

Mechanical waste plastic recycling

Introduction

Plastic has been recognised as the most useful innovation in the 19th century by many scientists for its unique characteristics. However, it has become the biggest environmental hazard in the 20th century when it is disposed as waste. Plastics do not degrade naturally and when they are disposed in an ad hoc manner, it creates numerous environmental problems that can deteriorate the life of flora and fauna.

The production and use of plastics has a range of environmental impacts. Firstly, plastic production requires significant quantities of resources, primarily fossil fuels, both as a raw material and to deliver energy for the manufacturing process. It is estimated that 4% of the world's annual oil production is used as a feedstock for plastic production and an additional 3-4% during manufacture. Due to its low density, plastics take up a large amount of valuable land filling space and obstruct natural and man-made drainage systems creating flash floods mainly in urban areas.

From 1 tonne of plastics we can produce:

400,000 (1litre) soft drink bottles or 120,000 shopping bags

Waste plastic recycling is an option to Separate the waste plastics from other waste as it has a value as a material. Plastics are used in a wide range of applications and some

plastic items, such as food packaging, become waste only a short time after purchase. Other plastic items can be reused many times over.

Types of Plastics

The virgin plastic material is produced using fossil fuel as raw material. According to chemical physics, plastic is defined as a polymer. Polymer is developed by combining a large number of similar chemical units known as monomers.

Depending on the chemical composition and the arrangement of the monomers the characteristics of the polymers vary. Therefore, the types of plastics can be categorised based on their chemical properties.



Who to contact: Project Manager – Solid Waste Management or the Resource Desk at

Practical Action (formerly ITDG)

No 5, Lionel Edirisinghe Mw, Colombo 5, Sri Lanka.

T +94 (11) 2829412 F +94 (11) 2856188 W www.practicalaction.org www.janathakshan.org E srilanka@practicalaction.org.lk

For specific details please contact the Project Officer in the Practical Action:

Hambantota T +94 (11) 4379339 E southern@practicalaction.org.lk



Ampara T +94 (11) 2224932 E eastern@practicalaction.org.lk





Broadly, plastics can be categorised into two types based on their physical and chemical properties Viz:

- **Hard plastics** (relatively large and thick solids such as cans, bowls, etc)
- **Sheet plastics** (thin sheets such as polythene, shopping bags, etc.).

However, based on the chemical properties, there are different types of plastics. In plastic recycling the segregation of the waste plastics into both of these categories are important. The reactions for different chemicals such as acids and physical conditions such as temperature and impact vary with the type of plastic

Table: 1 Things to be composted and excluded from composting bin

Name & Standard Symbol	General Use	Special Features	Identification
High Density Polyethylene  HDPE	Used in packaging of low shelf-life products such as Milk bottles, Vinegar bottles. Detergent bottles Vehicle oil cans Saline bottles	Good chemical and moisture resistance. It is used for packaging many household and industrial chemicals such as detergents and bleach good barrier properties and stiffness	Slightly waxy to the touch; semi-rigid to flexible; does not crack when bent; scratches to some degree; floats in water.
Unpigmented HDPE	Grocery bagssshells, coconut husk, komba etc.	Pigmented HDPE bottles have better stress crack resistance than unpigmented HDPE bottles.	Unpigmented Opaque matte finish (not shiny)
Pigmented	Fats/cooking oils Hazardous material like batteries, bulbs, electronic components, chemicals		Pigmented - Translucent matte finish (not shiny)
Polyvinyl Chloride (PVC)  PVC	Plastic tiles, Pipes, fittings Wire, cable insulation, and synthetic leather products, Pharmaceutical bottles, medical tubes Can be broadly divided into rigid and flexible	excellent chemical resistance, good weather ability, flow characteristics and stable electrical properties	Tough; very smooth surface; forms opaque white line when bent; semi-rigid; scratches easily; sinks in water, bottles have seams Clear bottles sometimes have faint blue tint; bottom has blow-moulding smile.

