



RECYCLING PLASTICS

Plastics – what are they and how do they behave?

Plastics are organic polymeric materials consisting of giant organic molecules. Plastic materials can be formed into shapes by one of a variety of processes, such as extrusion, moulding, casting or spinning. Modern plastics (or polymers) possess a number of extremely desirable characteristics; high strength to weight ratio, excellent thermal properties, electrical insulation, resistance to acids, alkalis and solvents, to name but a few.

These polymers are made of a series of repeating units known as monomers. The structure and degree of polymerisation of a given polymer determine its characteristics. *Linear polymers* (a single linear chain of monomers) and *branched polymers* (linear with side chains) are *thermoplastic*, that is they soften when heated. *Cross-linked polymers* (two or more chains joined by side chains) are *thermosetting*, that is, they harden when heated.

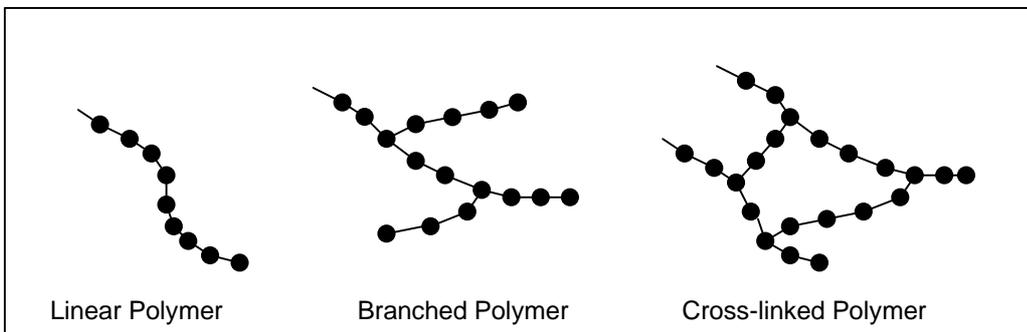


Figure 1: Polymer structures

Thermoplastics make up 80% of the plastics produced today. Examples of thermoplastics include;

- **high density polyethylene** (HDPE) used in piping, automotive fuel tanks, bottles, toys,
- **low density polyethylene** (LDPE) used in plastic bags, cling film, flexible containers;
- **polyethylene terephthalate** (PET) used in bottles, carpets and food packaging;
- **polypropylene** (PP) used in food containers, battery cases, bottle crates, automotive parts and fibres;
- **polystyrene** (PS) used in dairy product containers, tape cassettes, cups and plates;
- **polyvinyl chloride** (PVC) used in window frames, flooring, bottles, packaging film, cable insulation, credit cards and medical products.

There are hundreds of types of thermoplastic polymer, and new variations are regularly being developed. In developing countries the number of plastics in common use, however, tends to be much lower.

Thermosets make up the remaining 20% of plastics produced. They are hardened by curing and cannot be re-melted or re-moulded and are therefore difficult to recycle. They are sometimes ground and used as a filler material. They include: **polyurethane** (PU) – coatings, finishes, gears, diaphragms, cushions, mattresses and car seats; **epoxy** – adhesives, sports equipment, electrical and automotive equipment; **phenolics** – ovens, handles for cutlery, automotive parts and circuit boards (The World Resource Foundation).

Nowadays, the raw materials for plastics come mainly from petrochemicals, although originally plastics were derived from cellulose, the basic material of all plant life.

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Why recycle plastics?

In 'western' countries, plastic consumption has grown at a tremendous rate over the past two or three decades. In the 'consumer' societies of Europe and America, scarce petroleum resources are used for producing an enormous variety of plastics for an even wider variety of products. Many of the applications are for products with a life-cycle of less than one year and then the vast majority of these plastics are then discarded. In most instances reclamation of this plastic waste is simply not economically viable.

In industry (the automotive industry for example) there is a growing move towards reuse and reprocessing of plastics for economic, as well as environmental reasons, with many praiseworthy examples of companies developing technologies and strategies for recycling of plastics.

Not only is plastic made from a non-renewable resource, but it is generally non-biodegradable (or the biodegradation process is very slow). This means that plastic litter is often the most objectionable kind of litter and will be visible for weeks or months, and waste will sit in landfill sites for years without degrading.

