Small Scale Recycling of Plastic Waste

Technical Field:
- ☐ Energy / Environment (E)
- ■ Water / Sanitation (W)
- ☐ Agriculture (A)
- ☐ Foodprocessing (F)
- ☐ Manufacturing (M)

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Dr.-Ing. Heino Vest (1995, revised in 2000)

Materials and articles have always been recycled, particularly when the product was rare or difficult to produce and therefore expensive. In the past the main reasons for recycling was economic. Nowadays, ecological reasons are more important. Since a number of process sequences when producing new products can be saved by recycling, the raw material and energy input as well as the pollutants and residues can be reduced.

The majority of plastics are produced from mineral oil. Since the oil price was relative low over long time periods products made from plastic were and still are very cheap. Especially in the developed countries of the North, but even in developing countries, the local market is flooded with plastic articles. Since plastic was so cheap nobody dared to think of recycling and re-use for a long time. In the meantime the plastic waste has become a nuisance and an environmental hazard as well. The inability of plastic to degrade and to decompose naturally, made the plastic waste everlasting. Today, even in the middle of the bush or remote savannahs plastic containers, bags or toys can be discovered.

In the developed countries plastic recycling became soon necessary to cope with the increasing waste volumes. Still not very economically viable plastic recycling takes place in these countries merely for environmental reasons. In developing countries plastic waste was discovered as valuable raw material for small scale production and income generation. In opposite to the traditional recycling of metals, organic, paper and glass the processes for the recycling of waste plastic are new and commonly not well-known.

General considerations

The value of waste as secondary resource depends on its purity and composition. Normally just one type of material is required for further processing. Since there are a great number of different plastics in use, separating them into the different material components causes many problems. In industrialised countries where a great deal of plastic wastes is generated, the automatic sorting of plastics is very complicated and is not satisfactory as yet. This is basically the reason why these countries are trying to develop techniques (pyrolysis, hydration, gasification, etc.) to split mixed plastic wastes back into their original components and raw materials.

Several experiments and research projects have proven that sorting domestic wastes produces high quality material, when sorted by hand. The ability of the human eye to distinguish between the different materials is still superior to machines. In industrialised countries, where human labour is very expensive, hand sorting is no solution. Machines have

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to handle this task. Labour costs in developing countries, however, are still low, which argues for recycling of used plastics in those countries.
Best suited for sorting and recycling plastics in developing countries are those technologies, that make extensive use of the (comparative) advantage of cheap labour. The secondary raw material obtained by hand sorting is of high quality and offers an excellent basis for producing high quality recycling products by small and medium scale industry.

Recycling of thermoplastics

Thermoplastics (uninterlaced polymers) in particular are easy to recycle with simple technologies. Unlike thermosets and elastomers, they melt again when heated. Because the liquidifying temperatures of the various thermoplastics differ, sorted plastics of one kind or with similar melting properties are needed to obtain a homogenous melt.

Polyethylene (PE) and polypropylene (PP) can be used in a mixture as they have similar liquidifying characteristics. On the other hand, polyvinyl chloride (PVC), another common thermoplastic, cannot be used in a mixture with PE or PP, particularly because of its different material and melting properties. These materials need to be separated.

Since the majority of all plastic waste from households consists of PE, PP and PVC which can be recycled with simple technologies, initial plastic recycling operations in developing countries should primarily make use of these materials. In the following a technique for processing PE/PP-wastes in developing countries is outlined. Figure 1 shows a flow sheet of a simple plastic recycling process.

Sorting of plastics

After receiving the waste from the collectors, an intensive hand sorting with trained personnel has to take place.

The major part of all domestic plastic waste consists of:

- blow formed articles of HDPE (high density PE)
- injection moulded articles of HDPE, PS (polystyrol) and PVC
- extruded pipes or profiles from PVC, PE and PP