Name & Standard Symbol	General Use	Special Features	Identification
<p>Low Density Polyethylene (LDPE).</p> 	<p>Flexible film bags for dry cleaning, bread, produce, trash, etc.</p> <p>Rigid items such as food storage containers, squeezable bottles and flexible lids</p>	<p>Ease of processing, strength, toughness, flexibility, ease of sealing, barrier to moisture.</p> <p>Used predominately in film applications due to its toughness, flexibility and relative transparency, making it popular for use in applications where heat sealing is necessary.</p>	<p>Slightly waxy to the touch; flexible; stretches before tearing when pulled; easily scratched; floats in water. Can be nearly transparent (e.g., dry cleaning bags) or opaque: can be coloured; low to high gloss.</p>
<p>Polypropylene (PP)</p> 	<p>yogurt containers and margarine tubs, medicine bottles, Battery cases</p>	<p>Strength, toughness, resistance to heat, chemicals, grease and oil, versatile, barrier to moisture.</p>	<p>Smooth surfaces; semi-rigid; tough; cannot be scratched; floats in water</p> <p>Transparent, translucent, or opaque; clear or coloured; can have shiny or low gloss finish.</p>
<p>Polystyrene (PS).</p> 	<p>Heat resistant containers, Disposable lunch boxes, foam packing, foam plates, cups, utensils</p>	<p>Lightweight; heat resistant; buoyant, relatively low melting point</p>	<p>Smooth surface; cracks easily when bent; lightweight and fluffy; easily scratched; floats in water. Opaque only; smooth to grainy finish; foamed, thick walled</p>
	<p>Depends on the product</p>	<p>Use of this code indicates that the package in question is made with a resin other than the six listed above, or is made of more than one resin listed above, and used in a multi-layer combination.</p>	<p>Varies on the product</p>

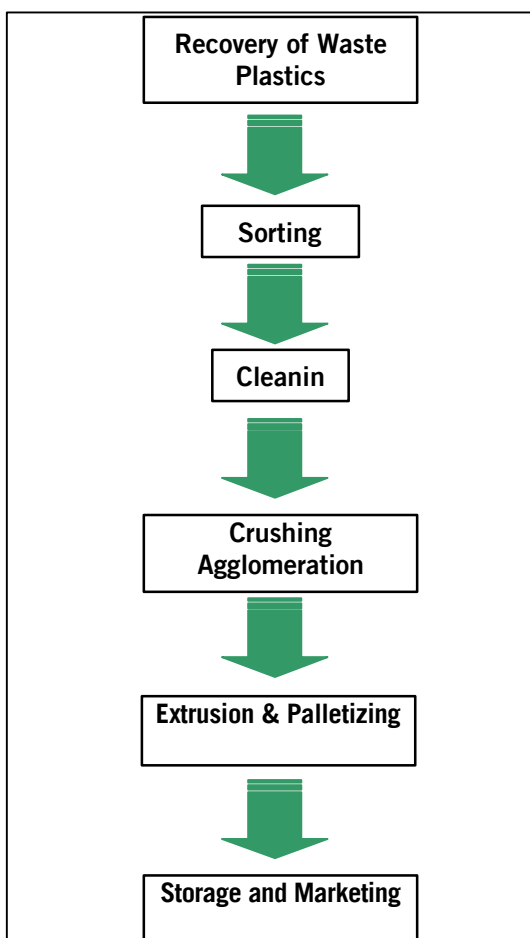
Recycling of Plastics

Recycling of plastics will definitely reduce the waste material at waste disposal while reducing the piling up of plastic virgin material on the earth. At the same time it will reduce the energy and water consumption and emission of toxic gases and chemicals in the virgin material production process. When all these factors are taken into account the overall impact of waste plastic recycling would be very high.

In plastic recycling, the end product can be replaced for virgin material and will generate the above mentioned enviro-economic benefits. Plastic recycling can be done in two ways namely, mechanical recycling and chemical or feedstock recycling.

Chemical recycling

Chemical recycling is the breaking down of the plastic polymers again into monomers and rearranging them to produce new material using different technologies. Chemical recycling is very capital intensive and needs large quantities of plastics to make it a financially viable process.



Mechanical recycling

Consists of melting the plastics under controlled conditions, reshaping, shredding and granulating the waste plastics. Simple and comparatively low cost technologies can be used in the mechanical recycling process and it is this process which is explained in this brief.

