. Ten processing plants will service this project. Plans for two more processing plants in the US and Canada are being discussed.

City wide participation in Guelph will be well above 80 per cent. Household consumption of plastics in Canada, where HDPE plastic milk jugs are not used, is lower than in the US. Twenty lbs/year of plastic are handled by the average US household, while Canadian households handle 10 lbs/year.

Dow last week also announced a two year research and demonstration project in Akron, OH. The company will join wTe Corp. (Bedford, MA) and the city of Akron to co-ordinate curbside collection, separation, and processing of an estimated 7 m.t./day of recyclable glass, metals, newspapers, and plastics. According to Dow Chemical's business director of solid waste solutions, the project is aimed at "research to determine the role of a plastics company in the recycling process".

Dow says more than 12,000 households, or a quarter of the city's population, will participate in the Akron project. wTe will be responsible for separation of collected materials and will also process all non-plastics. A joint facility operated by both Dow and wTe will then separate plastics by type and process them for sale.

Dow is pursuing the project in the belief that "automated technology can be developed within the project's life-time".

A variety of factors must contribute to the long-range profitability of recycling. New applications for once-used materials must be developed. Also, the collection of plastics must be made economically viable. At a New York meeting of the Council of Plastics Packaging in the Environment (COPPE) last week, the corporate vice-president of Wellman (Johnsonville, S.C.), a leading PET recycler, said "curbside collection is the wave of the future. We must build the infrastructure to make curbside collection realizable."

Other companies are also making waves in recycling. Hoechst Celanese announced a waste-minimization and plastics-recycling programme this month, pledging to "find better and more efficient ways of handling the generation, recycling, and disposal of solid waste".

Amoco expects it venture with wTe to separate polystyrene foam from McDonald's restaurants will start operations in 2-4 weeks. A pilot project to collect waste from 20 McDonald's restaurants in New York City and Long Island was initiated "to measure the economic viability and practical application of recycling".

Procter & Gamble's Spic and Span cleaning product will be packaged in the first 100 per cent recycled PET bottles sometime this year. Test areas for the product, to determine the reliability of the bottle during transportation, storage, and shelf life are currently being selected. National marketing of the product - and others using recycled PET - will follow if regional tests are successful.

Recycling: A promise of growth
(billion lbs)

	1988			1989		
	Total Vol	Amt Re-cycled	Per cent	Total Vol	Amt Re-cycled	Per cent
Polyolefins	43.3	1.3	3.0	66.4	5.9	8.8
PVC	17.8	0.2	1.6	26.6	1.1	4.0
PET	2.0	0.1	6.7	4.7	0.8	16.7
Styrenics	12.1	0.3	2.7	16.3	1.3	7.8

(Extracted from Chemical Week, 29 March 1989)

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Trends in plastics waste recycling

Modern synthetic materials have revolutionized the way of life in most countries. Not only have they replaced traditional materials such as metal and wood for many purposes, modern packaging would be unthinkable without them, as would be many medical application, among others. The disposal of synthetic wastes, however, represents one of the most intractable problems facing public authorities. From used plastic packaging to disposable syringes, the virtually undegradable plastic materials in numerous mutually incompatible varieties refuse to rot in the ground, nor can they be burned without severe environmental pollution.

In 1960, the US produced 69 million tons of municipal solid waste, less than 1 per cent of which was plastics. Steady penetration of markets is projected to increase plastics wastes to 14.1 billion tons (9.8 per cent) by the year 2,000. Figures also pinpoint the limited scope of existing post-consumer plastics recycling systems. The recovery rate for plastics (1 per cent by weight in 1984) trails those for ferrous metals (2.7 per cent), rubber (3 per cent), glass (7.2 per cent), aluminium (28.6 per cent), and paper (20.7 per cent).

The US plastics industry has responded by placing recycling of post-consumer waste at the centre of its agenda, working to foster: (i) resurgence of PET bottle re-use including new technologies, grass-roots plants, plant expansions, and innovative end-uses; (ii) identification of additional plastics for re-use such as engineering resins, HDPE oil bottles, drums and milk jugs; and (iii) support for research into post-consumer plastics waste treatment covering technologies for reprocessing mixed waste, auto-shredder residue, and engineering plastics, and pyrolytic conversion of plastics wastes into energy.

An equipment that converts mixed plastics scrap into useful products, called Extrusion Technology 1 (ET1 for short), was officially introduced by Advanced Recycling Technology Ltd., Belgium, at "Recyclingplas II", the annual plastics recycling conference held in Washington DC, USA and sponsored by the Plastics Institute of America. The commingled plastics recycling method embodied in ET1 is being implemented in the US by the Plastics Recycling Foundation. It is claimed that the plastic lumber made by this process is proving a cost-effective, higher-performing replacement for wood. The lineals can be cut, nailed and sawn in the manner of wood, but are resistant to rot, water and bacteria. ET1 equipment is already in commercial use in 12 plants in Western and Eastern Europe. Applications are in fencing, planks, boardwalks, docks, outdoor furniture, park benches, road markers and reflecting posts. The cost of an entire ET1 line (shredder, densifier, conveyors, extruder and moulding equipment) is $350,000 to $400,000. The supplier estimates that the plastic profiles can be made for 65 to 80 cents/kg.

Other recent developments in recycling that surfaced at "Recyclingplas II" include technologies for the following: (i) removal of PVC coatings from X-ray industrial film scrap; (ii) removal of PVDC from polypropylene and PS film; (iii) economical recycling of HDPE milk and chemical-containing bottles; (iv) conversion of HDPE and commingled plastic waste into lineals up to 5 m long and 20 cm diameter; and (v) recycling of PET to make sheet for thermoforming berry baskets and business cards, and to make woven geotextiles, roofing membrane, extrusion-coated plywood and an additive that raises the heat distortion temperature of asphalt.

Austria throws out something like a quarter of a million tons of plastics waste annually, more than half of it from private households. Now researchers at the Austrian Institute for Synthetic Materials in Vienna have succeeded in developing a new recycling process for plastics waste. This "grafting" technique allows waste consisting of mixed synthetic materials to be "refined" and converted into a completely new product with new properties. In the course of this process, whose development is being supported by the Austrian Ministry for Science and Research, a special synthetic material is added to the waste, and anchored in its molecular structure. The result is that the plastics waste is converted into high-grade material which, among other applications, can be used for electronic articles such as radio and television casings. The first test applications have proved highly successful.

At the present time, British households generate 18 m tons of rubbish annually, of which only 6 per cent is burnt for energy. The remainder requires acres of landfill, using up valuable agriculture and building land. Glass and paper are the only components that are recyclable. However, there is hope that one day plastic containers will be made of PHB (Polyhydroxy-butyrate) which is totally bio-degradable by algae, fungi and bacteria in the soil within a year or so. PHB is a "natural" polymer produced by fermentation of the bacteria, Alcaligenes eutrophus commonly found in soil. PHB is being developed by a British firm.

The idea of a "natural" polymer is not new - it was identified as long ago as 1925 at the Pasteur Institute in Paris - but exploitation has been slow owing to the much higher costs involved than with normal PET (Polyethylene) plastics. It is hoped that manufacturers of "natural" products, such as cosmetics and herbal remedies might switch to PHB as higher packaging costs could be more easily absorbed into such products and sold on an environmental basis attractive to such markets. (Source: Asia-Pacific Tech-Monitor, January-February 1989)

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A new wave of plastics recycling

Producers of plastics and plastic products have traditionally countered consumer accusations about solid waste with statistics: they note, for example, that plastics compose only 7 per cent of the solid-waste stream in this country. Lately, however, producers have been doing more than cite facts and figures.

Late last month, Du Pont and Waste Management formed a joint venture to recycle plastics collected from consumers into "high-value materials". The new combination is the latest in a series of announcements by resins producers. While companies routinely recycle internal waste from manufacturing operations, these projects represent some of their first efforts to process trash generated by external sources, such as schools, fast-food restaurants, and households.

One can easily assume that all the major polymer companies are now looking at whether they should be recycling, have a joint venture with a recycler, or, at the very minimum, support an organization like NAPCOR". NAPCOR, the National Association for Plastic Container Recovery, is an industry group that works to facilitate recycling in communities.

While the market is expected to see significant growth in the next few years, industry sources say the recent activity has been spurred as much by public and legislative pressure as it has by the vision of new opportunity. Much publicized bans against the use of plastic products, such as those already passed in Minneapolis/St. Paul, Suffolk County, NY, Berkeley, CA, and other communities, have prompted producers to come up with ways to try and prevent the spread of such laws.

"Just the idea that plastics can be recycled will take the pressure off", says one industry source regarding the value of recent announcements. And the producers have ll noted that part of the reason they are embarking on such projects is to show the public that plastics are easily recycled. Some observers even question if the companies are really serious about recycling municipal waste. The industry source points out that a polyethylene producer that recycles high-density polyethylene has lost an internal customer.

Companies admit that the plastics recycling industry is still in its infancy, but they believe it presents some good business opportunities. Industry projects, for example, that while about 150 million pounds of PET (polyethylene terephthalate) goes into recycled products today, that number will likely jump to 600 million pounds by 1992. The Environmental Protection Agency projects that by 1992, 25 per cent of municipal solid waste will be recycled, 2-1/2 times the current rate.

Plastics recycling will become "a whole new segment of the industry", predicts the project manager for the Dow/Domtar joint venture - in the same way, for example, the scrap-metal business has become a key part of that industry. He notes that some of Dow's customers are already requesting recycled plastics. "They want to be able to say, 'We have recycled materials.'"

Just how long it will be before these projects are profitable and how big a market for recycled plastics will develop are at the moment unknown. Mobil Chemical expects its plant in Massachusetts to turn a profit within two years. Amoco Chemical's one million lb project in Brooklyn, NY, on the other hand, which the company describes as "a demonstration plant", was built to commercial standards as an effort "to make sure we have sound economics for doing the same thing elsewhere".

Calculations show that in theory at least, a 20-million lb PET recycling plant involves a $2.5-million investment; if all 20 million pounds were sold at 25 cents/lb, yearly profits could be $1 million on revenues of $5 million, obviously a decent rate of return. But he points out that the industry today is nowhere near operating rates like that.

Plastics producers hope to avoid the snag by recycling the waste for internal use. Amoco Foam intends to manufacture construction materials from the polystyrene it recycles.

But industry sources agree that the biggest problem limiting market growth is getting a steady stream of waste. While legislation that would make collection and recycling of plastics mandatory has been passed in New Jersey, Rhode Island, and California, and is under consideration in many other states, the current supply is uneven.

"There aren't enough suppliers of post-consumer plastics", says a spokesman for the Council on Solid Waste Solutions. The real problem, he continues, is getting more communities to institute curbside collection. This involves getting consumers to deposit their used plastics in a special bin outside their homes for waste haulers to pick up, separate, and then supply to recyclers. Observers have noted that because Waste Management is a waste hauler, the joint venture with Du Pont is a step in the right direction.

But even in areas where laws have been passed, it will be some time before their impact can be assessed. "Too many laws are brand new", says the president and chief executive officer of the large plastics recycler, Wellman (Shrewsbury, NJ). Communities, he says, are "still sorting it out".

Over the next few years, legislation that mandates recycling will help develop the organization necessary to get a steady supply of plastic waste to processors. This summer, EPA is expected to address the problem of municipal waste, with Congress. And while some observers are skeptical that all the announced projects by polymer producers will actually come on-line, they are optimistic about the market's potential.

"Recycling can and will be profitable" for plastics producers, says a Chem System's consultant. "All they need is an infrastructure." (Source: Chemical Week, 10 May 1989)

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Plastic waste: fuel for small power plants?

Mobil Chemical (USA) has commissioned a research project to study the use of mixed plastic consumer waste as a fuel in small power plants. The study will consider the economics of segregating plastics from other solid wastes and converting them to pellets or another form that facilitates burning them as a primary fuel in small plants. Such plants are typically used by college campuses, hospitals, municipal buildings and office or industrial parks.

In mass-burn incineration, plastics are valued for their high-energy content which improves combustion of other wastes, thereby producing fewer pollutants and less ash for landfill disposal. Plastics, which are derived from petrochemicals, have four times the fuel value of the average mix of municipal solid waste, about the same value as residual fuel oil and twice that of coal. Developing a refuse-derived fuel from used plastics for small power plants would take further advantage of these energy benefits.

The Mobil research will include a review of existing plastics incineration technology in the US, Europe and Japan, and consultation with a wide variety of solid waste experts. (Source: Industrial World, December 1988)

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Recyclers find plastics in short supply

Paper and glass? More than they can handle. Plastics? Cannot keep up with demand.

Recyclers calling on county recycling centres in New Jersey find they have more paper and glass than they can sell but cannot keep up with the demand for plastic bottles. The proliferation of recycling laws has forced communities to collect all the paper and glass they can but only a few pick up plastic containers.

According to government and industry officials, however, plastic recycling is on the verge of explosive growth, in part because the plastics industry is under pressure to take responsibility for its share of the solid-waste problem. Although only a small percentage by weight, plastics make up as much as 30 per cent of the volume of trash. Yet, only 1 per cent of plastic packaging is recycled and most of that consists of plastic soda bottles from the 10 states that have enacted deposit laws.

Plastic recycling is attracting entrepreneurs because it is cheaper to turn old soda bottles into polyester fiberfill than to buy new plastic as raw material. A variety of companies large and small are trying to cash in, including Day & Zimmerman the giant Philadelphia engineering firm, which negotiating to build a recycling facility in Carneys Point, NJ, using technology licensed from the Rutgers Center for Plastics Recycling Research.

Another company, Polymerix, Inc., of Lincoln Park, NJ, is building a plant that will mix different types of plastic into TriMax, a rot-free lumber that, on a price basis, should compare favourably with pressure-treated wood. (Extracted from Chemical Engineering Progress, February 1989)

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6. MARKETING

There's (plastic) gold in them thar landfills

Across the country a backlash is building against one of the staples of American life - plastic. It is spurred by the declining availability of cheap landfill sites and concerns about plastic litter - foam coffee cups and food wrappers that only disappear from beaches and roadsides when picked up. To tackle these problems, local and State governments are rushing to write new laws to control the use and disposal of plastics. Suffolk County on New York's Long Island will ban polyethylene grocery sacks and polystyrene and polyvinyl chloride fast-food packaging beginning in July 1989. Florida and 14 other States also are considering similar measures.

Besides imposing outright bans on the use of some plastics in packing, legislators also are mandating that plastic containers be made of materials that sunlight or bacteria can break down. These responses, however, could ultimately be counterproductive. There are doubts about the real utility for degradable plastics, and some researchers are voicing concern that growing use of these materials could pose problems for emerging plastics recycling operations.

There is, however, little argument about the need to do something about the growing volume of plastic waste. Plastics now account for 7 per cent by weight of all municipal refuse, a figure that analysts say will rise to 10 per cent by the year 2000. And because plastics can be spun into fibres, moulded, or made into films with relative ease, industry and consumers are expected to produce even more plastic waste in the next century. As with paper, steel, glass, and other materials, which account for the bulk of municipal refuse, waste managers and private companies are beginning to devise ways to reclaim plastics from the waste stream.

The challenge of disposing of plastics in municipal wastes has received little public attention until recently. The material has simply been buried or burned. But the rising costs of landfills and of transporting wastes to other states, and concern about the health implications of incinerating some materials, have forced States to seriously consider recycling or the use of alternative materials.

Shaping a strategy to deal with plastics, however, is hard because there is little information about the economics of recycling various plastics. Nor are there standards for deciding what plastics should be degradable. As a result, Government leaders, particuarly at the local level, are taking action without much information. Citing this scarcity of data, Richard V. Anthony of the National Recycling Coalition, Inc., recently appealed to Congress to set up an information centre that local governments can tap for facts.

The plastics recycling business is just beginning to bloom in the United States. The recycling of soft drink bottles made from polyethylene terephthalate (PET), for example, soared from 8 million pounds in 1979 to 130 million pounds in 1986 and could reach 600 million pounds in the United States by the mid 1990s. The executive director of the Plastics Recycling Foundation says similar levels of recycling may be achieved with high density polyethylene jugs.

Revenue generated from plastic recycling has the potential to equal that produced from the recovery of newspapers - some $300 million. Scrap high-density polyethylene jugs are going for around 12 cents a pound and 25 cents or more after being cleaned and reduced to flakes. Soft drink bottles and other containers using PET can bring 60 cents a pound.

Markets for recycled plastics have mushroomed because US virgin resin production facilities are operating at capacity and prices for these resins have escalated. Clean, reprocessed material sells at roughly half the cost of virgin material. End uses for PET, for example, include fibre fill for garments, strapping bands, engineering plastics, textiles, and carpeting. The associate dean of the College of Engineering at the University of Toledo says that the market for recycled plastics "has hardly been penetrated". Only 58 million pounds of recycled polyethylene are being sold yearly, while the US market consumes 7 to 8 billion pounds. He estimates that there is a market today for at least 400 million pounds of recycled polyethylene.