Although there is also a rapid growth in plastics consumption in the developing world, plastics consumption per capita in developing countries is much lower than in the industrialised countries. These plastics are, however, often produced from expensive imported raw materials. There is a much wider scope for recycling in developing countries due to several factors:

- Labour costs are lower.
- In many countries there is an existing culture of reuse and recycling, with the associated system of collection, sorting, cleaning and reuse of 'waste' or used materials.
- There is often an 'informal sector' which is ideally suited to taking on small-scale recycling activities. Such opportunities to earn a small income are rarely missed by members of the urban poor.
- There are fewer laws to control the standards of recycled materials. (This is not to say that standards can be low – the consumer will always demand a certain level of quality).
- Transportation costs are often lower, with hand or ox carts often being used.
- Low cost raw materials give an edge in the competitive manufacturing world.
- Innovative use of scrap machinery often leads to low entry costs for processing or manufacture.

In developing countries the scope for recycling of plastics is growing as the amount of plastic being consumed increases.

Plastics for recycling

Not all plastics are recyclable. There are 4 types of plastic which are commonly recycled:

- Polyethylene (PE) - both high density and low-density polyethylene.
- Polypropylene (PP)
- Polystyrene (PS)
- Polyvinyl chloride (PVC)

A common problem with recycling plastics is that plastics are often made up of more than one kind of polymer or there may be some sort of fibre added to the plastic (a composite) to give added strength. This can make recovery difficult.

Plastics fact file

- More than 20,000 plastic bottles are needed to obtain 1 tonne of plastic.
- It is estimated that 100 million tonnes of plastics are produced each year.
- The average European throws away 36kg of plastics each year.
- 4% of oil consumption in Europe is used for the manufacture of plastic products.
- Some plastic waste sacks are made from 64% recycled plastic.
- Plastics packaging totals 42% of total consumption and very little of this is recycled.

Sources of waste plastics

Industrial waste (or primary waste) can often be obtained from the large plastics processing, manufacturing and packaging industries. Rejected or waste material usually has good characteristics for recycling and will be clean. Although the quantity of material available is sometimes small, the quantities tend to be growing as consumption, and therefore production, increases.

Commercial waste is often available from workshops, craftsmen, shops, supermarkets and wholesalers. A lot of the plastics available from these sources will be PE, often contaminated.

Agricultural waste can be obtained from farms and nursery gardens outside the urban areas. This is usually in the form of packaging (plastic containers or sheets) or construction materials (irrigation or hosepipes).



Figure 2: mixed waste plastic requiring sorting before it can be recycled. Photo credit: Practical Action/Zul

Municipal waste can be collected from residential areas (domestic or household waste), streets, parks, collection depots and waste dumps. In Asian cities this type of waste is common and can either be collected from the streets or can be collected from households by arrangement with the householders. (Lardinois 1995)

Identification of different types of plastics

There are several simple tests that can be used to distinguish between the common types of polymers so that they may be separated for processing.

The water test. After adding a few drops of liquid detergent to some water put in a small piece of plastic and see if it floats.

Burning test. Hold a piece of the plastic in a tweezers or on the back of a knife and apply a flame. Does the plastic burn? If so, what colour?

Fingernail test. Can a sample of the plastic be scratched with a fingernail?

Test	PE	PP	PS	PVC*
Water	Floats	Floats	Sinks	Sinks
Burning	Blue flame with yellow tip, melts and drips.	Yellow flame with blue base.	Yellow, sooty flame – drips.	Yellow, sooty smoke. Does not continue to burn if flame is removed
Smell after burning	Like candle wax.	Like candle wax – less strong than PE	Sweet	Hydrochloric acid
Scratch	Yes	No	No	No

*To confirm PVC, touch the sample with a red-hot piece of copper wire and then hold the wire to the flame. A green flame from the presence of chlorine confirms that it is PVC.

Source: Vogler. 1984

To determine if a plastic is a thermoplastic or a thermoset, take a piece of wire just below red heat and press it into the material. If the wire penetrates the material, it is a thermoplastic; if it does not it is a thermoset.

A coding system has also been introduced in the United States to aid identification of plastics for reclamation. It is based on the 'Recycle Triangle' with a series of numbers and letters to help with identification. More information is available from the Association of Plastic Manufacturers in Europe (APME). See *useful addresses* section later in this brief.

