Overview of Plastics

Indian Centre for Plastics in the Environment

www.icpe.in

Chapter 1: What are Plastics?

Plastics are macromolecules, formed by Polymerization and having the ability to be shaped by the application of reasonable amount of heat and pressure or some other form of force.

Polymerization is the process by which individual units of similar or different molecules ("mers") combine together by chemical reactions to form large or macromolecules in the form of long chain structures, having altogether different properties than those of starting molecules ("mers"). Several hundreds, and even thousands of "mers" combine together to form the macromolecules, or what we call, Polymers.

Depending upon their nature and properties, the polymers are classified as **Plastics, Rubbers or Elastomers and Fibres.**

If the polymer chains are very flexible, the inter molecular forces of attraction low and the chains do not fit to a regular lattice structure easily, the material will tend to retract upon when external tension is released. This is the state typical for a Rubber or Elastomer. In the other extreme, if the polymer chains are inherently rigid, the intermolecular forces intense and the molecules fit readily into a crystal lattice, then the crystallinity once induced, will tend to be permanent. Such a material would be a typical Fibre. In the intermediate case, when the intermolecular forces of attractions are neither too high nor too low, the polymer is called Plastic. Generally speaking, a plastic material should posses sufficient rigidity, dimensional stability and mechanical strength at room temperature to serve as a useful household article, gadget or structural part and still be of such a character that it may be molded to shape by the application of reasonable temperature and pressure.

There are no intrinsic differences among Rubbers, Plastics and Fibres. Any apparent difference is a matter of degree.

Polymers can be classified into two categories : -

Natural Polymers and Synthetic Polymers.
Examples of Natural Polymer: Starch, Natural Rubber, Gelatin, Protein, Shellac, Cellulose etc.

Examples of Synthetic Polymers :
Polyethylenes - Low Density Polyethylene, High Density polyethylene, Linear Low Density Polyethylene, Polypropylene, Polystyrene, Styrene Butadiene Rubber(SBR), Nylon etc.

Polymers may also be sub classified into two categories:
Organic Polymers
Inorganic Polymers

In Organic Polymers, the main constituent is Carbon Atom along with any one or more of the following constituents: Hydrogen, Oxygen, Nitroge,Halogens etc.
Examples : Polyethylene, Polyvinyl Chloride, Nylon etc.

In inorganic Polymers the main constituents are other than carbon, like Silicon, Boron etc.
Examples : Polysilanes, Polysiloxanes etc.

Types of Plastics:

There are mainly two types of Plastics:
Thermoplastics and Thermosetting Plastics

Thermoplastics are those, which once shaped or formed, can be softened by the application of heat and can be reshaped repeatedly, till it looses its property.
Example: Polyethylene, Polypropylene, Nylon , Polycarbonate etc.

Applications are : Polyethylene Buckets, Polystyrene Cups, Nylon ropes etc.

Thermosetting Plastics are those, which once shaped or formed, cannot be softened by the application of heat. Excess heat will char the material.
Example : Phenol formaldehyde, Urea Formaldehyde, Melamine Formaldehyde, Thermosetting Polyester etc. Applications are - Backelite Electrical switches, formica / sermica table tops, melamine Cutlery etc.

Sources of Plastics

majority of the most commonly used plastics(commodity plastics) are derived from these chemicals :