Ways are also being found to use mixed plastics that cannot be easily or economically separated by type and chemical composition. Three plastic extruders capable of handling polyethylene, polystyrene, polypropylene, and limited amounts of polyvinyl chloride are operating in the United States now. They are being used to make landscaping ties, park benches, farm structures, boat docks, and other products. The challenge is to identify high-volume products that can be fashioned from these mixed materials. The task is made difficult at times because colour selection is usually restricted to dark tones and perfectly smooth finishes are not attainable.

While recycling holds tremendous potential, few states are looking at more than half their plastic wastes. New Jersey, for example, has set a goal for its counties of 25 per cent. What is left will continue to be incinerated or go to landfills.

Incineration is facing potential problems of its own, however. There are continuing questions about the safety of burning of plastics in municipal incinerators, especially polyvinyl chloride (PVC). This is a source of hydrogen chloride. It can be transformed in incinerators into dibenzoparadioxins and dibenzofurnas, which are thought to be carcinogenic. At this time, the Environmental Protection Agency (EPA) does not regulate the incineration of PVC plastics, but rules governing emissions from municipal plants were due in November 1989.

A recent test conducted by the New York State Energy Research and Development Authority indicates that emissions of dioxins and furans from PVC combustion can be minimized when municipal incinerators are operated above 1500°F. But further research is needed to understand the chemical reactions that are occurring and to examine the potential for dioxin emissions to rise if more PVC enters the municipal waste stream.

In the meantime, some localities are taking steps to ban use of PVC packaging materials. And in one instance in the Federal Republic of Germany has banned the use of PVC window frames in public buildings.

Even with better information that dispels the myths about the ecological and resource advantages of paper or metal over plastic; the fate of waste plastic may hinge on changing the mindset of the citizenry. The city of San José, for example, has a large, successful recycling programme with 180,000 homes separating glass, metal, and newspapers from their garbage. But the residents' response to the city's request that they add plastic pop bottles has been pitiful, says the director of the operation, which is run by Waste Management, Inc.

It is not surprising; people are not used to thinking of plastics as having an economic value or being recyclable. But the President of Resource Integration Systems, Ltd., of Toronto, Canada, a waste management firm, says it is just "a matter of time before communities are forced to recycle more".

More than half the nation's cities face higher disposal costs in the 1990s as they exhaust their landfill space. If trash collection fees are structured to reflect the full lifecycle costs of landfill and incineration facilities, people will "start being motivated to do the right things". (Extracted from Science, Vol. 241, 22 July 1988, pp. 411-412)

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Plastics recycling picks up momentum

Although the economics remain marginal, recycling is getting a big boost from unrelenting regulatory pressure

Plastics recycling, once a fringe operation for small waste-handling companies, is taking on all the trappings of a big business. New plants are being built, raw-material and distribution channels are being formalized, and some of the world's largest chemical companies are now setting up their own ventures. Market forecasters project a dramatic five- to ten-fold growth in the volume recycled from the present 150-200 million pounds in the US over the next five years or so. Nevertheless, most observers agree that the main impetus for the growth is increased legislation, rather than strong economics.

The legislative pressures that, one way or another, boost recycling are building almost daily. The Council on Plastics in Packaging and the Environment (COPPE, a Washington, D.C., trade group) has counted over 500 local or state regulatory initiatives. City and county governments throughout the US have instituted bans on certain types of plastic packaging, especially polystyrene foams. Others are attempting to ban "non-recyclable" materials (even while the definition of recyclability is open).

Europe is in a similar situation, too. Use of polyvinyl chloride (PVC)-based containers and packaging has been restricted or taxed, or legislative bans attempted, in Switzerland, Austria, Denmark and Italy. Deposits or premiums ranging from 5 cents to up to 25 cents per container have been imposed in the Federal Republic of Germany, Sweden and the Netherlands, as have 10 US states. And, voluntary "post-consumer" recycling programmes for metals and paper, as well as plastics, have been set up in most Western European countries, Japan and parts of the US.

Behind all these efforts is the realization that disposal costs of municipal solid wastes (MSW) can only rise as landfill space or incineration capacity becomes dear. In the US, plastics constitute around 7 per cent of the MSW stream by weight, but as much as 30 per cent by volume. Moreover, as plastics consumption continues rising, especially in new types of packaging, it is projected to constitute as much as 15 per cent (by weight) of the MSW stream in 10 years.

A spate of joint ventures

The sheer volume of the plastic "garbage" has not escaped the eyes of the plastics producers. It used to be that primary resin producers were content to say nothing about plastics recycling, asserts the Vice-President for Business Development at US Recycling Industries Inc. (Denver), an MSW and industrial-scrap recycler. "Now, they have turned 180 degrees on this issue, and while they used to be very defensive about it, now they are finding that recycled plastics could be a good alternative feedstock".

That theme of expanded interest in recycling was highlighted in April by Du Pont Co. (Wilmington, Del.) and Waste Management Inc. (Oak Brook, Ill.), with the announcement of a 50-50 joint venture to collect plastics and other recyclables, segregate the plastic and then process it into saleable products. The as-yet-unnamed venture will start with a $5 million, 40 million pound/yr plastics recycling facility in the US, a plant that both companies expect to be a prototype for other centres. Du Pont will buy all the recycled plastics from the plant for internal use. For its part, Waste Management will now have a landfilling alternative for the MSW it collects from nearly 900,000 homes in North America.

Entrepreneurial efforts abound

Even while the major plastics processors join the recycling bandwagon, a host of smaller efforts in the US and Europe pick up speed. Many of the smaller companies are concentrating on the mixed-plastic field, since this is where the raw material costs are lowest. The challenge is either to process these mixed plastics into a homogeneous cast or extruded material, or to develop economical methods for separating them.

The most popular "as is" recycling method appears to be an extrusion-moulding process whereby granulated mixed plastic is melted and moulded into bar-stock or planks - "plastic lumber". This process was first commercialized by Superwood International Ltd. (Bray, Ireland), using an adaption of Japanese technology. The firm has a plant producing 1,400 metric tons per year of products, and says that it has delivered a dozen extrusion machines to licensees. A similar process is offered by Advanced Recycling Technology SA (Brakel, Belgium), an equipment manufacturer.

The range of products these firms offer includes park benches, landscaping materials, agricultural-structure components, pallets, cradles for holding steel coils, waterfront or shoreline construction components, and related structures. There is a considerable amount of skill needed to compounding the mixed plastic. In particular, polyvinyl chlorides are a problem. If there is too little, it tends to decompose during the extrusion, releasing corrosive hydrochloric acid gas. One solution is to run this material through the extrusion at a higher concentration, thus performing the extrustion at a lower temperature.

An alternative technology is being commercialized in the US by Innovative Plastic Products Inc. (Atlanta), which cut the ribbon on a $5 million, 6,000 ton/yr plant in Greensboro, Ga., in April. The plant uses technology commercialized in the Federal Republic of Germany by Recycloplast AG (Munich). The process takes mixed plastic with a 50 per cent portion of either PVC or polyethylene, heats it to 160°C, and then masticates it in a kneading machine. The homogenized mixture is then immediately compression-moulded into sheets, troughs, floor tiles or other shapes.

New technologies

Mixed-plastic production, while a big portion of current activity, still remains a somewhat limited market.

PET, one of the largest-volume recycled materials currently, is the target of a process commercialized by Reko BV (Beek, the Netherlands), a DSM unit. The firm's proprietary grinding and classification system produces recycled PET with as little as 5 ppm non-soluble material, and polyolefin contamination of less than 50 ppm. The process, however, depends on highly specific limits on what types of bottle designs are accepted, without PVC contamination or even aluminium bottle caps in the raw material. A 2,500 mt per year plant - said to be the only PET-recycling plant in Western Europe - has been operating since 1985. Reko is looking to licence the technology in the US.

Another joint venture, between ITC Corp. (Baltimore) and the Federal Republic of Germany's minerals processor and equipment fabricator AKW Apparate und Verfahren GmbH (Hirschau), is planning a recycling centre in the Baltimore-Washington vicinity in 1990. AKW's process, called PolySource, has been tried at a 1,000-kg per hectare plant in Blumenrod, the Federal Republic of Germany. The route depends on AKW's proprietary hydrocyclones to wet-classify washed, granulated plastic. At Blumenrod, the system recovers only HDPE; the remaining plastic is not further processed. This plastic is then extruded into pellets, for use as regrind by plastics processors.

Yet another approach to achieving high value-added materials from mixed plastic waste is to use reactive chemical methods. As yet, the techniques are being researched extensively in laboratories (with dozens of patents having been issued in the past few years), but hardly any has been commercialized, due primarily to high production costs.

Goodyear Tyre and Rubber Co. (Akron, Ohio), a PET producer, may soon convert post-consumer PET into undisclosed intermediate chemicals, which could be made into virgin PET that meets the stringent food-grade requirements. The process could be taken back to ethylene glycol and terephthalic acid (the usual raw materials for PET), if that proves economically desirable.

Meanwhile, Du Pont's new foray in recycling will eventually result in many new ways to "compatibilize" mixed plastics.

The idea is to adapt rheology modifiers or tougheners used in such Du Pont products as Selar or Surlyn, and apply them to mixed, post-consumer streams. These modifications could include reaction-grafted polymers, and terpolymers that act as a binding agent for two other polymers. With the right compatibilization technology, these mixtures could be turned into high-value engineering plastics. (See diagrammes on page 96)
(Extracted from Chemical Engineering, July 1989)

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History of recycling post consumer plastics scrap

In the beverage industry, aluminium containers quickly were recognized as being a valuable material that should not be discarded. About 20 years ago, the aluminium companies initiated recycling programmes. Aluminium cans are well-known as being recyclable. Glass bottles have been mass produced since the turn of the century and are being recycled into new containers.

The plastic beverage container, made of polyester (PET) and polyethylene, was introduced nationally in 1978. Recycling began almost immediately through the efforts of small entrepreneur recyclers. These early plastic recyclers recognized the intrinsic value of this high-tech polymer. In 1979, only one year after the plastic PET bottle's introduction, 8 million pounds of bottles were recycled. This poundage of recycled beverage containers grew to 40 million pounds in 1982 and by 1985 an estimated 110 million pounds of bottles were being recycled. In 1987, this research estimated that 150 million pounds of PET beverage bottles were collected for recycling.

Deposit legislation on soft drink containers in nine states influenced this rapid growth. Recycling legislation aimed at reducing solid waste is expected to continue the growth of plastics recycling along with the recycling of other materials. Exhibit 1 on page 97 shows the rapid increase in the recycling of plastic beverage containers.

PET beverage container recycling

Polyester (PET) is the plastic being recycled most as post consumer scrap in the United States. Wellman, Inc., identified as being the major recycler in this area, recycled 100 million pounds of PET soft drink containers in 1987. Results show that present markets for recycled PET are carpeting, fibrefill, unsaturated polyester, polyols for rigid urethane foam, strapping, engineering plastics and extruded products. New applications, such as thermoformed products and textiles/geotextiles, offer additional opportunities to utilize post-consumer plastic scrap. See exhibit 2 on page 97 for current PET markets.

In 1987, there were 740 million pounds of PET used in manufacturing soft drink containers. Estimates showed that there exists a potential market for 500 million pounds of this material in non-food applications (see appendix A on page 99 for PET market projections).

Since only 150 million pounds currently are being recycled, this market is far from being saturated. A 10 per cent penetration into PET textiles alone would represent approximately a 350-million-pound market since filament yarn, staple and tow made from virgin PET is more than 3.5 billion pounds.

HDPE recycling

Total sales of high density polyethylene (HDPE) in 1987 were in excess of 7.8 billion pounds. Currently only about 72 million pounds per year of HDPE have been identified as being recycled. Markets identified for recycled HDPE are listed in exhibit 3 on page 97. Market research shows that a potential market of an estimated 400 million pounds could be developed to utilize recycled HDPE (see appendix B on page 100 for market projection details). Major potential markets for HDPE are soft drink basecups, plastics lumber, containers, drums, pails and various types of pipes.

Mixed plastics

Plastic scrap often is collected as a mixture of many types of plastics. Separation of this mixture into its various plastic components often would be costly. It is possible to process the mixed plastics into non-critical product applications. This type of mixed plastics recycling already has begun in Europe and Japan and is now starting in this country. High volume products that could be manufactured from mixed materials are being identified. Lumber substitutes for miscellaneous outdoor furniture, posts and farm structures are ideal markets. Many items have been mentioned by ART/Europe (Advanced Recycling Technology SA Ltd), Polymer Products Inc., New England CRInc, Processed Plastics, Inc., and Mid Atlantic Plastic Systems, Inc. (see exhibit 4 on page 98).

Six potential high volume products to be manufactured from mixed recycled plastics were identified. These products are:

1. Treated lumber;
2. Landscape timbers (1/2-billion-pound market);
3. Horse fencing;
4. Farm pens for poultry, pigs and calves;
5. Roadside posts;
6. Pallets (more than 300 million wooden pallets used annually).

Pallet market survey

Questionnaires were developed for use in surveying plastics recycling activity in the plastic pallet industry. These questionnaires were sent to 70 plastic pallet companies across the country. This survey's objective is to determine if recycled plastics currently are being used or are being considered for use in pallet manufacturing. Shown in exhibit 5 on page 98 is a graph of the board feet of wood being utilized in pallets and other shipping material. Also shown are estimates of equivalent amounts of mixed plastics based on the volume of wood used in pallet manufacturing.

If only 1 per cent penetration of recycled plastics was made into this pallet industry, approximately 370 million pounds of plastics could be utilized (see exhibit 6 on page 98).

Product testing

Testing was performed to better understand the limitations associated with using recycled plastics. Tests have been made on samples of 2x4s manufactured from mixed plastics. A series of nail and screw pull-out experiments show plastic lumber to behave quite differently than wooden lumber.

Nail pull out tests were performed on wood and recycled plastic specimens to compare their nail-holding strength (see exhibit 7 on page 98). The specimens were cut out of eight feet (2x4) construction members. Actual dimensions of the specimens were: 1 1/2" x 3 7/16" x 8'. Nails used have a diameter = 0.15". Nail penetration was 1 1/2" throughout the tests.

Results of these tests show that mixed plastics hold nails approximately 40 per cent better than typical wood at room temperature and when nails are perpendicular to the grain. When nails are driven parallel to the grain, wood significantly loses the ability to hold nails by approximately 50 per cent while plastics maintain relatively the same retention capability.

However, this advantage of recycled plastic lumber is rapidly lost at elevated temperatures of approximately 149°F [65°C]. A summary of test results of recycled mixed plastics compared to wood is shown in exhibit 7 on page 98. Wood retained much of its strength while being heated in a water bath. Recycled plastic lost 43.7 per cent of its nail holding strength due to the same conditions.

Consequently, utilization of lumber made from recycled plastics must be carefully evaluated regarding the environment in which it will be used in order to avoid inappropriate applications.

Plastics recycling future

Reduction of the solid waste stream has become a national issue. The ability of many plastics to be recycled easily is now being recognized as a means to efficiently and economically reduce solid waste. Material cost savings obtained by using recycled plastics also will be a driving force in accelerating the growth of the recycling industry.