Collection

When thinking about setting up a small-scale recycling enterprise, it is advisable to first carry out a survey to ascertain the types of plastics available for collection, the type of plastics used by manufacturers (who will be willing to buy the reclaimed material), and the economic viability of collection.

The method of collection can vary. The following gives some ideas;

- House to house collection of plastics and other materials (e.g. paper).
- House to house collection of plastics only (but all types of polymer).
- House to house collection of certain objects only.
- Collection at a central point e.g. market or church.
- Collection from street boys in return for payment.
- Regular collection from shops, hotels, factories, etc.
- Purchase from scavengers on the municipal dump.
- Scavenging or collecting oneself.

The method will depend upon the scale of the operation, the capital available for set-up, transport availability, etc.

Processing of reclaimed plastic – processes and technology for small-scale recycling enterprises

- *Initial upgrading.* Once the plastic has been collected, it will have to be cleaned and sorted. The techniques used will depend on the scale of the operation and the type of waste collected, but at the simplest level will involve hand washing and sorting of the plastic into the required groups. More sophisticated mechanical washers and solar drying can be used for larger operations. Sorting of plastics can be by polymer type (thermoset or thermoplastic for example), by product (bottles, plastic sheeting, etc.), by colour, etc.

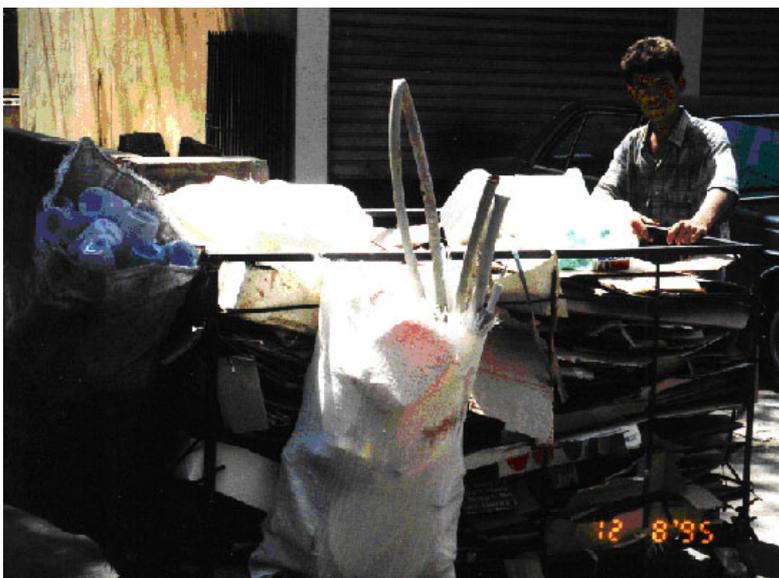


Figure 3: Collection of Waste Materials. © World Resource Foundation

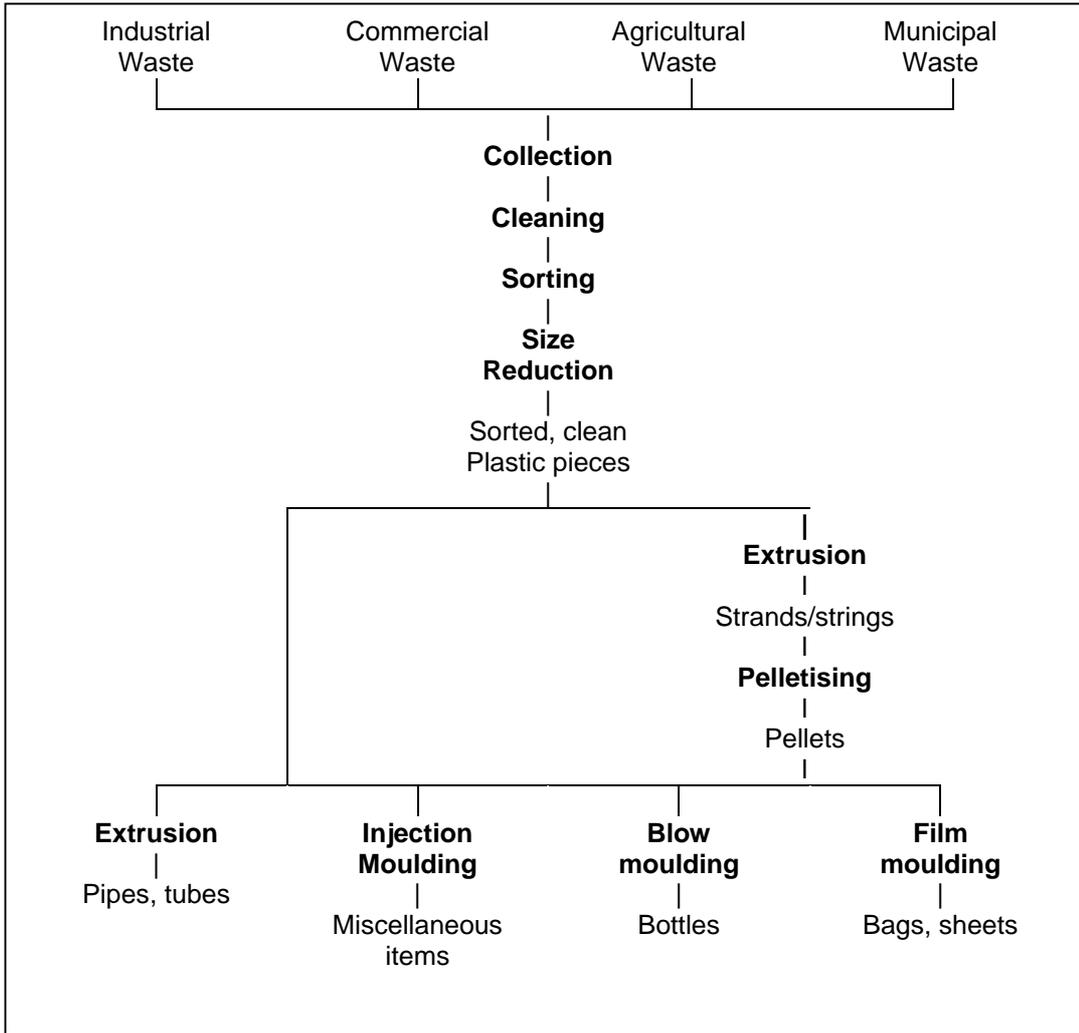
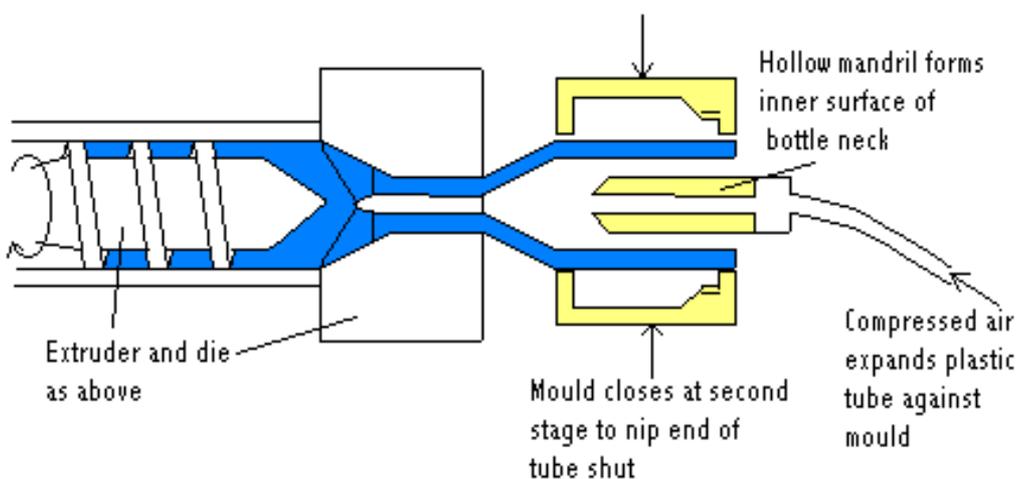


Figure 4: Flow chart of a typical waste plastic reprocessing stream in a low-income country (TOOL 1995)