Steps in Mechanical Recycling

The steps in mechanical waste plastic recycling are shown in the flow chart given below.

Recovery of Plastic Material

In the normal waste stream the plastics are mixed with other waste. This hinders the extraction of plastics for recycling purposes. The plastics need to be recovered from the main waste stream. It is highly desirable to recover plastics at their source. Promotion of source separation of waste would be beneficial at this point. Collection systems are also important in the recovery stage as the lack of waste material would hinder the continuation of the process. It is advisable that a target group is identified and their awareness be raised on source separation and plastic recycling prior to initiating plastic recycling.

Sorting

Sorting needs to be done based on the physical and chemical properties of the plastics. Hand-sorting can be done by skilled or unskilled labour. For unskilled labourers, the skill of identifying plastics and polythene can be learned within a very short period of time. Hand sorting can be done based on the physical and chemical properties of the plastics.

- First the waste plastics needs to be sorted into two broad categories as plastic (cans, large pieces, boxes, etc.) and polythene (sheet/film types).
- Each category needs to be sorted into other sub-types based on their chemical properties (as listed in the table above). Identification of polythene and plastic types, and segregation into colours are helpful to maintain final quality. The chemical properties needs to be identified in the following ways:



- **The standard symbol**

in most plastic products the relevant standard symbol is printed/embossed

- **Flexibility**

e.g.: HDPE plastics are relatively flexible and without breaking

- **Sound**

The sound created when crushing film plastics vary with the type. For e.g., crushing of the HDPE films gives a unique sound (like the sound emitted when crushing a normal grocery bag). Such identification can be done with little practice.

- **Reaction to fire**

e.g.: PVC burns with a greenish blue colour flame without dropping

- **Floating in water**

- **Some materials float on water while some sink**

However, with little experience, even a lay person can identify the type of plastic very quickly by its look and feel.

Cleaning of Plastics

This is the most important stage in the mechanical waste plastic recycling process. The value of the recycled plastic relies greatly on its purity. Even small dust particles can reduce the quality of the material drastically as it will disturb the polymer arrangement and later the quality of the final product. Therefore, thorough washing of the plastic material and drying should be done prior to processing. In washing, a diluted detergent can be used and precautions should be taken to remove the detergent from the material on completion of the process. Oil contaminants should be removed using an appropriate solvent, followed by a detergent and water.

Maintaining a clean working environment is an important aspect of the process. Maximum care should be taken to prevent sand and dust coming into the processing plant. Dust and sand particles can easily come in contact with the recycled plastic pellets which reduces the quality of plastic products. The behaviour of the workers in the recycling plant

should be adjusted accordingly such as to maintain a clean work area, for example be wearing clean shoes, etc. A considerable quantity of water will be required for the washing of raw material (waste plastics). Therefore, water treatment and reusing is important to reduce the cost of production and environmental pollution. Moisture in the raw material should be removed prior to the processing of plastics and therefore, reserving area for drying is equally important.

Crushing/Shredding

The large particles of plastic need to be broken down into small pieces to reduce storage and transportation space requirement. Such broken down HDPE, PP, and LDPE plastics can be sold as raw material for plastic production without any further processing. On the other hand, it can be re-extruded (the process is explained below) to produce pellets for plastic manufacturing. For PETE crushing can also be done to reduce the storage space requirement and easy transportation for further processing. A crusher should be used for this purpose and the resultant broken pieces of plastics should be the size of 2 – 0.5 cm. It is important to prevent mixing of plastic types to maintain the quality and value of the plastic. Mixed crushed plastics can be used only for low value and low quality products such as junction boxes used in electrical work or plastic lumbers.

The crusher should comprise of a rotating set of blades, feeding hopper, and motor. The size of the feeder depends on the maximum size of plastic that needs to be crushed. A cross section of a crusher is shown below. This size of crusher can be fabricated for a cost of Rs. 250,000/- in Sri Lanka. Operating a crusher is easy and the sorted and cleaned plastics can be fed into the feeding hopper manually and the crushed material should be collected and stored to prevent contamination with sand, dust, and moisture.