However, it is necessary that informational networking be increased to assist recyclers in locating business opportunities. The electronic data base developed in this research answers that need by providing the names of contacts in the plastics recycling industry. This data base will prove to be a valuable asset for future research work and understanding plastics recycling activities nationally. (Extracted from the Technical Report No. 31 "Market Research on Plastics Recycling", Centre for Plastics Recycling Research, The State University of New Jersey, Rutgers, Bush Campus, Bldg. 3529, Piscataway, N.J. 08855, USA)

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Polymer recycling being choked off by lack of feeds

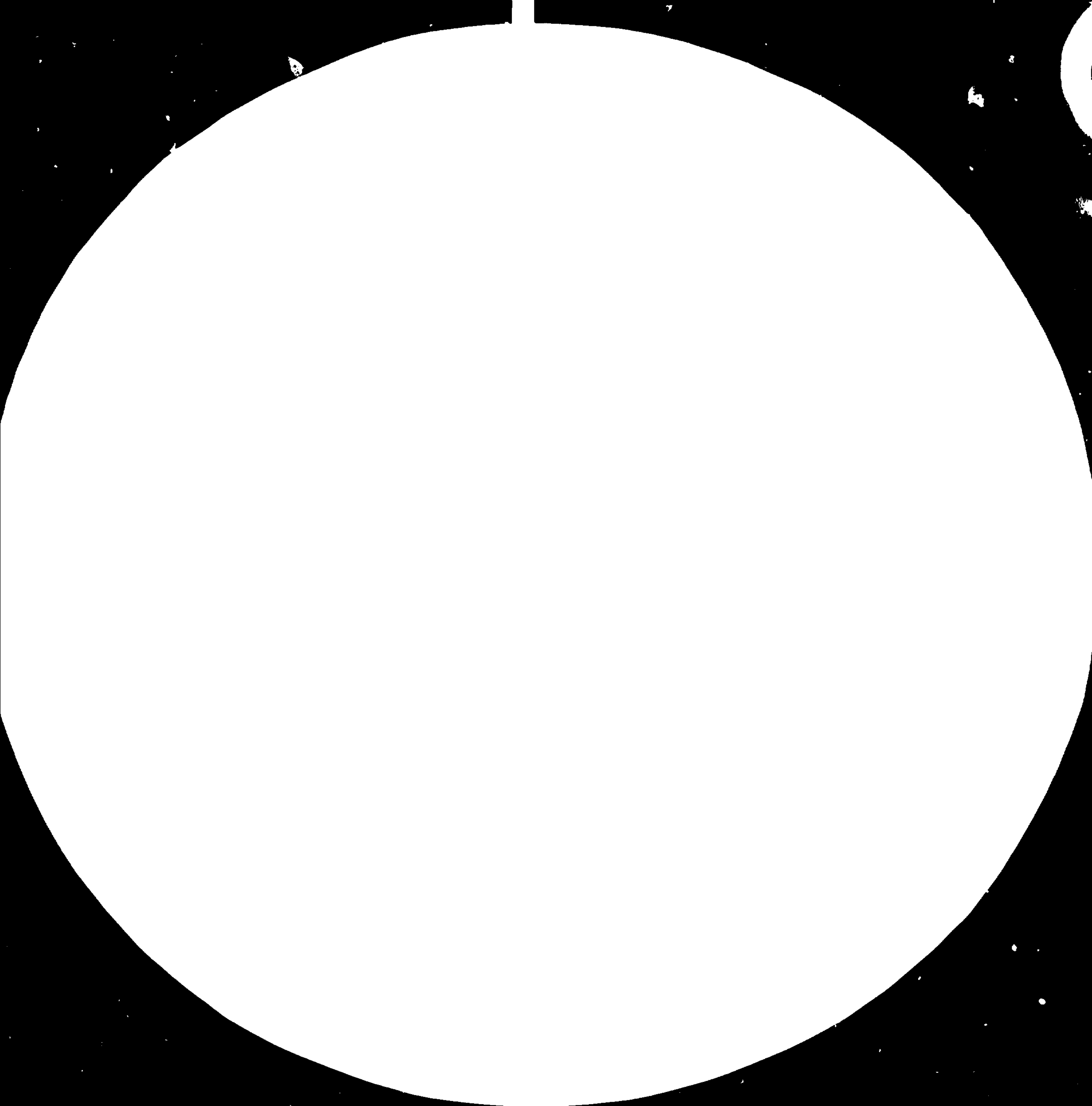
Post-consumer, reprocessed polymers have promised to be the boon of the 1990s. And the number of firms entering the industry on all sides - reprocessing, consumption and equipment manufacturing - shows the race is on.

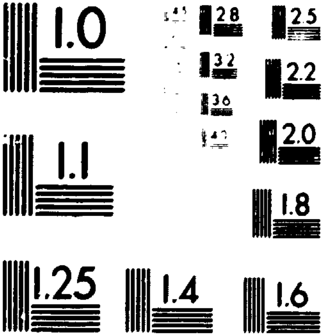
But a severe lack of feedstock is keeping growth in check, a situation reprocessing advocates are calling less-than-optimal. Because of the shortage, a huge imbalance exists between the level of polymer that is reprocessed and remarketed (the vast majority being polyethylene terephthalate and high density polyethylene) and actual demand for reprocessed polymer.

In a study by the Plastics Recycling Foundation Inc., the current shortage is made clear. Consumption of recycled PET in 1987 totalled 150 million pounds, rising to an estimated 170 million in 1988. The markets for the material being fibre, injection moulding, extrusion and building insulation.

The potential market, however, came closer to 500 million pounds, according to the research conducted at Ohio's University of Toledo, and will reach 700 million pounds by 1993. In 1987, some potential markets, non-food bottles and exports, had not even been tapped.

As for HDPE, the study found a potential market of 440 million pounds, more than six times the





MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS
STANDARD REFERENCE MATERIAL 1010a
(ANSI and ISO TEST CHART No. 2)

volume actually reprocessed in 1987. A scant 70 million pounds of reprocessed HDPE were marketed or consumed that year by reprocessors for the production of pipe, pails, PET-bottle bases and items such as crates and pallets.

By 1993, the potential market for reprocessed HDPE will grow to 600 million pounds.

Despite the fact that 1.8 billion pounds of virgin PET and 8.2 billion pounds of virgin HDPE were consumed in the US in 1988, less than 300 million pounds of post-consumer PET and HDPE feedstock combined made their way into the embryonic reprocessing market.

The current lack of post-consumer recycling programmes with an emphasis on plastics has been underlined repeatedly for the lagging development of a feed-stock stream. And behind this exists a vacuum of knowledge on the part of policy makers unaware of the feasibility of plastics reprocessing.

Reprocessors are waiting for a steady supply of resin to become available before setting up shop, and municipalities are tending not to set in motion laws favourable to reprocessing because they are unaware of the possibility. Until communication between the two parties improves, the feedstock shortage will remain critical.

On a micro-economic scale, though, a growing number of entrepreneurs are becoming aware of the industry. Plastic Bottle Institute, a unit of Society of the Plastics Industry, recently reported a 32 per cent increase in the number of firms participating in all areas of the reprocessing business. It lists 172 firms in its 1989 directory.

Two types of processors are emerging. The most visible is the merchant reprocessor circulating the resins back into the marketplace. The second, less visible reprocessor, is the captive reclaimer, using the reprocessed resin captively for down-stream moulding or compounding.

Four dominant forces

Most of these operations are as developmental as the industry itself. But four stand out as dominant forces in the market.

As PET reprocessing stands now, the largest entity is Wellman Inc., a South Carolina-based reprocessor with a capacity of more than 100 million pounds.

In terms of merchant reprocessors, St. Jude Polymer, Frackville, Pa., is the foremost presence.

At present, processors like Wellman, St. Jude, and Albany, New York-based Star Plastics, which claims a PET reprocessing capacity of 30 million pounds, obtain feedstock from north-eastern states where either recycling programmes or bottle deposit laws guarantee a stream.

On the consumption end, the run-up in virgin resin pricing during 1987 and 1988 has been the driving force.

For a plastic moulder or extruder, the difference in pricing between virgin and reprocessed, post-consumer resin is tremendous. The difference in quality is claimed by reprocessors to be undistinguishable.

While virgin, bottle-grade PET is being traded at 70 cents per pound, reprocessed, repelletized PET is being traded for 35 to 40 cents per pound. The reprocessors obtain feedstock, in the form of baled bottles, for as little as 6 cents per pound.

PET reprocessors also tend to makret some reprocessed HDPE derived from the base cups on some PET bottles. This repelletized resin trades at 25 to 26 cents per pound. Its market is mainly base-cup moulding. Other sources of HDPE, however, are moulded milk and water and detergent bottles.

The largest reprocessor of HDPE derived from this stream is Eaglebrook Plastics, of Chicago. Much of its resin is used internally for production of agricultural drainage tubing and nursery pots, it also markets repelletized and flake polymer on the merchant market. Mixed colour pellets are trading at 35 cents per pound. (Extracted from Chemical Marketing Reporter, 24 April 1989)

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Recycled plastics demonstrate exceptional growth

Demand for recycled plastics in the US should expand by nearly 45 per cent annually through 1992 and reach 1.4 billion pounds, worth $730 million, according to Freedonia Group Inc. The firm says markets for recycled plastics are growing rapidly, but the real success of the industry is tied to the collection of plastics from post-consumer waste, public attitudes towards plastic waste, the cost and availability of virgin resins and advances in degradable plastics.

Freedonia reports recycled plastics may be used in an array of products at a substantial cost savings relative to virgin resins. Chief exceptions are products that require FDA approval for direct contact with food. Plastic waste, costing less than 10 cents per pound, and recycled plastics, ranging from 35 to 50 cents per pound, provide attractive margins for recyclers.

The principal markets for recycled PET are polyester fibre and fibrefill and strapping tape. Polyester strapping from recycled PET competes with steel strapping for bundling heavy and bulky items, and is expected to grow over 26 per cent per year through 1992 and reach 100 million pounds.

Over 130 companies recycle plastics. Most are small, privately-held and regional. Consolidation is expected as the industry matures, but Freedonia thinks the regional nature of plastics waste collection will favour small, independent recyclers. (Source: Chemical Marketing Reporter, 6 February 1989)

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US recycling growth rate put at 16 per cent per year

The roughly 45,000 tons of plastic consumer waste that was recycled in the US in 1988, representing about 3 per cent of total volume consumed, will grow to 2.2 million tons - or 8 per cent - by 1998. World-wide the figures are 900,000 tons in 1988, representing 2 per cent of the total, growing to 4.3 million tons or 7 per cent. The growth rate for recycled plastics in the US will be approximately 16 per cent annually.

These are among the findings of a study from R. M. Kossoff & Assoc., New York, titled "Recycled Waste Plastics, Markets and Profit Opportunities". The consultant concludes that the industry faces problems and profit opportunities in the recovery and recycling of polymeric scrap.

Polyolefins represent the largest scrap factor, growing from 344,000 tons in 1988 to over 1.3 million tons in 1998, followed by polyethylene terephthalate and polyvinyl chloride (see table on page 101). While packaging offers the greatest initial recycling potential, other markets like construction, consumer products, and automotive, could become significant in the decade ahead.

An increasing number of resin suppliers are evaluating the profit potential for reconverting recycled plastics - including engineering resins - into materials with price/performance ratios capable of penetrating new markets. For packaging, more states are planning to join the 10 that now mandate deposit/return for plastic containers. And local communities are responding to littering by considering bans on plastics food containers.

Concern is also emerging about life-cycle disposition from the auto industry, as polymer use accelerates. Suppliers such as GE Plastics have announced strategies to confront this potential problem.

The study recommends that the industry promote a National Uniform Bottle Law, mandating collection or return of major packaging containers of all types. It points out that such legislation would not only place plastics on an even footing with other recyclable packaging materials such as glass, paper, and the various metals, but also pre-empt local initiatives that can become emotion-driven. (Source: Modern Plastics International, April 1989)

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Recycling plastics from automobiles: an opportunity awaiting exploitation

The growing use of plastics in automobile construction is placing increasing stress on the industry responsible for disposing of scrapped vehicles. And according to the Director of the Association of Plastics Manufacturers in Europe (APME), management of car wrecks and of the waste material generated by car shredding will increasingly influence continued acceptance of plastics and composites in this field.

Speaking at a recent conference, "Plastics on the road", organized by the Plastics and Rubber Institute in London, he described the current situation in Europe and especially in the Federal Republic of Germany, where the plastics and automotive industries have a joint DM 2 million research programme on waste. The plastics content of Federal Republic of Germany cars, estimated at 60,000 t in 1980, reached 110,000 t in 1985, and is forecast to top 150,000 t by 1993. Plastics now account for 20 per cent of shredder residuals, and could rise to 40 per cent by the year 2005. But declining scrap prices (from an average DM 200 per ton in 1970 to less than DM 100 per ton in 1986) are forcing independent shredders out of business, leaving only steel industry-owned firms. The steel industry thus has a double incentive to persuade the automotive industry to reduce plastics in vehicles.

Cost of disposal of plastics is rising, because at present they are officially classified as "oil residue" materials, and therefore hazardous. But as car manufacturers use more high performance plastics for fuel economy, cost saving, and reduced maintenance, there will be profit in extracting these high value materials for re-use.

APME concludes from its studies that while plastics are not the major problem of the car shredders, they have an impact on the profitability of the scrap business, and the plastics industry is concerned that alternatives are developed to present methods of handling scrapped cars. An important aspect being studied by the Federal Republic of Germany consortium is that automobile components should be designed to facilitate dismantling and disposal.

Right now, no plastics are recycled from scrap automobiles, since it is simply not viable to do so. Non-metallic materials are normally incinerated or sent for landfill. Cost of both operations is rising sharply. In 1985, the additional cost of disposal of plastics to Federal Republic of Germany car shredders was DM 50 per ton. By 1995 it will have more than doubled. Over the same period the proportion of plastics materials used in cars will have risen from 10.5 to 15 per cent, while the proportion of ferrous metals will have dropped from just under 70 to 63 per cent.

The joint study programme covers four topics: trends in shredder waste handling, car developments for post-use waste management, revenue from plastics scrap, and processing of plastics scrap. This last comprises recycling, pyrolysis, conversion to fuel, and incineration/landfill. (Source: Modern Plastics International, April 1989)

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Dow, Domtar stake out niche in plastic waste

Two corporations are quietly laying the groundwork for what promises to be a huge market for recycled plastics in Canada and the United States.

Dow Chemical and Domtar, a Canadian company, are scheduled to sign agreements with Newark, NJ, Portland, ME, Buffalo, NY, and more than 30 other cities that will give the two organizations access to millions of pounds of plastic waste those communities generate each year.

Soon, the companies will announce sites for two new factories - one in Canada and the other in the United States - that will recycle up to 75 million pounds/yr. of polyethylene terephthalate and high-density polyethylene. The two plants, which are scheduled to come on line in 1990, will use a patented Dow process to turn out high-grade resin that will have a wider range of uses than recycled plastic now on the market.

One of the first steps in the Dow-Domtar venture will be to stockpile a year's worth of waste plastic. Domtar will be responsible for collecting and storing, in warehouses in Buffalo and Toronto, 20 million to 30 million pounds of plastic this year.

Dow and Domtar spokespeople say they expect the venture to turn a profit in its first year, although this will depend on the political future of recycling in the United States. (Source: Chemical Engineering Progress, June 1989)

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Recycled resin use soars

The plastics industry is developing its recycling processes so well that secondary resin consumption is predicted to increase 17.6 per cent annually to a total of 1.9 million short tons by 2000, according to Leading Edge Reports. PET bottles are leading the market, says the study, with demand far outpacing supply at present. (Source: Chemical Marketing Reporter, 19 March 1990)

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An answer to plastic recycling

Following years of research, High Tech Plastics in the Netherlands reports a major breakthrough in the complete and effective recycling of all types of plastic waste, with the introduction of a universal compatabiliser. Carrying the brand name of Bennet, the company says it is capable of producing a homogeneous blend of all waste plastic material in its molten state. In this recycling process, the waste plastic is granulated and fed into a compounder extruder. The mix, having been raised to a minimum temperature of 200°C, (depending upon the composition) is melted down and Bennet, in pellet form, is added. The compatabilised mix is extruded into strands which are then cut into pellets of approximately 3 mm length. The end product can be used to manufacture many household goods such as bowls, buckets and crates. For further information contact High Tech Plastics, Lorenzstraat 8, 6716 AD Ede, Holland. (Source: POLLUTION, February 1990)

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USSR, Austrian firm in recycle venture

Tasmet, a new 50-50 joint venture between Metafin GmbH of Austria and the Soviet Industrial Organization, a unit of the Ministry of Chemistry in the USSR, will build a plant to recycle a minimum of 8,000 tons a year of film waste.

The company will recover the silver content of photographic, movie, X-ray, graphic and other films, as well as the basic carrier materials consisting mainly of cellulose triacetate and a lesser quantity of polyethylene terephthalate. Operation of the plant is slated for mid-1990. (Source: Chemical Marketing Reporter, 27 November 1989)

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Plastic recycling boom predicted

Plastic recycling from the waste stream will probably grow much faster than metal or glass recycling in the next five years, if only because plastics only recently have begun to be included in collection programmes, according to a recent survey.

Released by Business Communications Co. Inc., a Norwalk, Conn., market research firm, the study anticipates only a 9 per cent increase in the rate of metals recycled from waste between 1989 and 1994 compared with a 31 per cent jump in plastics recycling. Glass recycling is projected to grow by almost 18 per cent.

"There is a great deal of legislative and public pressure on the plastics industry to recycle and find markets for the recycled materials", a BCC analyst said.

Currently about 2.6 million tons of all metal in the waste stream - about 19.5 per cent - gets collected for recycling. The study sees that amount increasing to about 4 million tons, or almost 26 per cent, by 1994.

That is out of a total of 26.9 million tons - almost 29 per cent - of various kinds of waste that are expected to be recycled in 1989 based on one-time recovery from the waste stream. The researchers expect the total quantity recycled to surpass 35 million tons, almost 35 per cent of all waste, by 1994.

Metals recycled from waste, especially in the form of aluminium used beverage cans, are expected to benefit from increased collections, the study said, although the high price of aluminium might cause it to lose market share in some applications to glass or plastic.

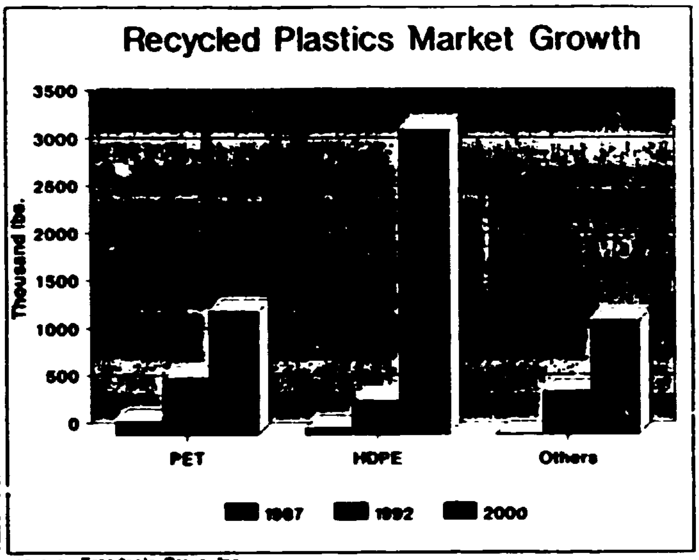
The study called for several measures to increase the collection and processing of materials from the waste stream:

- Automatic sorting equipment needs to be designed to "sort waste more accurately, remove contaminants and more effectively remove labels from containers".