called “hard” plastic, and

- film sheets of LDPE (low density PE), PP and few PVC

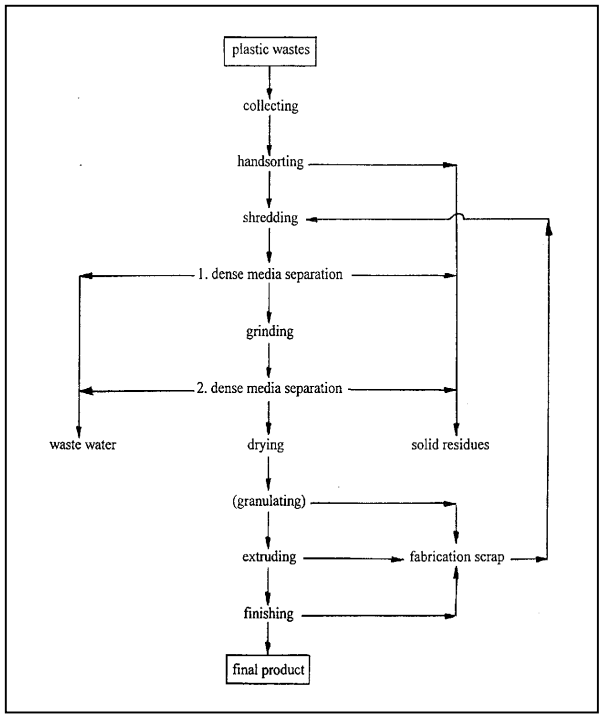

Fig. 1: Plastic recycling process

A first attempt to separate the materials can be done by eye and hand. As many different polymers look identical, considerable skill is needed to tell the difference. The following characteristics may be useful to distinguish between the materials:

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LDPE	Soft, flexible; easy to heat seal; only glass clear if very thin; thick sections are milky white (or coloured).
HDPE	Tough, stiffer than LDPE; even thin film is milky (or coloured).
hard PVC	Hard and tough, mostly coloured; emitting a smell of chloric acid when burned
plasticised PVC	Soft, flexible, rather weak; can be highly transparent; easy bonded to textiles, metals, etc.

If the plastic is dirty cleaning is necessary. The main cleaning steps are:

- Draining of the remaining fluids from containers into prepared collection barrels
- rough cleaning of plastic containers and other pieces of plastic
- removing of paper, plastic or metal stickers
- intensive washing in cold or hot water with addition of detergents or caustic soda.

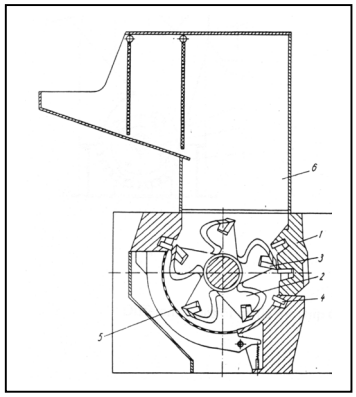
Film bags, sacks and sheeting have to be cleaned thoroughly. Since film has great area for little weight, it can carry more dirt, adhesive labels or tape than hard (solid) scrap. If bags and sacks are processed, residues of the former content may still be left inside. Theses impurities must be removed, which obviously is a time consuming and costly process.

Hard PE/PP can be easily separated from PVC by dense media separation in water. While PE with a density of approx. 900 kg/m^3 floats in water, PVC (and the majority of other plastics) with a density of approx. 1.300 kg/m^3 will sink. If LDPE (density of 0.91-0.92) should be separated from HDPE (density of 0.96), a suitable dense media (density of 0.93-0.94) is obtained by mixing water and alcohol (density: 0.79). In case PP is part of the mixture, too, a separation of PP and LDPE by dense media separation is not very certain because their densities can be very similar.

To assist the separation of the different components or to cut open containers to free possible air contents, a shredder operation prior to the dense media separation is necessary. To improve the sorting process it is advisable to apply a double dense media separation with a fine grinding step in between.

Grinding

Grinding of hard plastic takes place in a grinder/granulator, shredder or cutting mill. Due to the different physical properties of plastics there are a number of slightly modified models in use. Figure 2 shows a standard type of grinder (granulator) for hard plastic.



Cutting mill (granulator)

1) Mill housing
2) Cutting rotor
3) Cutting knife
4) Stator knife
5) Discharge grate
6) Feeding chute

Fig. 2: Grinder/granulator for hard plastic

After grinding and separating the product has to be dried. Later on it is fed either directly or after applying a pelletising step into an extruder to produce the final product.