- *Size reduction techniques.* Size reduction is required for several reasons; to reduce larger plastic waste to a size manageable for small machines, to make the material denser for storage and transportation, or to produce a product which is suitable for further processing. There are several techniques commonly used for size reduction of plastics;
 - *Cutting* is usually carried out for initial size reduction of large objects. It can be carried out with scissors, shears, saw, etc.
 - *Shredding* is suitable for smaller pieces. A typical shredder has a series of rotating blades driven by an electric motor, some form of grid for size grading and a collection bin. Materials are fed into the shredder via a hopper which is sited above the blade rotor. The product of shredding is a pile of coarse irregularly shaped plastic flakes which can then be further processed.
 - *Agglomeration* is the process of pre-plasticising soft plastic by heating, rapid cooling to solidify the material and finally cutting into small pieces. This is usually carried out in a single machine. The product is coarse, irregular grain, often called crumbs.
- *Further processing techniques*
 - *Extrusion and pelletising.* The process of extrusion is employed to homogenise the reclaimed polymer and produce a material that is subsequently easy to work. The reclaimed polymer pieces are fed into the extruder, are heated to induce plastic behaviour and then forced through a die (see the following section on manufacturing techniques) to form a plastic spaghetti which can then be cooled in a water bath before being pelletised. The pelletisation process is used to reduce the 'spaghetti' to pellets which can then be used for the manufacture of new products.

- Manufacturing techniques**

 - Extrusion.** The extrusion process used for manufacturing new products is similar to that outlined above for the process preceding pelletisation, except that the product is usually in the form of a continuous 'tube' of plastic such as piping or hose. The main components of the extrusion machine are shown in Fig. 2 below. The reclaimed plastic is forced along the heated tube by an archimedes screw and the plastic polymer is shaped around a die. The die is designed to give the required dimensions to the product and can be interchanged.
 - Injection moulding.** The first stage of this manufacturing process is identical to that of extrusion, but then the plastic polymer emerges through a nozzle into a split mould. The quantity of polymer being forced out is carefully controlled, usually by moving the screw forward in the heated barrel. A series of moulds would be used to allow continual production while cooling takes place. See Figure 2 below. This type of production technique is used to produce moulded products such as plates, bowls, buckets, etc.
 - Blow moulding.** Again the spiral screw forces the plasticised polymer through a die. A short piece of tube, or 'parison' is then enclosed between a split die -which is the final shape of the product - and compressed air is used to expand the parison until it fills the mould and achieves its required shape. This manufacturing technique is used for manufacturing closed vessels such as bottles and other containers. See Figure 2 below.
 - Film blowing.** Film blowing is a process used to manufacture such items as garbage bags. It is a technically more complex process than the others described in this brief and requires high quality raw material input. The process involves blowing compressed air into a thin tube of polymer to expand it to the point where it becomes a thin film tube. One end can then be sealed and the bag or sack is formed. Sheet plastic can also be manufactured using a variation of the process described.