- To increase plastic and paper recycling rates, recycling equipment needs to accommodate more "so-called non-recyclables".

- Foreign markets for recycled materials should be pursued because "their limited natural resources, reluctance to pay for higher-priced primary materials and interest in 'green' issues" could make them profitable partners in recycling.

The survey, titled "New Directions in the Solid Waste Recycling Business", is BCC's study No. GB-127 and can be ordered from the company at 25 Van Zant St., Norwalk, Conn. 06855, USA. (Source: American Metal Market, 20 November 1989)

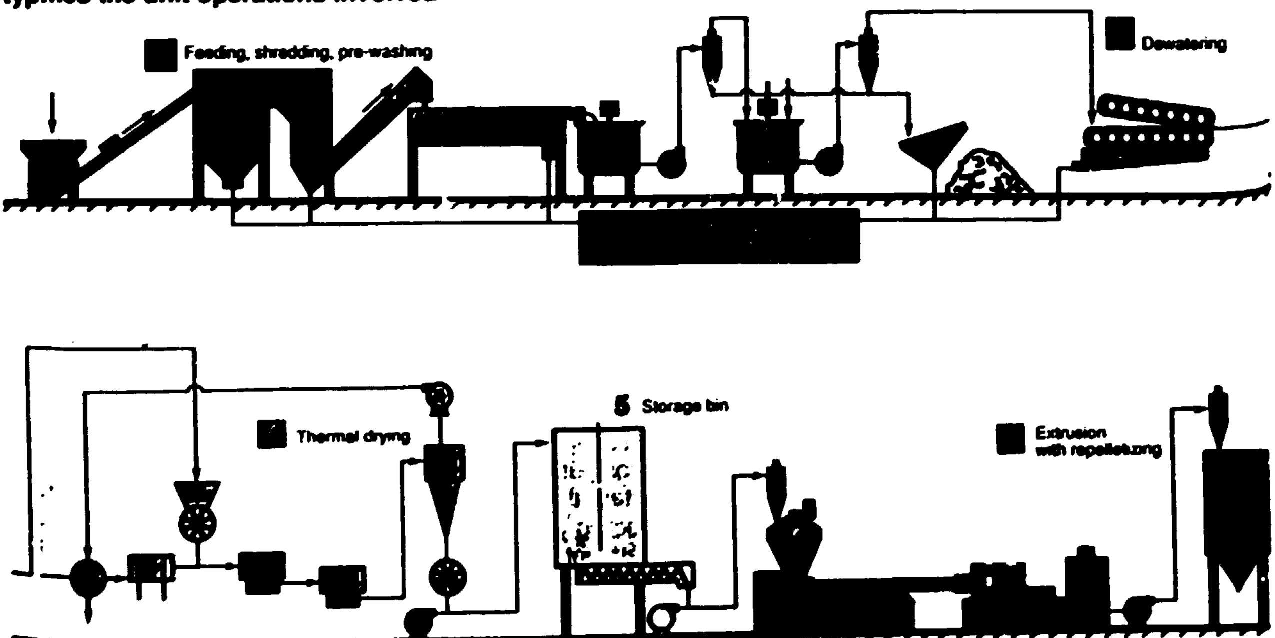


Source: Freedonia Group, Inc.

Plastics recycling will shoot up at rates of 30 to 50%/yr

BASTA

This polyethylene-recycling plant typifies the unit operations involved



(Extracted from Chemical Engineering, July 1989)

Exhibit 1

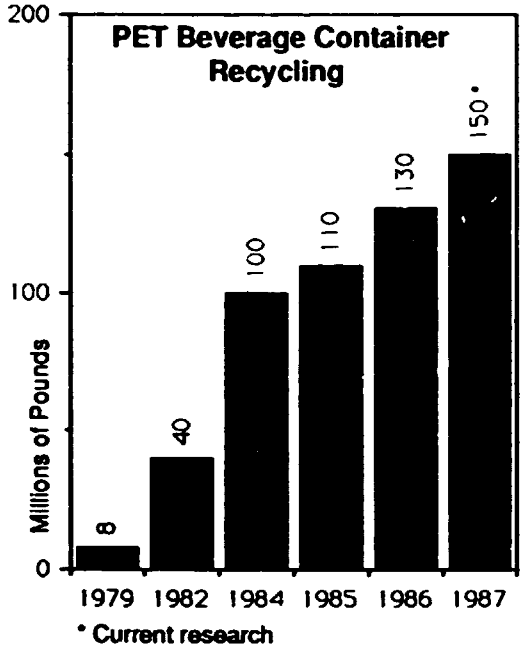


Exhibit 2
Markets for Recycled PET Products

CIVIL ENGINEERING
- Geotextile
- Urethane Foam

RECREATIONAL
- Skis
- Surfboards
- Sailboat Hulls

INDUSTRIAL
- Carpeting
- Fence Posts
- Fiberfill
- Fuel Pellets
- Industrial Paints
- Strapping
- Unsaturated Polyester
- Paint Brushes

TOTAL VOLUME
150 million pounds in 1987

Exhibit 3
Markets for Recycled HDPE Products

AGRICULTURE
- Drain Pipes
- Pig and Calf Pens

MARINE ENGINEERING
- Boat Piers (lumber)

CIVIL ENGINEERING
- Building Products
- Curb Stops
- Pipe
- Signs
- Traffic-Barrier Cones

RECREATIONAL
- Toys

GARDENING
- Flower Pots
- Garden Furniture
- Golf Bag Liners
- Lumber

INDUSTRIAL
- Drums/Pails
- Kitchen Drain Boards
- Matting
- Milk Bottle Carriers
- Pallets
- Soft Drink Base Cups
- Trash Cans

TOTAL VOLUME
72 million pounds (1987)

(Extracted from the <u>Technical Report</u> No. 31 "Market Research on Plastics Recycling", Centre for Plastics Recycling Research, The State University of New Jersey, Rutgers, Bush Campus, Bldg. 3529, Piscataway, N.J. 08855, USA)

Exhibit 4

Recycled Mixed Plastics Products

AGRICULTURE
- Barrier Retainers
- Duck Boards
- Electric Fences
- Erosion Control Timber
- Fruit Tree Supports
- Gates
- Horse Stalls
- Markers
- Pig and Calf Pens
- Poultry Construction
- Ranch Fences
- Tree-guards
- Vine Stakes

INDUSTRIAL
- Car Stops
- Fencing
- Flooring
- Footings, Posts, and Sill Plates
- Highway Construction
- Loading Dock Rails
- Markers
- No-load Grating
- Pallets
- Pipe Racks
- Planks
- Sign Posts
- Slab Separators
- Stair Treads
- Traffic Barriers
- Truck Flooring
- Wire Racks

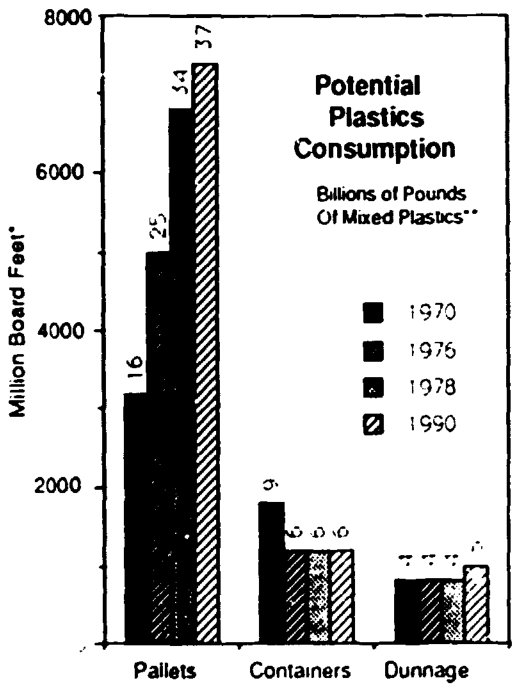
MARINE ENGINEERING
- Beach Erosion Control
- Board Walks
- Boat Docks
- Coast Erosion Protectors
- Dock Side Fenders
- Fishing Boat Wear Plates
- Lobster Traps
- Pier Impact Protectors
- Rub Rails
- Sea Walls
- Trawler Net Rollers

GARDENING
- Compost Enclosures
- Fences, Gates
- Enclosures
- Garden Boundary
- Landscaping Timbers

RECREATIONAL
- Flower Pots
- Flower and Tree Boxes
- Golf Course Walk Ways
- Park Benches
- Picnic Tables
- Playground Equipment
- Sand Box Kits
- Stadium Seating
- Storage Bins

CIVIL ENGINEERING
- Barriers
- Bearing Pads
- Fences
- Road Delineators
- Traffic Direction Posts
- Retainer Walls

Exhibit 5



* Source of board feet consumption: U.S. Dept. of Agriculture, Forest Service.
** Plastics poundage estimates based on approximately five pounds of mixed plastics per board foot.

Exhibit 6

	Wood	Mixed Plastics
Market Size (1990)	7.4 billion bf (>300 million pallets)	37 billion lbs
Estimated Penetration		1%
Estimated Markets		370 million lbs

Exhibit 7

	Room Temp	Heated 65° C Bath	% Loss
WOOD Maximum Pull-out Force - pounds	112	116	3.2%
MIXED PLASTIC Maximum Pull-out Force - pounds	157	88	-43.7%

(Extracted from the Technical Report No. 31 "Market Research on Plastics Recycling", Centre for Plastics Recycling Research, The State University of New Jersey, Rutgers, Bush Campus, Bldg. 3529, Piscataway, N.J. 08855, USA)

Appendix A

POLYETHYLENE TEREPHTHALATE - PET - Recycling Projections

Major Markets [million lbs.]	1987 Actual Sales	1987 Potential % Recycled	1987 Potential Volume Recycled	Projected 1993 (11% annual growth) Sales	Projected 1993 Potential Recycled
Polyester Thermoplastic (PET)					
Blow molding					
Soft-drink Bottles	740	0%	0	1,384	0
Custom Bottles	135	10%	14	253	25
Extrusion					
Film	470	10%	47	879	88
Magnetic Recording Film	75	0%	0	140	0
Ovenable Trays	25	0%	0	47	0
Coating for ovenable board	12	0%	0	22	0
Sheeting (for blisters,etc)	7	10%	1	13	1
Strapping	28	40%	11	52	21
Exports	175	10%	18	327	33
Total PET	1,667		90	3,118	168
Polyester, Unsaturated					
Reinforced Polyester					
Molded	785	2%	16	1,468	29
Sheet	190	2%	4	355	7
Surface Coating	18	0%	0	34	0
Export	10	0%	0	19	0
Other	312	0%	0	584	0
Total Unsaturated Polyester	1,315		20	2,460	36
Reinforced Polyester; Unsaturated					
Aircraft/aerospace	33	0%	0	62	0
Appliance/business	90	2%	2	168	3
Construction	393	2%	8	735	15
Consumer	130	0%	0	243	0
Corrosion	326	0%	0	610	0
Electrical	55	0%	0	103	0
Marine	350	2%	7	655	13
Transportation	195	2%	4	365	7
Other	50	0%	0	94	0
Total Reinforced Unsat. Poly.	1,622		21	3,034	38
Polyurethane - Rigid Foams					
Building Insulation	445	2%	9	832	17
Refrigeration	119	2%	2	223	4
Industrial Insulation	65	2%	1	122	2
Packaging	50	2%	1	94	2
Transportation	64	2%	1	120	2
Other	32	0%	0	60	0
Total Polyurethane	775		15	1,450	28
Textile*					
Filament Yarn	1,180	10%	118	1409	141
Staple and Tow	2,369	10%	237	2829	283
Total Textile	3,549		355	4,238	4.4
GRAND TOTAL	8,928		500	14,299	695

*Textile growth at 3%

(Extracted from the Technical Report No. 31 "Market Research on Plastics Recycling", Centre for Plastics Recycling Research, The State University of New Jersey, Rutgers, Bush Campus, Bldg. 3529, Piscataway, N.J. 08855, USA)

Appendix B
HIGH DENSITY POLYETHYLENE - HDPE- Recycling Projections

Major Markets [million lbs.]	1987 Actual Sales	1987 Potential % Recycled	1987 Potential Volume Recycled	Projected 1993 (7% annual growth) Sales	Projected 1993 (7% annual growth) Potential Recycled
Blow Molding					
Bottles					
Milk	740	0%	0	1,111	0
Other Food	278	0%	0	417	0
Household Chemicals	895	10%	90	1,343	134
Pharmaceuticals	184	0%	0	276	0
Drums (>15 gal.)	110	5%	6	165	8
Fuel Tanks	54	0%	0	81	0
Tight-Head Pails	78	10%	8	117	12
Toys	70	5%	4	105	5
Housewares	45	0%	0	68	0
Other Blow Molding	235	0%	0	353	0
Total Blow Molding	2,689		106	4,0[illegible]5	160
Extrusion					
Coating	42	0%	0	63	0
Film (< 12 mil.)					
Merchandise Bags	162	0%	0	243	0
Tee-shirt Sacks	106	0%	0	159	0
Trash Bags	76	0%	0	114	0
Food Packaging	88	0%	0	132	0
Deli Paper	13	0%	0	20	0
Multiwall Sack Liners	45	0%	0	68	0
Other	96	0%	0	144	0
Pipe					
Corrugated	152	25%	38	228	57
Water	63	0%	0	95	0
Oil & Gas production	76	0%	0	114	0
Industrial/Mining	54	0%	0	81	0
Gas	118	0%	0	177	0
Irrigation	42	50%	21	63	32
Other	55	0%	0	83	0
Sheet (> 12 mil)	210	10%	21	315	32
Wire & Cable	124	0%	0	186	0
Other Extrusion	35	10%	4	53	5
Total Extrusion	1,557		84	2,337	125
Injection Molding					
Industrial Containers					
Dairy Crates	61	10%	6	92	9
Other Crates, Cases, Pallets	139	10%	14	209	21
Pails	410	10%	41	615	62
Consumer Packaging					
Milk-bottle Caps	26	0%	0	39	0
Other Caps	63	0%	0	95	0
Dairy Tubs	147	0%	0	221	0
Ice-cream Containers	82	0%	0	123	0
Beverage-bottle Bases	124	50%	62	186	93
Other Food Containers	47	0%	0	71	0
Paint Cans	36	10%	4	54	5
Housewares	242	0%	0	363	0
Toys	84	5%	4	126	6
Other Injection	250	10%	25	375	38
Total Injection Molding	1,711		156	2,568	234
Rotomolding	122	10%	12	183	18
Export	915	0%	0	1,373	0
Other	830	10%	83	1,246	125
GRAND TOTAL	7,824		441	1,742	662

(Extracted from the Technical Report No. 31 "Market Research on Plastics Recycling", Centre for Plastics Recycling Research, The State University of New Jersey, Rutgers, Bush Campus, Bldg. 3529, Piscataway, N.J. 08855, USA)

U.S. recycled plastics by type

Type	1000 tonnes 1988	1998
Polyolefins	344	1340
PET[a]	54	238
PVC	34	282
Nylon[b]	273	49
Styrenics	39	220
Eng. polymers	0.5	75

a Bottle scrap
b Mostly fiber scrap

Source R M Kossoff & Associates

Global recycled plastics by market

Market	1000 tonnes 1988	1998
Packaging	500	2136
Construction	182	773
Consumer	136	455
Industrial	91	545
Automotive	36	227
Electrical	N[a]	136
Total	945	4272

a Negligible

Source R. M. Kossoff & Associates

(Source: Modern Plastics International, April 1989)

7. CURRENT AWARENESS

Hoechst eyes recycling

Hoechst Celanese Corporation plans to launch a programme to address minimization of solid waste and recycling of plastics. Lee Starr, Hoechst Celanese corporate vice-president and chief technical officer, will be responsible for developing the corporate-wide programme.

Dr. Starr will work with the corporation's senior management, environmental, health and safety experts and research scientists.

"As a major industrial corporation in the US, we believe it is our responsibility to find better and more efficient ways of handling the generation, recycling and disposal of solid waste", says Dr. Ernest H. Drew, president and chief executive officer.

Dr. Starr explains that such a programme also makes sense from a business and environmental control standpoint because of the rising cost and decreasing availability of solid waste disposal options and the growing concern about the issue.