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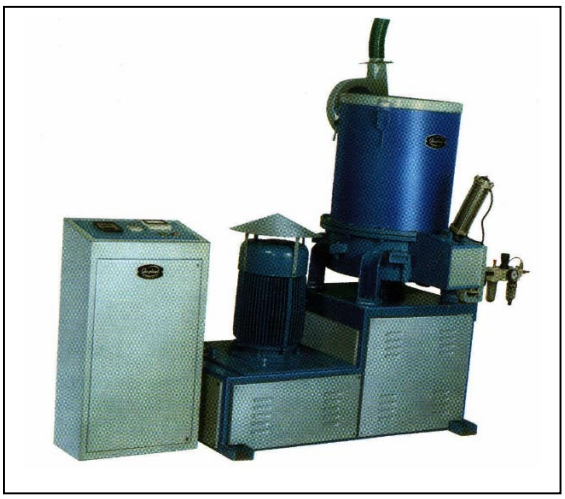

Fig. 3: Agglomerator for plastic film sheets

Agglomeration

Clean film sheet waste is process in an agglomerator. The agglomerator consists of a vertical drum with a set of fast moving blades at the bottom (see figure 3). The agglomerator chops the sheets into thin film flakes. Due to the cutting and friction energy of the process the flakes are heated until they start to melt and form crumbs or agglomerate. This will increase the bulk density of the material which is now fit to be feed directly into the extruder for injection moulding, blow forming or film blowing

Pelletising

For many purposes it is recommended to convert plastic chips or agglomerate into pellets before further processing. During pelletising (re-melting in an extruder and production of “spaghettis” which are sub-sequently chopped into pellets, figure 4), the recycled plastic can be homogenised, blended, degassed, coloured or stabilised.

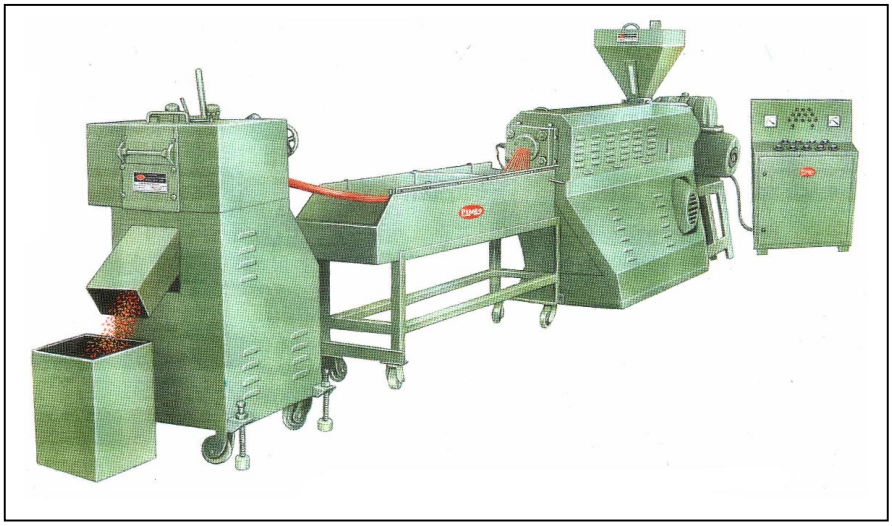

Fig. 4: Pelletiser

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Between extruder and extrusion tool sieves are installed to remove major solid impurities. This is important because problems caused by solid impurities can be very serious when extruding thin-walled products like foils or bags. Extruded thick-walled products like water tubes or profiles are normally less sensitive to enclosed impurities.

Extrusion of pipes or profiles

Chips, agglomerate or pellets from recycled PE and PVC can be used to produce pipes or profiles. Since recycling material is never homogenous tests should be carried out to determine the correct mixture (e.g. of LDPE and HDPE) to achieve a product with the desired physical properties.

Pipe or profile are extruded continuously. The plastic is melted in the extruder and pressed through the extrusion tool. To preserve the desired shape until the plastic has solidified water cooled calibration tools are used. Finally the pipes or profiles are cut to length or are coiled (pipes). Since this technology is quite simple and easy to control, it is an option for small scale production of final products in developing countries. Figure 5 shows the general set-up of a pipe extrusion plant.