Note:

The operator of the crusher and helpers should wear ear plugs to protect their ears as the crusher creates a high noise level. Exposure to such noise levels over a long period can create hearing impairments. It is also advisable to use gloves when handling plastics.



Agglomeration

The term 'agglomeration' itself provides an idea of forming a crumb out of smaller material. Agglomeration is done for film plastics (polythene) instead of crushing. Film plastics cannot be crushed due to its properties. Agglomeration can be performed on LDPE and PP type film plastics. An equipment call the "Agglomerator" is used for agglomeration.

The Agglomerator is simply a metal drum in which a set of blades are rotating at high rpm (rotations per minute). When the film plastics are fed into the agglomerator it cuts into small pieces by the blades inside. Consequently the heat generated due to the high rotation speed, it makes the pieces of film partially melt and bind into a small crumb. This crumb can be fed to the extruder (please refer section below) easily to ensure smooth functioning in extrusion.

Operating of an agglomerator should be done with caution. First, a small quantity of film plastics (about 3 kg) needs to be put in and machine switched on. Then feeding should be done gradually until the drum filled up to 2/3rds of its capacity. The first batch needs more time to get agglomerated as the drum gets heated slowly. In a 100Kg capacity agglomerate the first batch takes 45 minutes for processing, while the following batches take only 25 minutes. The agglomerated film plastics (polythene) should be taken out quickly and allowed cool. The optimum time of agglomeration is when approximately 50% of the particles are in crumbs with 0.5 – 1cm diameter. Over agglomeration (long time in agglomerator) can melt the films too much and can result in pieces of film binding into larger particles. In addition, the rotation of the blades can be disrupted due to over-molten polythene blocking the rotating shafts. Over melting will also make manual handling of the material difficult due to high heat and stickiness of the material.

Note:

Agglomeration can be performed only with LDPE and PP films. To agglomerate HDPE films, higher temperatures should be achieved within the agglomerator if not the films may block the rotating blades. Under high temperatures

LDPE and PP film cannot be agglomerated as the melting points of these plastics are lower than that of HDPE. Therefore, a special agglomerator should be designed to agglomerate HDPE with heat elements and insulators.



Extruding

Extruding is a mechanism used to obtain plastic material in a required shape and size. In recycling, the plastic pellets are the most common final product obtained through extruding. An extruder is used in this process. An Extruder is simply a screw rotating in a zone which is heated under controlled conditions. The Thermoplastics (includes HDPE, LDPE and PP) will melt under specific temperatures and can be remoulded into a required shape. Extruding can be done either to produce plastic pellets (used as raw material in plastic goods production) or to produce plastic goods. In the recycling process of waste plastics the final product in extruding is plastic pellets.

An Extruder machine contains following components:

- Motor,
- Screw,
- Heating elements (1500W),
- Feeding hopper,
- Control panel,
- Die head with sieving net,

Generally the motor used in the extruding machine is 7.5 HP x 1440 rpm motor. The motor rotates the screw inside the extruder which is mounted on a horizontal barrel. There are three main areas in the extruder - feeding zone, compression zone and metering zone - as depicted in the diagrams below. A feeding hopper is fixed in the feeding zone through which the crushed plastics or polythene crumb is fed. In the compression zone the plastic material is melted and compressed.

In the metering zone the compressed melted plastics is pressed through a sieving mesh and die head. A 0.5mm² Sieving mesh is fixed before the die head to extract any sand, dust and other particles from the recycled pellets. The

number of strands extruded is equal to the number of holes on the die head.

Within the extruder there are six 1000W bend heating elements. Five of them are mounted around the screw and one is located on the die head. Based on the heating pattern there are four heating zones. Zone 1 is located at the starting point of compression zone and the 4th zone is the die head. Each zone has "J type" heat sensors. With the control panel the temperatures at different zones are maintained at required levels by coarse and fine adjustments. The required levels of temperatures in each zone (in Co) vary with the type of plastics, as mentioned in the table below. The temperature of each zone can be read in digital screens.