The Hoechst Celanese manufacturing sites have waste minimization programmes, Dr. Starr says. One such programme is at the corporation's polyester film plant in Greer, S.C. In a recycling and recovery project initiated last year, the plant is said to have reduced its hazardous waste by 20 per cent and off-site treatment of the waste by 37 per cent. Next year, when the project is fully operational, hazardous waste generation is expected to be reduced by 40 per cent. (Source: Chemical Marketing Reporter, 20 March 1989)

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PET Polymers (Roosevelt, NY, USA) has launched an impact-modified PET copolymer made from recycled PET bottles. The PET copolymer can be used for a variety of purposes, even the replacement of ABS. Independent and field tests show the PET copolymer offers "excellent impact, UV and low-temperature properties". (Source: Bev. Wld., January 1989)

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Making recycling more efficient

Curbside recycling costs can be cut more than 20 per cent in some cases, according to Willard Bishop Consulting (Barrington, IL.). Among the suggestions the firm makes in its recent study: use one-person collection crews, minimize driving time, and reduce the cubic volume of glass, aluminium, or plastic as early as possible in the collection process. (Source: Chemical Week, 22 February 1989)

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An environmental prize for plastic

To promote innovations for reducing the amount of plastic packaging in the waste stream, Du Pont has created a new category in its food-packaging awards. The new award is part of a programme Du Pont sponsors in conjunction with the National Food Processors Association to honour advances made by any company in plastic food packaging. The environmental award will recognize enhancements that reduce the impact of plastics waste on the environment. "Du Pont has a vital stake in reducing any adverse impact of plastic waste and has taken a leadership role in spurring the development of plastics recycling and resource recovery", says Frank Aronhalt, Du Pont director of environmental affairs. Innovations in plastic materials, processes, product design, or any other effort in recycling or waste minimization of plastics packaging are eligible. Each company involved in the effort would be recognized. (Source: Chemical Week, 24 May 1989)

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The plastics recycling industry "is growing exponentially", according to Dennis Sabourin of Wellman Inc. (Shrewsbury, NJ). Wellman currently reprocesses the plastic polyethylene terephthalate (PET), a waste formerly considered nearly intractable, into more than 88 million kg/yr of polyester and nylon fibre. Plastics Again (Leominster, MA) has started up a facility to recycle waste polystyrene into insulating material and flower pots. Darrell Morrow of the Plastics Recycling Research Center of Rutgers University believes that demand for recycled plastics will be at least high enough to assure markets for all the material the plastics recycling industry can produce. (Source: Environmental Science & Technology, Vol. 23, No. 3, 1989)

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The National Association for Plastic Container Recovery (NAPCOR, Charlotte, NC) is optimistic about prospects for the recycling of plastics. NAPCOR president Luke Schmidt told a news conference on 2 March 1989 that experience in ten states, including California, Minnesota and Texas, showed that recycling programmes - especially for containers made of polyethylene terephthalate (PET) - are working. The PET is recycled into new containers and articles such as carpets and sleeping bags. Du Pont has a programme to make park benches from mixed plastic litter collected from beaches in Palm Beach and Broward counties, Florida. Moreover, Dow and vTe Corp. (Bedford, MA) plan an advanced plastics recycling project to begin in Akron, OH. (Source: Environmental Science & Technology, Vol. 23, No. 5, 1989)

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Du Pont sponsors recycling programme

Du Pont will be part of a pilot programme in Mississippi for the recycling of plastic pesticide containers made from high-density polyethylene (HDPE). The company will sponsor the project along with the National Agricultural Chemicals Association, other agricultural products manufacturers, the state of Mississippi, and Washington County, Mississippi. In the county, about 40,000 pounds of HDPE pesticide containers, or about 0.1 per cent of what is used nationwide, are expected to be carried to a reclamation facility in Findlay, Ohio. Mississippi has received a grant for about $80,000 from EPA for the programme and Du Pont and other companies are providing funds for transporting and analysing the recycled plastic for other industrial uses. (Reprinted with permission from Chemical and Engineering News, 21 August 1989, American Chemical Society)

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Recycling: A success story

One third of the people in Rhode Island (USA) currently participate in the state's plastic milk- and soda-bottle recycling programme. They generate 20 tons of those bottles every week - enough, says Richard A. Johnson, chairman of the Rhode Island Solid Waste Management Corp. (Providence), "that the bottles could cover a distance of 12 miles lined up side by side". In the hope of collecting and recycling even more of that plastic, the firm is testing equipment to compact the bottles on the recycling trucks during collection. Compaction should allow the trucks to collect more plastic and get to more homes. The National Association for Plastic Container Recovery - which counts such firms as Du Pont, Hoechst Celanese and ICI Americas among its members - is funding the study with a $25,000 grant. (Source: Chemical Week, 1 February 1989)

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New recycling plans from Tesco

Tesco has plans to start the first PET collection scheme in the UK. This latest initiative comes only weeks after it launched its innovative recycling scheme linked to local wildlife projects and only days after it announced the opening of its 100th bottle bank - the first retailer in the UK to achieve this figure.

The introduction of the PET collection scheme at its "green" test bed site at Colney Hatch, North London, is a pilot project intended to discover whether or not customers are willing to return plastics for recycling. If collected in sufficient quantities, it could be remelted and used to make other items such as non-food packaging and plastic pallets. The PET collected at Colney Hatch will be sent abroad for recycling as there is no facility as yet for recycling it in this country.

Every year, Britain buries or burns about 750 million pounds in waste and pays almost the same amount again to do so. Tesco is committed to reducing this waste and to encouraging others to follow its example. (Source: Pollution, August 1989)

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Plastic bottles best for recycling

Manufacturing and recycling plastic bottles produces less pollution and requires less energy than aluminium or glass containers, according to a study commissioned by the plastic bottle industry.

Luke Schmidt, president of the National Association for Plastic Container Recovery, said the report goes a long way toward rebutting critics of plastic bottles who say the containers are less "environmentally friendly" than aluminium or glass.

The study, prepared by Franklin Associates of Prairie Village, KS, uses a "cradle-to-grave" economic model intended to weigh all parts of the container production processes. The plastic bottle analysis was limited to those made from polyethylene therephthalate, which represents approximately 26 per cent of the plastic container market.

At current recycling rates, Franklin Associates estimates that, per 1,000 gallons of liquid containers, the aluminium can industry uses an average of 33 million BTU's. For glass bottles, the energy input is 2[?] million BTU's/1,000 gallons.

For plastic bottles, however, the energy input is only 20 million BTU's, including the fuel value of the petroleum that goes into plastic resin for the bottle.

The report suggests that although making plastic bottles is an energy-intensive process, it is less energy-intensive than refining aluminium or melting and blowing glass bottles. (Source: Chemical Engineering Progress, July 1989)

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Du Pont leads recycling study

Du Pont (Wilmington, DE, USA) is co-sponsoring a feasibility study in rural Mississippi with the National Agricultural Chemicals Association and the Environmental Protection Agency to collect 40,000 lbs of HDPE pesticide containers. The containers will be cleaned and reprocessed into flake and the resin analysed for potential further use. Du Pont, which got involved in the programme through its plastics recycling division, says the flake HDPE will most likely be made into construction materials like pipe or board. The EPA is providing about $85,000 in a grant, while industry is providing personnel, equipment, and management. If the project is successful, it will be expanded. Du Pont says Minnesota, Florida, and Iowa have expressed interest. (Source: Chemical Week, 23 August 1989)

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Xytec starts recycling facility programme for handling plastics

A formal recycling programme for handling plastics and the opening of a recycling facility to service the Midwest were announced last week by Xytec Inc., Tacoma, Washington, USA.

The $1 million recycling facility is operated by Plastic Visioneering, Deckersville, Michigan, and has a capacity to handle 12 million pounds of recyclables annually.

Xytec is a major manufacturer of large, returnable structural foam shipping containers and has a heavy concentration of users in the automotive industry.

Xytec will purchase non-usable containers in truckload quantities for cash or credit and pick up the containers from the user for transport to the recycling facility. Initially, recycling will be limited to the company's own products but may be extended to other structural foam polyethylene products. (Extracted from American Metal Market, 6 September 1989)

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Anti-litter plastics

Special plastics which will break up and disappear through their reaction to everyday ultra-violet light could be one solution to the rising tide of plastic litter in Britain's streets and countryside. Originally invented by the Cambridge-based Nobel Prize winner, the late Professor Norrish and further developed in Canada, Ecolyte anti-litter plastics can make some of the most visible forms of street litter, such as crisp packets, polythene bags and take-away food clams, break up and disappear in weeks. Now, the London-based Mountain & Molehill company is importing the special Ecolyte plastics from Canada and the United States. These plastics are blended with ordinary plastics such as polythene and polystyrene at the production stage. Because of the special way in which they are made, any ordinary plastic which contains Ecolyte is recyclable. Details from the company at 56 Britton Street, London EC1H 5NA. (Source: Pollution, October 1989)

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Scientists work on recycling plastics, developing biodegradable forms

Scientists at the Center for Plastic Recycling at Rutgers University, a National Science Foundation (NSF) Industry-University Co-operative Research (IUCR) Center, have developed and are licensing a cost-effective, large-scale recycling system that separates polyethylene terephthalate (PET) soft drink bottles and high-density polyethylene (HDPE) containers for milk and various household products from other plastics. The first commercial plastic bottle recycling plant to use this process will be built in Logan Township, New Jersey, USA.

The IUCR Center at Rutgers also has a demonstration system that extrudes forms made from mixed plastics remaining after removal of PET and HDPE. The system incorporates technology invented by Advanced Recycling Technology of Belgium. The extruded plastic is used in construction to make park benches or parking blocks, with many more applications planned.

In addition to NSF support, the Center receives state funding from the New Jersey Commission on Science and Technology, as well as major support from industry groups including the Plastics Recycling Foundation and the Center for Solid Waste Solutions. Scientists at Rutgers are also examining the potential of degradable plastics that would be broken down into carbon dioxide, water and soil-fertilizing humic material by microbes in a matter of months. (Source: MRS Bulletin, October 1989)

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Recycled plastics could improve concrete

GE Plastics (Pittsfield, Mass.) and Master Builders, Inc. (Cleveland) are jointly studying ways of improving concrete made from portland cement by mixing it with recycled engineering thermoplastics. The plastics could improve the concrete's workability, consistency and abrasion and thermal resistance; in addition, the concrete is expected to require less patching and maintenance.

The diminishing availability of rock and other aggregates used to customize and improve the performance of concrete makes plastics good candidates for concrete aggregate, according to Master Builders. Potential applications include precast panels, roofing systems, and other architectural uses. (Source: Chemical Engineering, September 1989)

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Noise and pollution barrier along autobahn

The city of Cologne (FRG) is using 110 tons of plastic trash (bottles, yoghurt containers, etc.) to build a noise and pollution barrier along the autobahn. The waste is being ground into small pieces, heated and poured into molds to form components for the 3-meter-high wall. (Seen in the Wall Street Journal, 6-7 October 1989)

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Molder turns commingled plastic waste into money

Processed Plastics Co., Ionia, Michigan, USA, is getting in on the ground floor in the relatively new business of making plastic products from post-consumer and industrial plastics waste. It is the first American company producing commercial products using the ET/1 extrusion/molding system for processing commingled plastic waste. The two-and-a-half-year old company, which entered the recycled product business in late 1988, is making picnic tables, park benches and boat bumpers, as well as products for the steel and paper industries.

Polyethylene, polypropylene, polystyrene, expanded polystyrene (EPS), polyethylene terephthalate (PET), along with some polyvinyl chloride (PVC), nylon, polyester and engineering alloys comprise the bulk of the plastic waste recycled by Processed Plastics. The company also recycles the scrap from its own fabricating operations. The company expects to recycle 3 million pounds of plastic waste this year at the current rate of consumption.

Processed Plastics also has developed a proprietary process for producing large, thick plastic sheet from commingled waste. Departments of Public Works in several states are testing the sheet in various ground contact and other outdoor applications. It is currently being used in manufacturing hog feeders. The company is also using the process to "cast" the ends for park benches and picnic tables.

Although the extruded end-product of the ET/1 system is commonly called "plastic lumber", it is not a substitute for wood, steel, aluminium or concrete. He points out that a wood board would cost far less than a plastic one, but on the basis of extended service life the plastic board would be more economical.

Many plastic waste sources

Processed Plastics uses both post-consumer and industrial plastic waste in its processes. The company uses only plastic waste that is destined for the landfill. The industrial waste comes from automotive companies and their parts suppliers, and other Midwest plastic processors. It consists of polyolefins, engineered alloys, and polyester film laminates.

Post-consumer plastic comes from four prisons in the area and is mainly large polyethylene and polystyrene containers and packaging films. Municipal recycling centres and milk and soft drink bottlers supply all kinds of HDPE, PVC and PET bottles. The company also has a collection station on its property where local people deposit their plastic wastes, including HDPE, PVC and PET bottles, and bags.

A tolerant process

The processor mixes plastics that are most compatible and have similar physical properties for 85 per cent of the melt. It restricts PET to 15 per cent of the total melt because of its higher melt temperature which can reduce the strength of the extruded product. Depending on the desired end-product properties, the process can accept up to 25 per cent of EPS in the melt.

The ET/1 system produces products that range from black and many shades of grey to brown. To provide a specific colour, the company uses granular colourants. Also it segregates baled bottle scrap by colour when possible. Because of the colourant cost addition and extra handling for sorting by colour, a uniformly coloured product carries a higher price tag. (Extracted from Plastics World, September 1989)

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Occidental to recycle PVC bottles

Occidental Chemical, a major producer of polyvinyl chloride, will establish a commercial programme for recycling PVC bottles. In the past several years, the recycling of plastic bottles has focused primarily on those made from polyethylene terephthalate (PET) and high-density polyethylene (HDPE). PET and HDPE bottles make up about 86 per cent of all plastic bottles. According to figures from the Plastics Recycling Foundation, only about 7 per cent of plastic bottles are made from PVC. To initiate the programme, Occidental Chemical will investigate the commercial potential of recycling PVC and plans to buy back used bottles at prices comparable to those for PET bottles. The company supports programmes to develop PVC separation and reprocessing methods and will look for ways to re-use material in extrusion or injection molding applications. (Reprinted with permission from Chemical and Engineering News, 2 October 1989, American Chemical Society)

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Plastics recycling venture in the UK

EVC is to enter the plastics recycling business through a joint venture with PVC Reclamation Ltd. The new company, Reprise International Plastics Recycling, will operate from at least four sites in the north-west of England. The operation will involve both the recycling of industrial and post-consumer plastic waste.

The most important and complex part of the project is the reprocessing of post-consumer plastics. This is scheduled to commence during the early part of 1990 and will involve the separation of a stream of mixed plastics into its components and its upgrading to a material suitable for re-use. It is envisaged that plastic bottles will form a prime source of post-consumer waste. Reprise is already seeking the support of major retail chains, local authorities and waste management firms to provide the plastic waste. (Extracted from European Chemical News, 16 October 1989)

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Recycling firms attacking solid waste problem

A joint venture between a West German industrial equipment manufacturer and a US minerals and fibre products producer will build and operate plants to recover plastics and other recyclables from post-consumer trash. The new company, Polymer Resource Group, will sell the separated plastics to industrial users, while other recovered materials will be marketed through normal commercial channels.

The firm will open its first PolySource recovery plant in the Baltimore-Washington area in March 1990.

ITC's German partner, AKW Apparate and Verfahren GmbH, an internationally known engineering firm specializing in wet mineral refining processes, is responsible for much of the waste separation technology to be used in PolySource plants. Main products are polyethylenes, polyethylene terephthalate (PET) and polyvinyl chloride (PVC).

The Dow Chemical-Domtar plant in Canada, due for a 1991 start-up, is lining up "feedstocks" with curbside collection contracts in three Canadian provinces and in several US border states. Dow will market the recovered high-density polyethylene and Domtar will use the PET in its line of building materials.

Du Pont-Waste Management, Inc. joint recycling operation will be on line in 1990. It too will use curbside collection to supply the plant.

Plastics Recovery Systems - a joint venture of Plastics Technologies, Inc., Toledo, Ohio, and a metal reclaimer - has developed a proprietary process for recovering this discarded plastic, which consists of about 35 per cent PVC and 60 per cent polyolefins.

More products based on mixed plastics scrap are emerging. One such enterprise, Innovative Plastics Products, Inc., compression molds thermoplastic sheet based on a mixed-plastics filler in a PE or PVC carrier resin at a new plant in Greensboro, Ga.

Superwood International, located in Wicklow, Ireland, has developed a thriving business for molding highway markers, fence posts, dock supports, and similar items several feet long from mixed plastics. The company has developed a special indexing-mold, water-bath machine, material recipes, and coating processes to meet the strength and appearance requirements for these applications. Cycle time is two to five minutes. (Excerpted from Plastics World, July 1989)

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.....Many plastics products companies have endorsed the idea of recycling post-consumer solid waste, but few have moved as far, or as fast, as Rubbermaid Commercial Products, Inc. in actually developing uses for recycled plastics in its operations.

The company has set up a special materials group charged with two missions: finding reliable sources of recycled resins; and developing recipes and process controls for using the resins to maintain the quality standards applied to 100 per cent virgin content.