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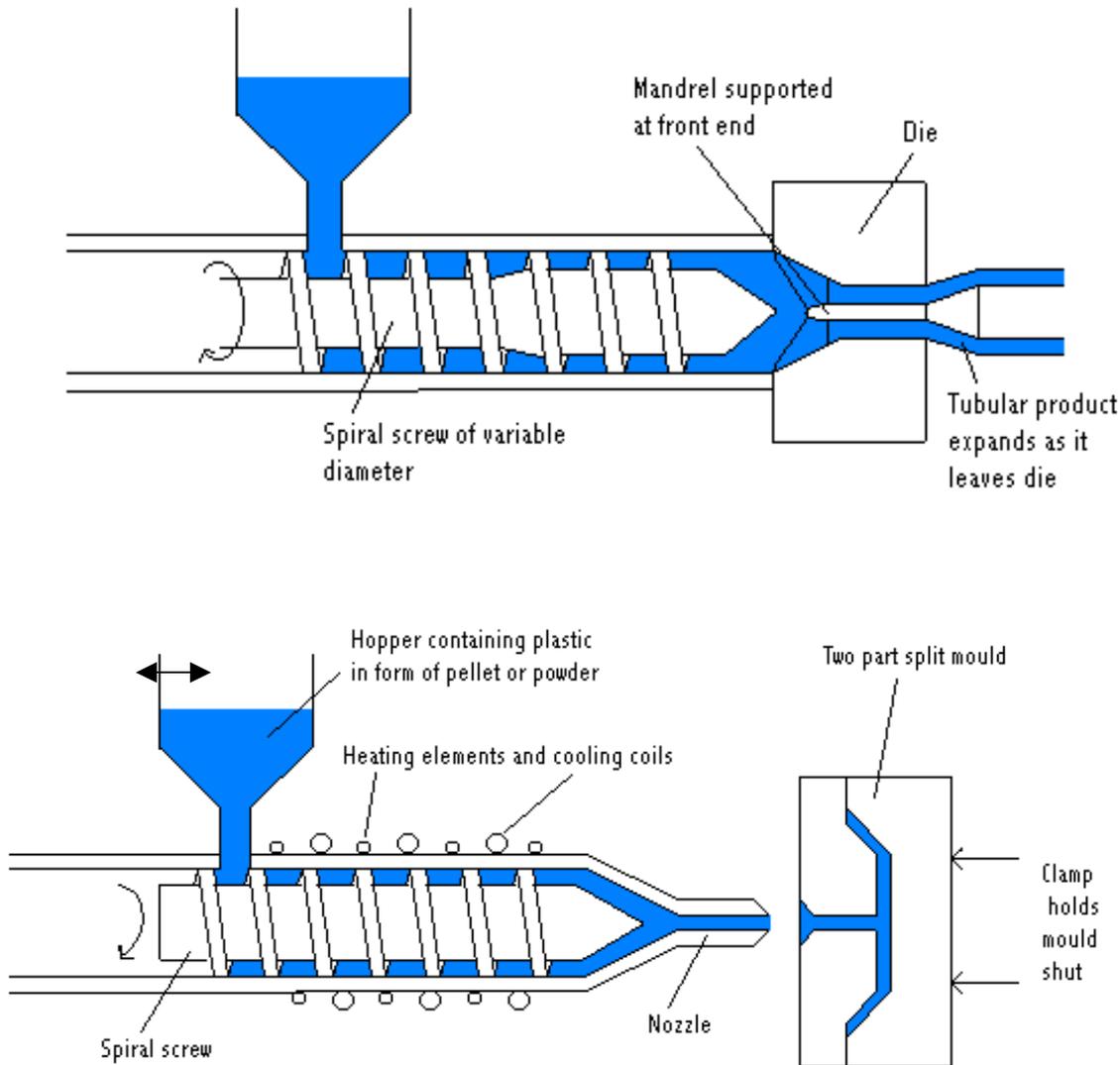


Figure 5: Plastic manufacturing techniques; extrusion (top), blow moulding (middle) and injection moulding (bottom).

Products from plastic

There is an almost limitless range of products that can be produced from plastic. However, the market for recycled plastic products is limited due to the inconsistency of the raw material. Many manufacturers will only incorporate small quantities of well-sorted recycled material in their products whereas others may use a much higher percentage of recycled polymers. Much depends on the quality required.

In developing countries, where standards are often lower and raw materials very expensive, there is a wider scope for use of recycled plastic material. The range of products varies from building materials to shoes, kitchen utensils to office equipment, sewage pipe to beauty aids.

Manufacturers of plastics recycling equipment

Machinery for plastics recycling and processing varies in size and sophistication. In most developing countries it is not possible to find new equipment which can be purchased off-the-shelf and machinery will either have to be imported, manufactured locally, or improvised. Within the informal sector, the latter is usually the most common method of procuring equipment and the level of improvisation is often admirable and ingenious.

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Below are the addresses of some manufacturers and suppliers of plastics recycling equipment (for a more comprehensive list see Vogler [1]):

Brimco Plastic Machinery Pvt. Ltd.
55 Gort Industrial Estate,
Kandirli (West),
Mumbai 400 067,
India.

Produce general equipment for plastics manufacture.

Plasplant Machinery Ltd.
Bordon Trading Estate,
Oakhanger Road,
Bordon, Hants, GU35 9HH.
UK.

Suppliers of used and new equipment for plastics recycling. Many years experience of supplying to developing countries.