Material	Zone 1 C°	Zone 2 C°	Zone 3 C°	Zone 4 (Die head) C°
PP	140 – 160	160 – 180	180 – 200	170 – 180
LDPE	170 – 190	190 – 210	210 – 230	180 – 200
High Impact PS	–	200 – 210	210 – 220	180 – 200
HDPE	220 – 240	240 – 260	260 – 280	210 – 230

When the extruder machine is operated melted plastic strands will come out from the die head and pass through a cooling tank and then through the pelletizer. The extruded plastic strands are in semi-liquid form. They should be cooled to make them hard. Therefore, the extruded stands are sent through a water tank to stabilize them. The length of the water tank should be about 10 feet. The Pelletizer is a rotating blade by which the stands are cut into small pieces (pellets). The length of the pellets can be changed by adjusting the speed of the motor which is done by changing the pulleys.

Required facilities

Three phase electricity

The extruder and crusher machines require 3 phase electricity to operate.

Water Supply

Water is required for cleaning waste plastics, cooling the extruder machine parts and cooling the extruded plastic strands. The water used in cooling the tank and as coolant in the extruder machine needs to cool. It can then be reused. A simplified cooling tower can be used to reuse this water. A simple water treatment unit can be used to reuse water using in cleaning.

Storage facilities

Storage facilities are required to store waste plastics, cleaned plastics and recycled plastics. To ensure continuous operations the continuous supply of raw material is important and storage space should be available in order to store different types of waste plastics in adequate quantities. During rainy periods the drying of washed waste plastic will be a problem. Therefore, storage facilities should

be available to store standby stocks of cleaned and dried waste plastic material. After production the products also need to be stored before marketing. In this case, special containers are required to store recycled plastics to protect them from contamination, moisture and pests.

Safety equipment

Safety should be a prime concern in plastic recycling as in any other industry. The workers in the factory should have adequate protection in handling material and operating machines. Gloves should use in handling material all the time. Heat resistant gloves are required for the handling of agglomerated film plastics and extruded plastics. Ear plugs and ear protectors should be used in crushing and agglomeration areas to protect ears from high noise levels. Goggles should use when feeding material into crushers, the agglomerator and the extruder. Masks with gas filters should be worn when working at the agglomerator, extruder and when cleaning waste plastics. It is recommended that all the workers should wear protective boots when working in the factory.

Toolkits

Three separate toolkits are needed with basic tools for the agglomerator, extruder and crusher.

Points to Consider

- **Source Separation** – Source separation of waste will ease the process of recycling and it will increase the rate of recycling. Source separation will take away the labour costs and reduce the cleaning costs involved in plastic recovery from mixed waste and it will in turn increase the economic viability of the recycling industry. On the other hand, mixed waste will increase the contamination of recyclables and consequently the rate of recycling. Community participation is heavily required at this stage.
- **Cleanliness** – Cleanliness throughout the entire recycling process will increase the quality and the value

of the recycled products. Cleanliness should be maintained in source separation, transportation, processing, storage and other operations.

- **Minimum processing** – Minimum processing in plastic recycling will reduce the cost of production. It is recommended not to extrude crushed/shredded plastics as the crushed material can directly replace pellets in plastic production. Minimum processing will increase the recyclability of the material.
- **Safe Storage** – The waste plastics should be stored properly ensuring that it will not accumulate water. It must not be allowed to be in direct contacting with rain. Water should be stored appropriately as accumulated water can be a breeding ground for mosquitoes, especially those which spread dengue fever. It also increases the possibility of contamination of waste plastics. Keep in mind that rats can damage plastics severely.
- **Promote reusing over recycling** – People will tend to send materials that can be reused for recycling. This should be prevented and reuse should be promoted as much as possible. Give examples by reusing. Lead by example, reuse material at the recycling site.

Conclusion

Plastic recycling is a newly emerging industry and it has already been identified that there is a good potential to this sector.

The recycled plastics can be shared with both small and large scale industries to produce new plastic items. Further, recycled plastics can replace pure material being imported from other countries and this will create many job opportunities amongst the people.

Recycling of plastics therefore, is a resource that one could obtain maximum benefit out of it and helps minimise environmental degradation. Therefore, plastic material should not be disposed or buried without a proper disposal mechanism.