Starting from ground-zero nearly two years ago, Rubbermaid has steadily increased its consumption of recycled plastics - all of it recovered from the post-consumer waste stream by commercial recyclers. By the end of this year, the firm will be using more than 1 million pounds of reclaim and by the end of 1991, the figure is expected to rise to 3 million pounds or more.

Production uses growing

In developing applications for reclaim, Rubbermaid has concentrated mainly on HDPE because of its availability. Starting with several styles of Brute refuse containers, it now incorporates reclaim in its 15-gallon cylindrical Marshal and the 35- and 45-gallon square-sided Ranger lines. The HDPE-using Brutes are made for municipal and private recycling programmes, like the one now in place in New York City, which increasingly are calling for specific percentages of recycled resin in their purchase specifications.

In anticipation of more abundant supplies of reclaimed PP and PS, Rubbermaid also has begun to incorporate those resins into its products. A mop wringer based on 100 per cent recycled PP has been developed, and other items such as janitorial and food-service carts will follow. (Extracted from Plastics World, September 1989)

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.....Unusual, if not unique among resin recyclers, MRC Polymers, Inc., Chicago, is following the beat of a different drummer. Ten years in the business, MRC has opted to work the other side of the street. Instead of volume-resin reclaim, it specializes in recycled engineering resins - mainly polycarbonate (PC), nylon, PET and PC/PET - into value-added engineering compounds for injection and foam molding and sheet and profile extrusion. Using engineering materials as a "feedstock", it produces 10 million lb/year of upgraded reclaim.

MRC reprocesses PC from discarded 5-gallon water bottles and from industrial scrap that cannot be re-used in the original application - such as medical and optical products and compact discs. Its nylon comes from fibres and textiles, and its PET from bottle manufacturers and post-consumer recyclers. (Extracted from Plastics World, September 1989)

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Equipment for plastics recycling
(Following are excerpts from, Plastics World, September 1989)

One solution to recycling expanded polystyrene packaging waste into reusable pellets is available in three series of reprocessing machines from Japan-Repro Machine Industries Co., Ltd. These machines melt and extrude recycled industrial EPS packaging waste, as well as PE, PS, and PP bottle and film scrap. The units have a rotary-type feeder which compresses the crushed scrap into the melting section where it is melted to a flowable state. The melt then flows down into an extrusion section where the gases are removed and further melting occurs before the material is extruded. In the FS series, the extruded material is cooled either by a chill roll or a water bath before it enters a pelletizer or chip cutter.

The FT machine works like the FS units except that it extrudes the reprocessed material into a resin box where it cools into a solid block of any desired size. **Uniglobe Kisco, Inc., White Plains, N.Y., USA.**

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Another approach to reducing the volume of expanded polystyrene waste prior to reprocessing is the Sekisui A.P. Shrinker. This machine is basically a heat tunnel with infrared heating elements that densifies the scrap foam by degassing it, and exhausting the gases through a chimney. The A.P. Shrinker reduces the volume of the molded piece by up to 93 per cent. An integral conveyor carries the cleaned foam scrap through the 5-foot long tunnel. **Texmac, Inc., Charlotte, N.C., USA.**

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Recyclers faced with the problem of providing an evenly metered feed rate of mixed post-consumer and industrial plastic wastes to downstream granulators may find that primary size reduction using the Model 1000-E low-speed, rotary shear shredder is the solution. The bagged or loose post-consumer waste is conveyed to the unit's shredding chamber where it is reduced to a 0.5-inch x 5-inch particle size. **Shredding Systems, Inc., Wilsonville, Ore., USA.**

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High value-added products molded from 100 per cent recycled plastic scrap are being produced on two new injection molding machines incorporating unusual injection technologies. The first technology, a slow-speed, low-pressure reciprocating screw process called thermoplastic cellular and solid molding (TCM/TSM) makes parts weighing up to 16 pounds. The second process is a "first-in, first-out", two-stage method in which melt from the first stage extruder is fed to the injection unit through the bore of its hollow injection plunger. Both methods "ease" the material into the mold slowly and at relatively low pressures. The machines can accommodate both mixed and separated plastic waste.

Companies in the Federal Republic of Germany, Holland, Austria and Japan are molding floor and carpet tiles, bathroom sinks, large pallets and automotive trim with these machines. Unseparated polyethylene and polyvinyl chloride cable insulation scrap, mixed high-density polyethylene and polypropylene waste, polystyrene packaging scrap, and phenolic resin are used in these products. **Bettinga Equipment, Inc., Des Moines, Iowa, USA.**

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Another system for reclaiming in-plant or post-consumer plastic scrap, built by the Austrian firm of Erema GmbH, is available through Reifenhauser-Van Dorn. The Erema system incorporates a proprietary shredder/densifier, extruder, screen changer and hot-face pelletizer (strand pelletizer if processing polyester).

The system takes washed granulate, from which paper and other contaminants have been removed, and then shreds and densifies it. The densifier preheats the scrap to about 212°F. It then processes the densified material in an extruder and passes it through the screen changer and pelletizer. **Reifenhauser-Van Dorn, Danvers, Mass., USA.**

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Extruder Technology I (ET/1) is an integrated system that takes commingled post-consumer and industrial plastics waste and processes it into "lumber-like" products. Developed in Belgium by Advanced Recycling Technology SA, it is being marketed in the USA by Mid-Atlantic Plastics Systems, Roselle, NJ.

The ET/1 extruder can process most types of thermoplastic scrap, including mixed, contaminated post-consumer waste and mixed co-extruded or laminated industrial waste. The extruder can produce up to 450 lb/hour, depending on the composition and density of the plastic waste. The molded product, called Syntal (synthetic alternative), stands up to weather, water, fungus, rot and insects. It is also non-conducive. Syntal is unaffected by organic solvents at ambient temperatures, or acids and alkalis up to 250°F. The molded products can be fabricated using conventional wood-working and machine-shop tools.

The ET/1 system consists of a hydraulically driven adiabetic extruder with a short L/D screw, a horizontal rotating turret on which 10-12 linear molds are mou... recirculating water bath, and associated mixing hoppers and product-handling equipment. The molds can be changed quickly and easily.

The system makes products 3 to 14 ft long and up to 6" x 6" in cross-section. Parts can be square, round, rectangular, oval, tapered, or irregular to fit the application. Potential applications for the molded products include: pilings, boat docks, harbour fenders, animal pens that require sterilization, tree planters, outdoor playground equipment and stadium seating. **Mid-Atlantic Plastics Systems, Roselle, NJ, USA.**

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Recyclers are using air aspirators to remove paper and metal contaminants from granulated bottle scrap and chopped up wire and cable, and dust from polystyrene foam granulate. An air aspirator separates materials of different densities in plastic regrind. It also removes fines and "angel-hair" from virgin or repelletized plastics to improve processing. The Multi-Aspirator pulls high velocity air through the falling resin or regrind at six evenly spaced levels opposite which are slots for removing the lighter materials or fines. The unit discharges clean, heavier materials into a gaylord and the lighter materials or fines are discharged into an airtight container. **Rice Industries, Inc., Wichita, Kansas, USA.**

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Reclaimers processing polyester bottle scrap must recrystallize it before it can be repelletized. In Conair's CR 1000 crystallizer, the granulated PET is rapidly heated to the crystallized stage. A specially designed agitator in the insulated hopper keeps the particles in motion to prevent agglomeration during the recrystallizing process. **Conair Franklin, Franklin, Pa., USA.**

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Recycled plastic bottles must be reduced in volume to permit reprocessing. There are two specially modified small granulators from Cumberland Engineering. One is a 20-hp model with a 12" x 12" throat and three-blade scooped rotor for large bottles. A 35° tilt chamber and a modified tangential cutting chamber reduce bottle bouncing on the rotor. It processes 500 lb/hour of baled bottles or 250 lb/hour of uncrushed bottles. The other model is a 5-hp unit with a top-feed hopper, an 8" x 12" throat that accepts one-gallon bottles, and a two-blade rotor that pulls bottles into the cutting chamber. **Cumberland Engineering, Providence, R.I., USA.**

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Carpco electrostatic separators are being widely used in the recycling industry to remove metal contaminants from granulated polyethylene terephthalate (PET) bottle scrap and plastic-jacketed wire and cable prior to remelting and pelletizing. The clean, dry granulated PET scrap usually contains up to 1.5 per cent aluminium by weight which the electrostatic separator reduces to 50-100 ppm. The HTE series separators have a PET throughput of 1,500-2,000 lb/hour. The chopped wire scrap contains 4-10 per cent residual metal, which the separator reduces to less than 0.5 per cent. **Carpco, Inc., Jacksonville, Fla., USA.**

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For recyclers of large-size injection molded plastic scrap, Nelmor supplies its Bold Series Model G1820M and G1830M granulators. These machines have large throat sizes - 18" x 20" and 18" x 29.5", respectively - and a tangentially fed cutting chamber that ingests scrap in front of the knives. A three-blade open-winged rotor with slant knife mounting provides good air flow through the cutting chamber, thus reducing heat build-up in the granulate. The bed knives are reversible for longer cutting life. G1416M granulator is for scrap recovery from blow-molded bottles up to 1-gallon size at rates of 300 lb/hour. The tangential feed feature prevents bouncing on the rotor and flyback. **Nelmor, North Uxbridge, Mass., USA.**

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To help municipalities and companies collect and segregate plastic and other recyclable wastes for sale to recyclers, Recycling Services, Inc. builds, leases and sells a transportable plastics recycling centre. The unit is a 50-75 cu. yd. steel roll-off container which fits on to a tractor-trailer. The container is divided into compartments for holding waste paper, plastics and metal cans. The unit has portholes in the side to permit people to drop their segregated waste for recycling. Two container sizes are available: 8-ft x 8-ft x 20-ft and 8-ft x 8-ft x 30-ft. **Recycling Services, Inc., Claremont, N.H., USA.**

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An innovative recycling development for communities with curbside waste separation programmes is a truck-mounted granulator for grinding up plastic bottles at curbside. By reducing the bulk bottles to granulated chips, the truck can collect more waste in fewer trips. The specially modified Gloucester Engineering granulator has a 14" x 18" throat that accepts up to 1-gallon bottles. The hopper is faced outward to simplify feeding. The unit's cutting chamber is designed for blown parts and has a special rotor that ingests the bottles. A stainless steel screen is used to combat corrosion from fluid residues in the bottles. The unit is hydraulically driven through a power take-off from the truck. **Shred-Tech Limited, Cambridge, Ontario.**

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Recrystallized PET bottle regrind must be dried just the same as virgin PET resin. For reclaim operations repelletizing PET regrind, a dehumidifying drier with a high volume throughput is required. Una-Dyn DHD 40 and DHD 60 driers with throughputs of 1,000-2,000 lb/hour are widely used by PET reclaimers. **Universal Dynamics, Woodbridge, Va., USA.**

Other suppliers of large-capacity dehumidifying driers for recycled plastics regrind include: Compu-Dry desiccant driers with throughputs of 100, 200 and 400 lb/hour. **Comair Franklin**, Franklin, Pa., USA.

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Recycling service extends to Asia

Shuman Plastics (Pacific) Limited, Hong Kong, is to represent Shuman's Resource Recovery Service Division throughout Asia. The division was created in 1986 in the US and expanded into Europe when Euro Polymers BV, Amsterdam, was appointed to represent it. The division provides consulting services in a number of areas ranging from methods of recycling scrap through to purcahse of recyclable surplus or waste. Shuma Plastics (Pacific) Limited, Room 506 Beverly House, 93-107 Lockhart Road, Wanchai, Hong Kong (Source: Modern Plastics International, November 1989)

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Recycling of plastic waste

Company in the German Democratic Republic has developed a process for the recycling of three kinds of thermoplastic waste materials - pure-grade clean waste, pure-grade contaminated waste, and mixed contaminated waste. Recovery of valuable secondary raw materials is effected through the washing, grading, drying, and regranulating of plastic household and industrial wastes, by a continuous and automated process. Company will supply turnkey package, embracing plant, production know-how, erection and other engineering services, and personnel training. (Source: International Licensing, December 1989)

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PVC separated

Rutgers University's Center for Plastics Recycling Research (USA) claims to have discovered a method of separating PVC bottles from other plastic bottles by using X-rays. While PVC is said to account for only about 3 per cent of plastic bottles in the US, the detection system would make the essential separation of plastics faster. The system is said to sort up to 600 bottles a minute. (Source: Chemical Marketing Reporter, 26 March 1990)

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Listed below are just a few R&D centres in the USA and Europe dealing with plastics recycling:

Center for Plastics Recycling Research. Rutgers University, Building 3529-Busch Campus, Piscataway, N.J. 08855. Conducts research on the recycling of post-consumer plastics waste. Initially focused on reclamation technology and end-uses for polyethylene terephthalate (PET) and high-density polyethylene (HDPE). Now includes polyvinyl chloride (PVC), polystyrene and polypropylene.

Council for Plastics and Packaging in the Environment (COPPE). 1275 K St. N.W., Washington, D.C. 20005. COPPE was formed in the mid 1980's to inform consumers, the media and elected officials about solid waste issues. Includes more than 50 companies and is quite broad-based, from resin producers to food processors.

Council for Solid Waste Solutions. 1275 K St. N.W., Suite 400, Washington, D.C. 20005. Established in 1988 by major resin companies, the council funds solid waste projects, lobbies and conducts educational programmes. It has in effect become the voice on solid waste issues for the plastics producing industry in place of the Society of the Plastics Industry (SPI), with which it co-operates closely.

The National Association for Plastics Container Recovery. 5024 Parkway Plaza Blvd., Suite 200, Charlotte, N.C. 28217. NAPCOR works with communities to institute PET recycle. There are currently active programmes in eight to ten states. It is supported by 12 companies that produce PET or PET bottles.

The National Soft Drink Association. 1101 16th St. N.W., Washington, D.C. 20036. This group of soft drink makers and their suppliers supports comprehensive recycling programmes that do not focus on specific containers. Recently expanded its interest to all solid waste issues. Literature available includes "Plastics Recycling" and "Promoting Recycling to the Public".

Keep America Beautiful. Nine West Broad St., Stamford, Conn. 06902. Founded in 1953 as a non-profit anti-littering organization, Keep America Beautiful has branched out into solid waste and is now funded by more than 300 companies. Its approach is development of community-based programmes and is in the third printing of its "Recycling Manual" for communities.

Flexible Packaging Association. 1090 Vermont Avenue, N.W., Suite 500, Washington, D.C. 20005. This approximately 200-member group, which was founded in 1950, is an important voice on the use of plastics and other materials in many packaging applications. Its solid waste activities have included a Washington Government Relations Conference and a flier outlining its positions.

The Plastics Bottle Information Bureau. 1275 K St. N.W., Suite 400, Washington, D.C. 20005. The Bureau is part of the Plastics Bottle Institute (BPI), which in turn is a division of the SPI. It spearheaded in 1988 a voluntary system of container coding to facilitate post-consumer sorting. Actual recycling activities of the Bureau have been transferred to the Council on Solid Waste Solutions as part of a policy decision by the SPI to use the council as the focal point of solid waste activities.

Plastics Recycling Corp. of California. 3345 Wilshire Blvd., Suite 1105, Los Angeles, Calif. 90010. Set up in 1987 in response to the California Beverage Container Recycling and Litter Reduction Act.

National Solid Wastes Association. 1730 Rhode Island Ave. N.W., Suite 1000, Washington, D.C. 20036. This 2,800-member trade association lobbies and promotes recycling through seminars and other programmes. It represents waste hauling and collection businesses.

Plastics Recycling Corp. of New Jersey. P.O. Box 6316, North Brunswick, N.J. 08902. Set up in 1988 in response to mandatory curbside recycling in New Jersey, this group is working to convince communities to include plastics containers, particularly PET.

The National Recycling Coalition. Organization of recyclers and local recycling groups, can be contacted at 45 Rockefeller Plaza, Room 2350, New York, N.Y. 10111, USA.

Polystyrene Packaging Council. 1025 Connecticut Ave. N.W., Suite 513, Washington, D.C. 20036. Founded in 1988, the council lobbies and conducts public information programmes on polystyrene recycling. Publications produced by the council include "Taking out the Garbage" and "Polystyrene Foam Food Service Projects: Environmental Impact and Waste Disposal Implications".

Plastics Recycling Foundation. 1275 K St. N.W., Suite 400, Washington, D.C. 20005. Founded in 1985, the PRF sponsors research demonstrating the feasibility of plastics recycling in pilot-scale facilities and then disseminates information on recycling technology.

The Vinyl Institute. 155 Route 46 West, Wayne, N.J. 07470. The Institute was formed in 1982 to counter attacks on vinyl materials by metal pipe and conduit producers. Recently, it has played a leading role in research on vinyl incineration as well as vinyl recycling. It is funded by the major polyvinyl chloride producers.

Several organizations mentioned above offer literature and other information on plastics recycling. Some of these organizations perform a predominantly technical function, while others engage in public education and lobbying.

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Metal Box plc Research and Development Department

Address: Denchworth Road, Wantage OX12 9BP., UK. Telephone: (02357) 2929. Telex: 837929.

Research centre within an industrial company.