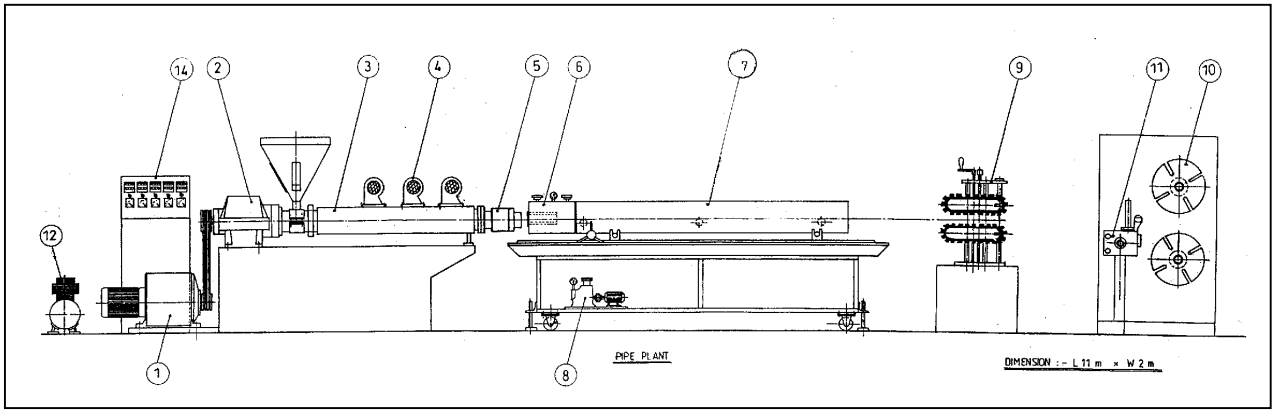

Fig. 5: Set-up of pipe extrusion plant

1)	Eddy current coupling drive
2)	Helical gearbox
3)	Extruder
4)	Blower
5)	Extruder head and pipe die
6)	Vacuum chamber
7)	Water cooling tank
8)	Vacuum pump
9)	Haul off
10)	Coiler
11)	Traverse unit
12)	Compressor
14)	Control panel

Injection moulding

For injection moulding pellets, chips or agglomerate are melted in an extruder. The molten plastic is intermediately stored in a supply chamber at the front of the extruder. In certain intervals the molten material is injected into a mould. After solidifying the produced item is removed from the mould. In the meantime a new supply of molten plastic has been built up, ready for the next injection “shot”.

To operate this process extensive control mechanism are required. Therefore, automatically operating injection moulding

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machines are sophisticated and expensive.

For small scale use in developing countries manual operated injection moulding machines have been developed for example in India and Egypt. Figure 6 shows a simple manual operated injection moulding machine. In this type of device injection moulded items of up to 50 g can be produce. A single worker is able to produce up to 150 pieces in an hour.

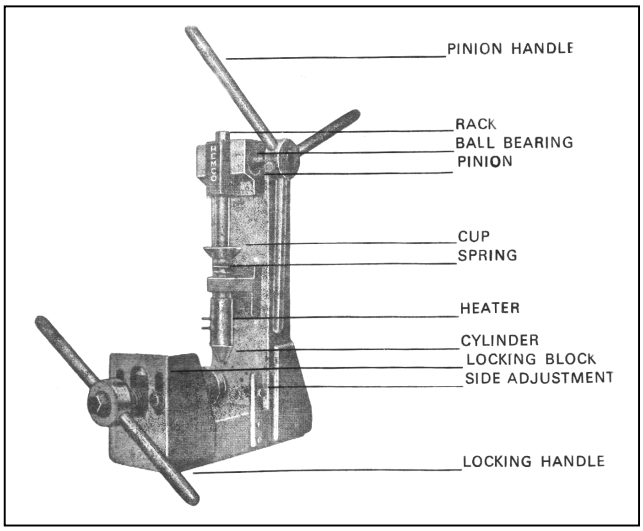

Figure 5: Hand operated injection moulding machine

Ecological aspects of recycling plastics in SMEs in developing countries

Similar to other activities of the production sector, recycling plastics generates residues and may contaminate the environment. It is necessary to offer appropriate solutions which can actually be applied in SME of developing countries. The following critical areas and required measures for environmental protection need mentioning :

collection residues:

- collection containers for unwanted material brought by waste collectors,
- collection barrels for remaining fluids of delivered plastic containers,
- collection containers for rejects from the hand sorting or dense media separations.

waste water treatment: -

pre-treatment of generated waste water (surface water, washing water, contaminated water of dense media separation) by filtration, sedimentation, oil separation and neutralisation.

off-gas filtration:

- collection and filtration of the off-gases from the mills, the drying section and the degassing fumes during extrusion.

The residues, flew dusts and the waste water have to be introduced into the joint waste management system in an orderly way.

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- www.recyclers-info.com (Recyclers Info Germany)
- www.waste.nl (Waste Consultants, Netherlands)

Indian producers of small scale recycling machines:

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- www.dgpwindsor.com (DGP Windsor India Ltd, Mumbai)
- plastic@vsnl.com (Boolani Engineering Cor., Mumbai)
- www.kolsite.com (Kabra Extrusionstechnik Ltd, Mumbai)
- www.pimcomachine.com (PIMCO Machines Private Ltd, Mumbai)
- info@gloplast.com (Glow Industries, Mumbai)
- www.aipma.org (Association of Indian Plastic Manufactorers)

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