References and further reading

1. Vogler, Jon, *Small-scale recycling of plastics*. Intermediate Technology Publications 1984. A book aimed at small-scale plastics recycling in developing countries.
2. Vogler, Jon, *Work from Waste*. Intermediate Technology Publications 1981. A classic text for those recycling wastes to create employment.
3. Lardinois, I., and van de Klundert, A., *Plastic Waste, Option for small-scale resource recovery*. TOOL 1995. A publication in the urban solid waste series. Gives many examples of successful plastics recycling operations in developing countries.
4. Birley, A. W., Heath, R. J., and Scott, M. J. *Plastics Materials*. Blackie, 2nd ed. 1988. Introductory scientific textbook.
5. Harper, Charles A., and others, etc. *Handbook of Plastics and Elastomers*. McGraw-Hill, 1975. Basic data on design, construction and use.
6. Roth, Laszlo. *A Basic Guide to Plastics for Designers, Technicians, and Crafts People*. Prentice-Hall, 1985. Introduction to materials and technology.
7. Sparke, Penny, ed. *The Plastics Age: from Modernity to Post-Modernity*. Victoria and Albert Museum, 1990. A celebration of the usefulness and aesthetics of plastics; well illustrated.
8. "Plastics," *Microsoft® Encarta® 98 Encyclopedia*. © 1993-1997 Microsoft Corporation. Encyclopedia article.

Useful addresses

World Resource Foundation
Heath House
133 High Street, Tonbridge
Kent TN9 1DH
Tel +44 (0)1732 368333
Fax +44 (0)1732 368337
email: wrf@wrf.org.uk
<http://www.wrf.org.uk>

The Warmer Bulletin' published 4 times a year (subscription required)

UNDP / World Bank
Integrated Resource Recovery
Programme,
1818 H. Street NW, Washington DC, USA.
Tel: +1 (202) 477 1254
Fax: +1 (202) 477 1052
Publications on policy and case studies

WASTE Nieuwehaven 201,
2801 VW Gouda, The Netherlands.
Tel: +31 (0)182 522 625
Fax: +31 (0)182 550313
email: office@waste.nl
Consultants in Urban waste management in developing countries.

TNO Plastics and Rubber Research Inst.
PO Box 6031, 2600 JA Delft,
The Netherlands.
Tel: +31 (15) 69 66 21
Fax: +31 (15) 56 63 08
Research into plastics and rubber, advice and training.

Useful addresses

RAPRA Technology Ltd.
 Shawbury, Shrewsbury,
 Shropshire SY4 4NR
 Tel: +44 (0)1939 250 383
 Fax: +44 (0)1939 251 118
 Website: <http://www.rapra.net>
 Technical info centre for rubbers and
 plastics, consulting and analysis services.
 Publish Journal '*Progress in Rubber and
 Plastics technology*' and a publications
 catalogue

Plastics Recycling Foundation,
 1275 K Street NW, Suite 400,
 Washington DC 20005, USA.
 Tel: +1 (202) 371 5337
 Sponsor R&D, Info on technology and
 markets.

Environmental Development Action in the
 Third World,
 Head Office: PO Box 3370, Dakar,
 Senegal.
 Tel: +221 (22) 42 29 / 21 60 27
 Fax: +221 (22) 26 95
 Regional offices in Colombia, Bolivia and
 Zimbabwe. Database, library, publications
 and advice. Quarterly magazine 'African
 Environment'

Internet addresses

<http://www.polymers.com/dotcom/home.html>

This is the polymers and plastics industry site which contains an online magazine, links to
 tutorials and chemistry guides, and links to related sites. Registration is required.

European Centre for Plastics in the
 Environment and Association of Plastics
 Manufacturers in Europe,(APME),
 Avenue E. van Nieuwenhuysse 4, BP3,
 B-1160 Brussels, Belgium
 Tel: +32 (2) 675 32 97
 Fax: +32 (2) 675 39 35
 General info on plastics waste recycling

Appropriate Technology Development
 Association,
 PO Box 311, Gandhi Bhawan,
 Lucknow-226001, U.P.
 India.
 Research Institute - rubber and plastics

CAPS
 Room 8, Maya Building, 678 EDSA, Cubao,
 Quezon City, Metro Manila,
 The Philippines.
 Contact: Mr. Dan Lapid
 Tel: +63 (2) 912 36 08
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 Consultants with on-line enquiries, training, info
 and education.

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