Activities: Development and evaluation of new packaging containers; biological safety of products and processes; food microbiology and preservation methods; electrochemical corrosion of metal containers; compatibility of food with container materials; analysis of trace metals in foods; properties and processing of packaging materials (metals, plastics, paper and board); analytical techniques for these materials; curing and performance of protective and decorative coatings on all types of container; printing technology on all container materials; security printing of cheques, stamps, labels, tickets; design of machinery for manufacture and closing of containers; CAD/CAM; electronics and computing; instrumentation and control engineering; noise control; energy conservation; materials recycling; sheet metal forming.

Publications: Metal Box News, monthly; annual report.

Brunel University

Address: Kingston Lane, Uxbridge, Middlesex, UB8 3PH, UK. Telephone: (0895) 74000. Telex: 261173 BRUNEL G. Status: Educational establishment with R&D capability.

Ecological Materials Research Institute. Activities: Contract research projects on the optimum exploitation of natural and synthetic materials. Typical areas of research include: development of environmentally acceptable materials; identification of new materials from renewable natural resources with associated production techniques: recycling of polymers and recovery of materials from urban and industrial waste.

Work in progress includes: continuous mixing studies related to problems of filled-polymer masterbatch production; the development of new composite polymeric materials with reduced lifetime in soil burial, having improved mechanical properties for use in packaging; optimization of slurry/colloidal dispersion flow properties involving the development of techniques in particulate technology; experimental and theoretical investigations of the propagation of ultrasound in concentrated suspensions and dispersions.

University of Surrey

Address: Guildford, Surrey GU2 5XH, UK. Telephone: (0483) 571281. Telex: 859331. Status: Educational establishment with r&d capability.

Department of Civil Engineering. Activities: Analytical and experimental studies of various types of space structures in steel, aluminium, plastics, timber, and reinforced concrete; investigations into the behaviour of fibre-reinforced plastics components used in structural and semi-structural applications; testing of large-scale civil engineering components; studies of the behaviour of various types of soils, stress analysis of piles and stability of clay slopes; development of replacement material for asbestos sheeting, cyclic loading behaviour of polymer-reinforced cement; demolition of structures; recycling of constructional materials.

Instituto de Plásticos y Caucho - IPC (Plastics and Rubber Institute)

Address: Juan de la Cierva 3, 28006 Madrid, Spain. Telephone: 91-262 29 00.

Activities: Synthesis and characterization of polymers and study of relationships between structures and properties (mechanical, thermal, crystallization), etc. - fundamental research and applications to thermal-resistant electrical insulant enamels, polymer modified concrete, photosensitive polymers, plastic processing in general. Plastics recycling - utilization of urban and industrial residues; rubber compounding with inorganic fillers - improvement of affinity and reinforcing ability of original and modified silica and natural silicates for the rubber manufacturing industry; composites.

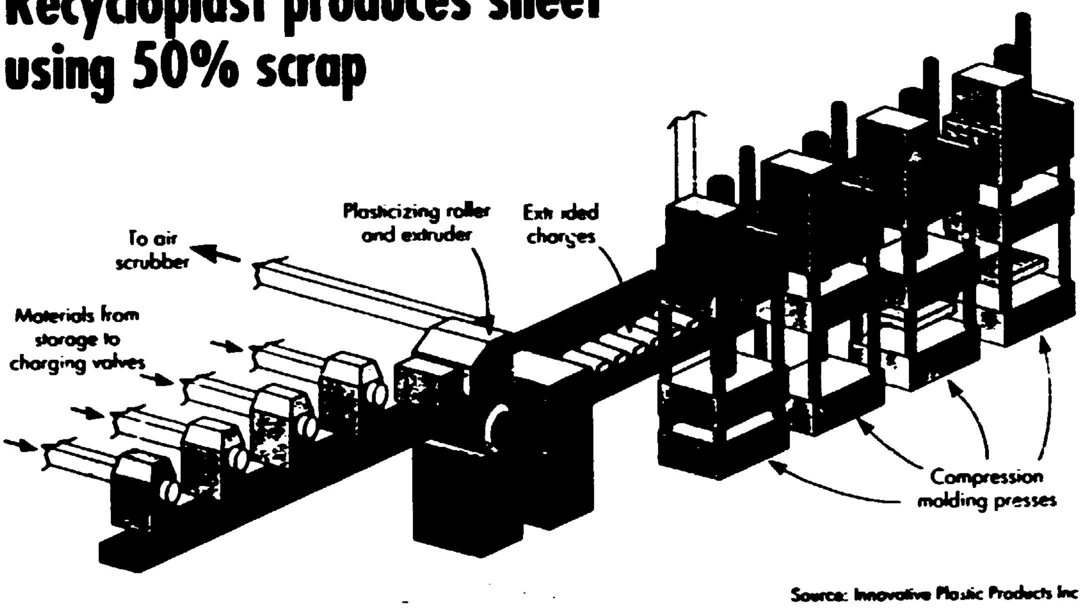
Société de Techniques en Milieu Ionisant - STMI

Address: 9 rue Fernand Léger, 91190 Gif sur Yvette, France. Telephone: (1) 69 28 01 73. Telex: 600419 FSTMIGIF.

Activities: The technical development department aims mainly at developing tools, methods and processes for the use of STMI's operational teams, such as: remote handling, waste-conditioning mobile units; waste-conditioning processes; decontamination processes, etc. It includes both engineering and research teams in very tight co-operation. Currently, it is working on: a new subwater electrodecontamination process; recycling of contaminated stainless steel; a polymer concrete cement waste matrix.

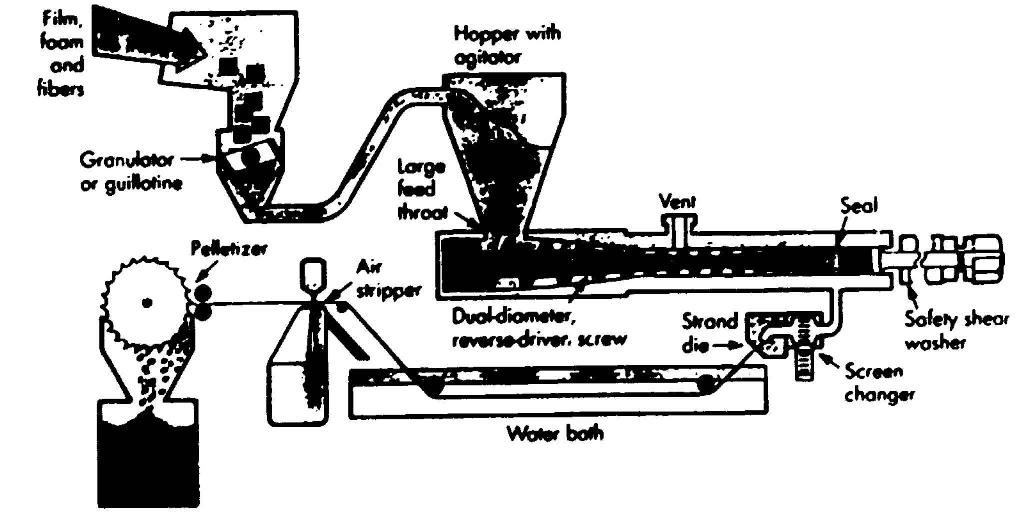
PW Recycle Mart

Recycloplast produces sheet using 50% scrap



This system granulates commingled scrap and plasticates it with a 50% PE or PVC resin carrier. Continuously extruded charges are fed to compression molding presses that produce sheet. (Innovative Plastic Products, Inc., Atlanta, Ga., USA)

Extrusion system geared for reclaim



For low bulk density scrap, this system has a dual-diameter screw driven from the discharge end. This allows 72:1 compression ratios and eliminates ram stuffers. The extruder is available in outputs of 300-3,000 lb/hour. **John Brown Plastic Machinery, Inc.,** Providence, R.I., USA

8. PUBLICATIONS ON PLASTICS RECYCLING AND OTHER MATERIALS

Recycling von Alt-Thermoplasten mit Aufwertung für gezielte Anwendungen am Beispiel von Polypropylen (Recycling of used thermoplastics with assessment of specific applications on the example of polypropylene.)

By Hugo Bonau. Published in German in 1988 by Technische Universität, Abt. Publikationen, Strasse des 17 Juni 35, D-1000 Berlin 12, Fed. Rep. of Germany.

This 19th volume in the series "Kunststoff-forschung" (plastics research) discusses the problems and limitations of recycling used thermoplastics parts into re-usable raw materials, specifically describing the projects running at the West Berlin technical university. The book majors on the recovery and re-use of polypropylene from scrap automotive battery cases.

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National recycling directory

Townswomen's Guilds and Waste Watch have announced the completion of the first National Directory of Recycling Information to be published in October 1989. The National Directory will provide details of all local authority recycling facilities and key local group contacts on a county by county basis. Details from Townswomen's Guilds, Chamber of Commerce House, 75 Harborne Road, Edgbaston, Birmingham B15 3DA, UK.

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Revised six-page brochure from Eriez Magnetics, Erie, Pa., describes the company's line of magnetic and vibratory separation equipment for solving product handling, purity, and processing problems in the recycling industries. Also included is information on metal detection equipment and ore treatment products.

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Recycling of plastics, commodity and engineering plastics

International techno-economic report by Vladimir M. Wolpert. Published by Vladimir M. Wolpert, Hunters, Holly Hill, Colemans Hatch, East Sussex TN7 4EP, England. 192 pp.

This report consists of sections on equipment, individual sources of plastics waste, and developments and trends in Western Europe, USA, Canada and Japan. It is based on discussions with plastics and recycling companies, their clients, and authorities on waste disposal in various countries. Included are assessments of different processes and interviews in which some controversial views are expressed. Names and addresses of the companies and organizations referred to are also provided.

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Antec 88 proceedings

Volume from the 46th Conference of the Society of Plastics Engineers (April 1988) contains more than 450 original technical papers. Topics covered include: colour and appearance; extrusion; injection moulding; electrical and electronic; thermoforming; engineering properties and structure; vinyl; thermosets; thermoplastic materials and foams; blow moulding; automotive analysis; mould making and design; medical grades; modifiers and additives; failure analysis; plasma polymerization; design; advanced composites; quality control; high temperature polymers; thermoplastic elastomers; computer uses; plastics disposal and recycling; and alloys and blends. The 1921-pp. softcover volume from Technomic Publishing Co., Inc., 851 New Holland Ave., Box 3535, Lancaster, PA 17604, USA.

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Plastics recycling as a future business opportunity

Proceedings of the RecyclingPlas III Conference, Washington, D.C., May 1988. Paper 8 1/2" x 11". 177 pages. Technomic Publishing Company, 851 New Holland Avenue, Box 3535, Lancaster, PA 17604.

This new volume contains proceedings of the technology exchange programme. RecyclingPlas III Conference, sponsored by the Plastics Institute of America in co-operation with the Department of Energy. Now in its third year, the conference has become an important national conference on the technology of plastics recycling as evidenced by the 17 reports from industry specialists on new developments that were presented at the May 1988 meeting in Washington, D.C.

In addition to new information on processing methods, the reports include details on product applications and markets, as well as economic, environmental and regulatory aspects. Several reports examine the recycling of plastic packaging materials; others describe plastics recycling methods used in other countries.

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Plastics Recycling as a Future Business Opportunity contains papers presented at RecyclingPlas III, held in May 1989. In addition to new information on processing methods, the reports include details on product applications and markets, as well as economic, environmental and regulatory aspects. Several reports examine the recycling of plastic packaging materials, while others describe recycling methods used in other countries. The conference was sponsored by the Plastics Institute of America in co-operation with the US Department of Energy. Order from Technomic Publishing Co., Inc., 851 New Holland Ave., P.O. Box 3535, Lancaster, PA 17604, USA.

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Recycling and Resource Recovery

Directory of Plastic Soft Drink Bottle Recyclers is available from the Plastic Bottle Information Bureau, 355 Lexington Ave., New York, NY 10017. Tel: 212/573-9468.

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The third annual edition of the American Recycling Market Annual Directory/Reference Manual, 344 pages, includes a glossary, specifications for materials, list of state agencies, and more. 7,500 listings are included all told. Box 577, Ogdensburg NY 13669, USA.

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The Economic Feasibility of Recycling: A Case Study of Plastic Wastes, could have been subtitled "everything you wanted to know about plastics recycling but couldn't find anyone to ask". Author T. Randall Curlee is an Oak Ridge National Laboratories employee. 200 pages. Prager Publishers Greenwood Press, 88 Post Road West, Box 5007, Westport, CT 06881, USA.

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Proceedings from a conference on "Plastics Recycling as a Future Business Opportunity".

The 139 pages cover a conference co-sponsored by the US Department of Energy and the Plastics Institute of America. Write PIA care of Stevens Institute of Technology, Castle Point, Hoboken, NJ 07030, USA.

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Technology Transfer Manual

The Center for Plastics Recycling Research (CPRR) at Rutgers. The State University of New Jersey now has available a technology transfer manual focusing on the science and economics of including post-consumer plastic beverage bottles in a multi-material collection/sortation programme for non-rural, single-family homes.

The manual details the results of research sponsored by the Plastics Recycling Foundation (PRF) at CPRR and various other universities, which "confirms that the inclusion of plastic beverage containers in a curbside collection programme along with glass, metal and aluminium containers is economically attractive".

The 200-page technology transfer manual includes an overview section on municipal solid waste and chapters on collection technology, sorting technology, economics and markets, as well as case studies of communities actively involved in plastics recycling and a look at research plans.

Copies of the manual or more details can be obtained by contacting: Center for Plastics Recycling Research, Rutgers, The State University of New Jersey, Building 3529, Busch Campus, Piscataway, NJ 08855, USA. Tel: (201) 932-4402.

The Information Services Division of the Center for Plastics Recycling Research, also at Rutgers, is constructing a data base of documents encompassing all aspects of plastics recycling. To the fullest extent possible, the original documents or copies thereof have been obtained and can be examined in a special information area established for this purpose. The use of this room and personal examination of documents therein are available without charge to personnel engaged in plastics recycling research.

In addition, a newsletter - the Plastics Recycling Report - reports on activities of the Center and provides news and other information relevant to the reclamation, reprocessing and re-use of plastics. It is available at no charge by letterhead request.

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New custom translations service available from MITS

Metallurgists and materials scientists who have technical publications in languages they cannot read can now have custom translations done by the Materials Information Translations Service (MITS).

For many years MITS has produced translations of selected technical papers relevant to ferrous and non-ferrous metallurgy, and more recently polymers, ceramics, and composite materials. Today, this collection contains more than 25,000 items, selected for translation because of their scientific importance and broad appeal.

The new custom translations service has been introduced in response to demand from existing customers. It will enable scientists working in the metals and materials fields to obtain translations of papers that are of interest to them but have not been included in the main lists.

All custom translations will be of the same high quality as the established translations series, they will be checked for scientific accuracy.

For further details and a free quotation for a custom translation, please contact:
Eleannor Baldwin, MITS, The Institute of Metals, 1 Carlton House Terrace, London, SW1Y 5DB, UK.

Materials Information is the joint not-for-profit information service of ASM International (USA) and the Institute of Metals (UK).

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Advanced Cutting Tool Materials, Kennametal Inc., P.O. Box 346, Latrobe, PA 15650, USA

A new 104-page catalogue presents the company's comprehensive range of advanced cutting tool materials, engineered to boost metalworking productivity and solve customer problems. Ceramic, cermet, polycrystalline diamond and CBN materials are offered by Kennametal Inc., in a wide selection of insert styles and geometries.

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Food and packaging interactions

Ed. J. H. Hotchkiss. Washington: American Chemical Society 1988. Ppxi + 305, ISBN 0 84121465 4.

The past decade has seen a significant increase in the use of plastics as food-contact packaging materials. Consequently, considerable emphasis is now being placed on studies of the ways in which foods interact with plastic packaging. The present volume consists of a collection of 21 research papers and reviews on this topic which were presented at a symposium organized by the agricultural and food chemistry division of the American Chemical Society in the spring of 1987, which brought together a number of leading research groups studying food and packaging interactions.

The papers cover four main areas of concern: (i) migration of components of the package to the food during storage or preparation (and the development of appropriate analytical methodologies for the determination of specific migrants); (ii) permeation of the food container to gases and water vapour; (iii) sorption and/or permeation of the container by organic vapours; and (iv) chemical changes in food packaging resulting from exposure to ionizing radiation.

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Alloying

A new book on a subject basic to materials technology, represents the efforts of three eminent researchers to provide a basic and comprehensive volume on alloying, the addition of elements to a material to modify its properties. Edited by J. L. Walter, M. R. Jackson and C. T. Sims, it offers a complete source of information on how alloying elements affect structures and properties in a wide variety of engineered materials. The first half of the book discusses information relevant to all alloying procedures. The second half deals with the alloying of ferrous and non-ferrous alloys, ceramics and electronic materials. 546 pages. Contact: ASM, Member/Customer Service Centre, Metals Park, OH 44073, USA.

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A Guide to Materials Characterizations and Chemical Analysis

Ed. by John P. Sibilia. VCH Publishers, Suite 909, 220 East 23rd Street, New York, NY 10010-4606. 1988. 318 pages.

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Lasers in Materials Processing - A Bibliography of a Developing Technology

By Alan Gomersall. Springer-Verlag, 175 Fifth Avenue, New York, NY 10010. 1986. 167 pages.

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Superconductivity Sourcebook

By V. Daniel Hunt, John Wiley & Sons, 605 Third Ave., New York, NY 10158. 1989. 308 pages.

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Materials selection book

Updated materials selection handbook details new phenolic, general-purpose encapsulation grade epoxy, speciality grade, vinyl ester, and polyimide carbon-fibre moulding compounds. Listing include in-depth specifications and selection aids. Performance features, physical properties, design tolerances, and applications are reviewed for all products. ICI Advanced Materials, Concord Pike & New Murphy Road, Wilmington, DE 19897, USA.

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Materials and the Designer

E. H. Cornish. Cambridge 1987, 282 pages, A 5, hardback, tables and illustrations, English.

This book is written for the designer and deals with the four categories of materials: metals, polymers, ceramics and composites.

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Processing of Advanced Ceramics

J. S. Moya, S. de Aza (eds.)

Proceedings of the workshop held at the Instituto de Ceramica y Vidridio, Arganda del Rey (Madrid, Spain), 28-29 October 1986. Madrid 1987, 233 pp., 22.5 x 16.5 cm, paperback (English).

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Ceramic raw materials

Edited by D. J. De Renzo. Noyes Publications, Park Ridge, NJ 1988. Pp. 890.

This massive reference work of 890 pages appears to be a comprehensive listing of ceramic materials available within the United States of America.

In Part 1 of the book 99 raw materials are listed alphabetically, ranging from alumina to zirconium nitride; both the traditional ceramic materials and the newer nitride and carbide materials are listed. Several different suppliers and grades of material appear under many of the entries. A short description of the typical uses of the raw material is often included.

Part 2 is in a similar form but details more specialized products such as additives, binders, glass decorating enamels, glazes, and electronic ceramic materials. The format remains the same as Part 1 with chemical, physical, and safety information tabulated in a form which is easy to use.

The suppliers listed are all based in the USA but of course many are part of multinational groupings which may make the data still relevant to readers outside the US.

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Advanced Composites III: Expanding the Technology: proceedings, 1987

Metals Park: ASM, 1987, 397 p. 620.1 TA418.9 87-071917 ISBN 0-87170-307-6.

Summarizes material presented at a conference designed to bring together all factions of the composites community. Development of synergism between the various industries attempting to optimize the use of advanced composites is the stated purpose. Focuses attention on applications in the aerospace, defence and automotive industries.

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Composites Guide Published

The US Society of the Plastics Industry's Composites Institute has published a new guide presenting applications of fibreglass reinforced plastic for solving corrosion problems in manufacturing operations. It includes case histories from companies such as Mobay, Dow, Barcroft, Gillette and Chevron, all of which have taken advantage of FRP's resistance to acids and alkalis as well as their improved impact and crack resistance.

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Fibre-reinforced composites: materials, manufacturing, and design

Mallick, P. K. NY: Dekker, 1988. 469 p (Mechanical Engineering; 62) 620.1'18 TA418.9 87-22692 ISBN 0-8247-7796-4. Contents: Materials, Mechanics, Performance, Manufacturing. Design. Index.

A textbook treating materials, mechanics, properties, manufacture, and design of fibre-reinforced composites. Coverage includes the differences in the characteristics and behaviour of fibre-reinforced polymers and common structural metals, fundamental design considerations and equations, available computer programmes, journals, and societies. Complex theory and detailed derivations of mechanics formulas are avoided. Intended for engineers involved in the design and use of composite materials and students studying materials, mechanical, civil, aeronautical, and automotive engineering. Includes worked examples.

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Volume 6 of the second edition Non-destructive Testing Handbook series, Magnetic Particle Testing, details the physical phenomena behind magnetic particle test methods, then discusses techniques for applying the technology to a large variety of test object configurations. 480 pages; extensively indexed. (American Society for Non-destructive Testing, 4153 Arlingate Plaza, Colombus, OH 43228-0518, USA)

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Polymer NDE

K. H. G. Ashbee, ed. Lancaster, PA: Technomic Publishing Co., 1986. xiv + 328 pp.

The proceedings of the European Workshop on Non-destructive Evaluation of Polymers and Polymer Matrix Composites address some of the problems faced in fabrication and in-service use of these exotic materials. The book is divided into nine technical sections: microstructure at the molecular level; molecular orientation; non-destructive evaluation (NDE) of laminates; acoustic emission; control of fibre orientation in short-fibre composites; electromagnetic wave propagation in composite materials; fracture mechanics as a method for quality control; vibrations, elastic waves, and ultrasonics; and rubber elasticity and anistropy under stress.

As is evident from the table of contents, the proceedings cover almost all the NDE tools available for the characterization of these polymers. Each section contains two to three detailed subsections written by prominent scientists. Each section is followed by a few comments or small discussion by the participants.

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Non-destructive Evaluation - A Tool in Design, Manufacturing and Service. Don E. Bray and Roderic K. Stanley. New York, NY: McGraw-Hill Book Co., 1989. xxiv + 581 pp.

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SESI Journal: Journal of the Solar Energy Society of India

Published bi-annually (June/December) by Wiley Eastern Publishers on behalf of the Solar Energy Society of India.

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Biomass: Regenerable Energy

Edited by D. O. Hall and R. P. Overend. Published by John Wiley and Sons, ISBN 0-471-90919-X, 1987. 504 pages.

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Plastic-composite springs

Custom plastic-composite mechanical springs, plastic sheathed metal springs, and plastic-coated metal springs for a large number of corrosive applications are presented in a technical brochure. Text explains how design and configuration of springs provide good performance in hostile environments. Tayco Technology, Tonawanda Island, North Tonawanda, NY 14120, USA.

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Chemical reactions on polymers

Edited by Judith L. Benham and James F. Kinstle. Washington, DC: Am Chemical, 1988. 483 p. 668.9 QD380 87-31913 ISBN 0-8412-1448-4.

Contains 33 papers presented at a symposium focusing on six research areas: reactive polymers, new synthesis routes, surface modification of polymers, specialty polymers with polar/ionic groups, chemical modification for analytical characterization, and chemical modification for functionalization and curing.

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Encyclopaedia of polymer science and engineering Vol. 12: Polyesters to polypeptide synthesis

Edited by Herman F. Mark et al. 2nd edition. NY: Wiley, 1988. 858 p. 668.9 TP1087 84-19713 ISBN 0-471-80944-6.

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Future directions in polymer colloids

Edited by Mohamed S. El-Aasser and Robert M. Fitch. Boston: Kluwer-Nijhoff, 1987. 402 p. 668.9 QD549 87-24818 ISBN 90-247-3625-0.

Contents: Emulsion copolymerization and particle morphology. Rheology of latex systems and concentrated dispersions. Polymer stabilized latexes. New techniques in characterization of polymer colloids. Polymer colloids in the biomedical field. Subject index.

Note: The objective of the first workshop was to develop position papers outlining future directions for research. Contains all five position papers as well as all invited papers presented at the workshop. Will be of value to scientists and engineers in both the academic and industrial worlds who are concerned with the fundamentals or the applications of polymer colloids. Research level collections.

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Handbook of thermoplastic elastomers

Edited by Benjamin M. Walker and Charles P. Radar. 2nd edition. NY: Van Nos Reinhold, 1988. 430 p. 668.4'23 TS1925 87-21576 ISBN 0-442-29184-1.

Contents, abridged: Styrenic thermoplastic elastomers. Elastomeric alloy thermoplastic vulcanizates. Copolyester thermoplastic elastomers. Automotive applications of thermoplastic elastomers. Hose, tubing, and sheeting. Electrical applications of thermoplastic elastomers. Thermoplastic elastomers, future market opportunities.

Note: Commercial practice and practical applications rather than theory and research activity of thermoplastic elastomers (TPEs) are emphasized. The second edition summarizes and documents the technological and commercial progress of TPEs since the publication of the original volume in 1979. Part II provides a detailed study of major market areas where TPEs have found commercial success. For researchers and technologists in the rubber and plastics industries.

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Kunststoffe in der Elektrotechnik und Elektronik (Plastics in Electrical Engineering and Electronics)

By Jürgen Bednarz. Published in 1988 in German by W. Kohlhammer GmbH, Hessbrühlstrasse 69, Postfach 80 04 30, D-700 Stuttgart 80, Fed. Rep. of Germany. 528 pp.

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Thermoforming - A Plastics Processing Guide

By G. Gruenwald. Published in 1987 by Technomic AG, Elisabethenstrasse 15, CH-4051 Basel, Switzerland. 224 pp.

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International Plastics Handbook, 2nd Edition

By Hansjurgen Saechtling. Published in 1987 by Carl Hanser Verlag, Postfach 86 04 20, D-8000 Munich 86, Fed. Rep. of Germany. 595 pp.

Second edition of this useful pocket book updates the original 1983 edition by including significant developments such as trends to copolymerization, alloying, and specialty compounding, technical and commercial development of high-temperature thermoplastics and advanced composites, and specialized application fields for high-technology engineering materials. As in the first edition, the treatment comprises basic aspects, materials synthesis, and processing technologies.

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Thermoplastic elastomers - an introduction for engineers

London: Mechanical Engineering Publications 1987. Pp. 40. ISBN 0 85298 6351.

This brief publication contains seven papers on various aspects of the title subject.

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Conducting polymers, special applications: proceedings of the workshop held at Sintra, Portugal, 28-31 July 1986

Edited by Luis Alcácer. Boston: Reidel Pub. 1987. 220 p. 620.1'9204297 QD382 87-9644 ISBN 90-277-2529-2.

The electrochemistry of electronically conducting polymers. Increasing the conductivity of polyacetylene films by elongation. Polymers with both ionic and electronic conductivity. New electronically conducting polymers. High conductivity in an amorphous cross-linked siloxane polymer electrolyte. Polyphtalocyanines. Subject index.

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Polymers for advanced technologies

Ed. M. Lewin. Weinheim: VCH 1988. Ppxvi + 953, ISBN 0-89573-293-9.

This book contains over 50 papers presented by distinguished scientists at an IUPAC macro-molecular division symposium in Jerusalem in August 1987.

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The applications of ferroelectric polymers

Edited by T. T. Wang, J. M. Herbert and A. M. Glass. NY: Chapman & Hall, 1988. 387 p. 620.1'92 TK7872 86-1005 ISBN 0-412-01261-8.

The discovery that strong piezoelectrical effects could be induced in the polymer poly(vinylidene fluoride) PVF2 or PVDF has led to a large number of applications in audio engineering, medical imaging and detectors for infrared imaging and security systems. A review of a variety of different applications for ferroelectric polymers, including the latest developments in electro-optical applications. For graduate students and working engineers.

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9. PAST EVENTS AND FUTURE MEETINGS

1989

August New York, USA	Chemical industry officials participating in a Council on Plastics and Packaging in the Environment (COPPE) seminar say they support kerbside collection of recyclable garbage - including plastics - and expect recycled materials to become a profitable niche once industry gears up recycling plants and finds new uses for the resurrected materials
24-25 May Washington, DC, USA	Recyclingplas IV-'89 (Plastics Institute of America)
August Moscow, USSR	International Exhibition for Recycling (Gebr. Helbig Industrie Messen GmbH, Postfach 1569, D-8480, Weiden, FRG)
20-21 September London, UK London, UK	Conference, "Plastics Recycling - future challenges. Contact: Sian Tauner, Conference Dept., Plastics and Rubber Institute, 11 Hobart Place, London SW1W OHL, UK
11-12 October New York, USA	Recycling. degradable plastics and package redesign conference, Sheraton Center, New York, NY, USA. Contact: Stephanie Finn, Modern Plastics, 1221 Ave. of the Americas, New York, NY 10020, USA

1990

26 February - 2 March New Delhi, India	XI International Conference on the Use of Plastics in Agriculture -ICPA '90. This is being organized by the Government of India and co-sponsored by Plastindia Foundation. Over 500 experts from some 50 countries are expected to attend
1-7 March New Delhi, India	Plastindia '90 - International Plastics Exhibition and Conference offers international and national organizations involved in the plastics industry a unique opportunity to present their technologies, product lines and services to an expanding Indian market. It offers the following benefits to exhibitors: **To international exhibitors** - Effective penetration for your products in this ever-expanding market in India; - Good possibilities for sale of the machinery and equipment, moulds and dies, tools and testing machines displayed in your stands; - Interaction with potential Indian partners for technical collaboration or joint ventures; - Identification of Indian partners for supply of raw materials, processing machinery, ancillary equipment, moulds and dies, sub-assemblies, processed articles and turnkey projects; - Exposure to visitors from other developing areas, especially from SAARC, ASEAN and OAU countries; - Boost in marketing support to your existing Indian agents, collaborators, partners
7-9 March Madrid, Spain	"Recycling of plastics" Conference. Contact: Dr. O. Laguna, Revista de Plásticos Modernos, Juan de la Cierva 3, 28006 Madrid, Spain
3-6 April Paris, France	SEPT, exhibition of plastics, ceramics and composite parts, Parc des Expositions de Paris-Nord. Contact: Fédération de la Plasturgie, 65, rue de Prony, 75854 Paris, Cedex 17, France
4-6 April Paris, France	European Congress on Composites. Contact: Centre de Promotion des Composites, 65, rue de Prony, 75017 Paris, France
22 April Washington, DC, USA	The environmental movement has been particularly hard on plastics, but the plastics industry is responding. In preparation for "Earth Day 1990", the Society of the Plastics Industry (SPI, Washington) is developing a programme to demonstrate how plastics have contributed to improving the environment during the past 20 years. A second part of the programme will detail how plastics manufacturers have made their operations more ecologically sound. This event will also celebrate the 20th anniversary of the establishment of the Environmental Protection Agency and the passing of new environmental legislation
22-26 May Munich, FRG	International Trade Fair for Waste Disposal Sewage Systems, Refuse, Recycling, City Cleaning. (Münchener Messe GmbH, PF 12.10.09, D-8000 München, FRG)
23-24 May Washington, DC, USA	Recyclingplas V'90 - Conference on Business Opportunities in Plastics Recycling (Plastics Institute of America)

29-31 May Davos, Switzerland	RECYCLE '90 (Maack Business Services, CH-8804, Au/near Zürich, Switzerland)
28-31 October Williamsburg, VA, USA	The 1990 TMS Fall Extractive Meeting will discuss the technological, economic and social incentives for recycling and recovery of valuable materials from industrial waste. The conference is sponsored by The Minerals, Metals & Materials Society An international group of experts involved in recycling research will present papers and stimulate an exchange on practical processing procedures for cycles of recovery and re-use. Major topic areas to be covered include: recycling of iron and steel, aluminium, copper, lead, zinc, tin, precious metals and engineered materials; advanced material separation; and materials recovery from industrial waste streams For more information contact: TMS, Meetings Department, 420 Commonwealth Drive, Warrendale, PA 15086, USA. Tel.: 412 776 9050. Fax: 412 776 3770

__Previous issues__

Issue No. 1	Steel
Issue No. 2	New ceramics
Issue No. 3	Fibre optics
Issue No. 4	Powder metallurgy
Issue No. 5	Composites
Issue No. 6	Plastics
Issue No. 7	Aluminium alloys
Issue No. 8	Materials testing and quality control
Issue No. 9	Solar cells materials
Issue No. 10	Space-related materials
Issue No. 11	High-temperature superconductive materials
Issue No. 12	Materials for cutting tools
Issue No. 13	Materials for packaging, storage and transportation
Issue No. 14	Industrial sensors
Issue No. 15	Non-destructive testing of materials
Issue No. 16	Materials developments in selected countries
Issue No. 17	Metal matrix composites

__One of Austria's largest department stores, "KGM", opened the first recycling station in Vienna on 10 November 1989__

Shoppers can not only dispose of hazardous material, old oil, chemicals, glass and aluminium cans, but also plastics items.

UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION
Advances in Materials Technology: Monitor; Code 504
Editor - Room D1950
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A-1400 Vienna, Austria

Advances in Materials Technology: Monitor
Reader Survey

The Advances in Materials Technology: Monitor has now been published since 1983. Although its mailing list is continuously updated as new requests for inclusion are received and changes of address are made as soon as notifications of such changes are received, I would be grateful if readers could reconfirm their interest in receiving this newsletter. Kindly, therefore, answer the questions below and mail this form to: The Editor, Advances in Materials Technology: Monitor, UNIDO Technology Programme at the above address.

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Do you wish to continue receiving issues of the Advances in Materials Technology: Monitor?

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Please make any other comments or suggestions for improving the quality and usefulness of this newsletter.

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Reader's comments

We should appreciate it if readers could take the time to tell us in this space what they think of the 18th issue of Advances in Materials Technology: Monitor. Comments on the usefulness of the information and the way it has been organized will help us in preparing future issues of the Monitor. We thank you for your co-operation and look forward to hearing from you.