1. Ethylene

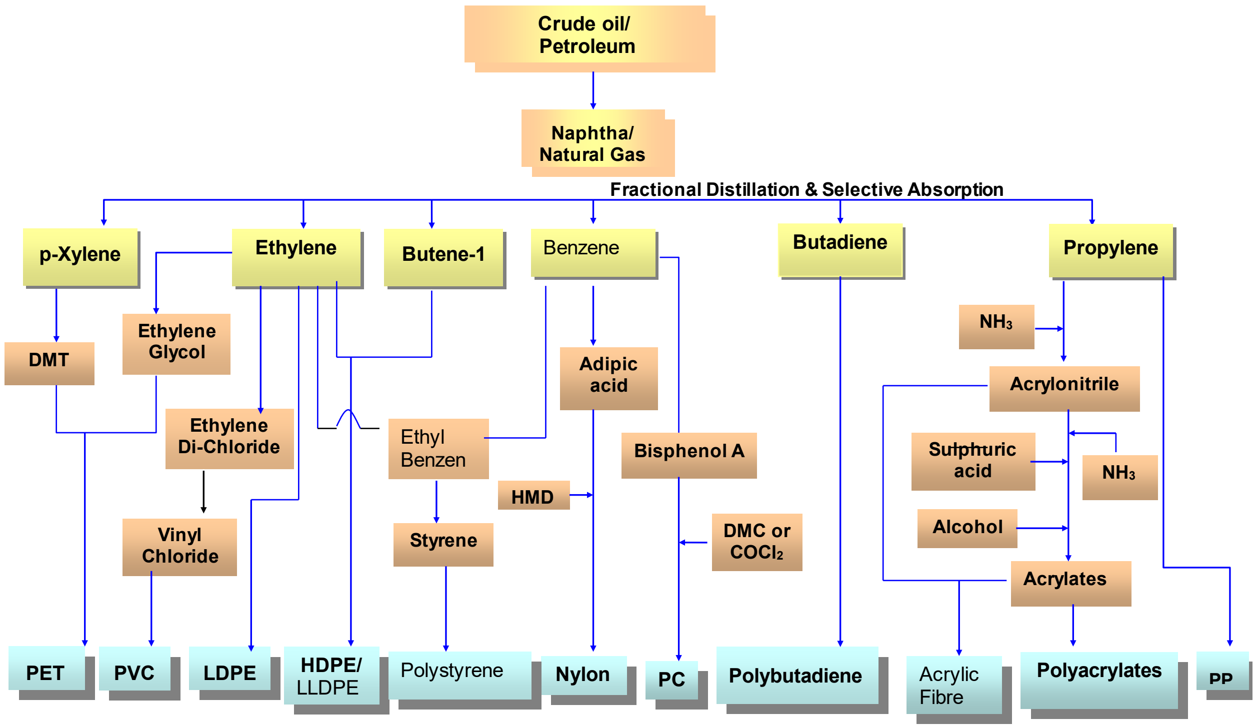
2. Propylene

3. Butadiene

4. Benzene

These chemicals are intern derived from Natha obtained during petroleum refining process or from Natural Gas,after procesing.

A flow chat of the sources of commodity plastics and some other important plastics, rubbers and fibre materials is attached



DMC-Dimethyl Carbonate
PC- Polycarbonate
LLDPE - Linear Low Density Polyethylene
HMD- Haxamethylene Diamine
PVC Polyvinyl Chloride
PP - Polypropylene
LDPE- Low Density Polyethylene
PET- Polyester
DMT- Dimethyl Terephthalate
HDPE – High Density Polyethylene

Why Plastics - The Importance of Plastics in Modern Society

Plastic have moulded the modern world and transformed the quality of life. There is no human activity where plastics do not play a key role from clothing to shelter, from transportation to communication and from entertainment to health care. Plastics, because of its many attractive properties, such as lightweight, high strength and ease of processing, meet a large share of the materials needs of man, and that too at a comparatively lesser cost and causing lesser environmental implications. From practically zero during the beginning of the 20th century, human kind today consumes more than 150 million tons of plastics per year.

Plastics possess a unique combination of properties. Plastics can be super tough, rigid as well as flexible, transparent as well as opaque and can allow permeation or act as a barrier material.

Growing population and material consumption has put severe pressure on our natural resources and fragile eco-systems. The material needs of our population are growing and plastics offer a cost effective alternative.

Plastics are employed in myriad applications where they actually conserve natural resources. For example, asceptic packaging of food in barrier packaging films will save refrigeration cost and saving capital and energy. Edible oils and milk are packaged in flexible packages eliminating the use of tin and glass containers. Rigid HDPE barrels are used for bulk chemical storage instead of steel drums. Apart from conserving natural resources, use of plastics in these applications saves transportation fuel as plastics are substantially lighter than tin, glass or steel.

Safe drinking water in PET bottles is a very common sight now-a-days. They provide confidence to consumer on the quality of water and help reduce water-borne diseases. Advance polymeric membranes help purify water from viruses and bacteria. They also provide potable drinking water from sea and blackish water through a process of desalination.

The fact that plastics are made from hydrocarbons derived from petroleum, which is non-renewable, has raised questions concerning its sustainability. Nevertheless, the consumption of petroleum hydrocarbon for the production of plastics is less than 5%, the balance being consumed as fuels and energy source. Consequently, the concerns about sustainability of plastic material is somewhat exaggerated. On the contrary, processing of many natural materials (glass, paper, wood, metals) consume far more energy and thus lead to greater consumption of fossil fuels. Additionally, research and development work currently in progress globally will provide future opportunities to make some of the plastics from biomass and other renewable sources. Thus, plastic manufacture will become even more sustainable in the years to come. It is fair to say that plastics replace several naturals, which are either scarce, consume more energy for processing or cause damage to the eco-system during their production.
Thus use of plastics makes positive contribution to the sustainability of earths resources.

Another issue that is often discussed is whether because of their non-biodegradability, plastics will cause damage to our eco-system

The signature of all natural materials made by biological process is that they are biodegradable and bio-assimilable. The long life and desirability of plastics, which have made them, a material of choice for many applications is seemingly a disadvantage when it comes to their disposal. However, when handled properly, plastics do little damage to our environment. Plastics have the advantage that they can be easily reprocessed and recycled.

Plastics offer the unique advantage that one can recover the fuel value contained in the hydrocarbon polymer after its use. Plastics can also be made environmentally degradable, especially for packaging applications. There are expectations that in the near future plastics will be made even biodegradable and compostable so that waste plastics can be handled the same way as wet food waste and agricultural waste. The overall eco-friendliness of plastics becomes apparent when one evaluates the total "life cycle", namely, an analysis of raw materials, energy, effluents, methods of disposal etc. of a material from its origin to its final disposal.

History of (Synthetic) Plastics

In 1862, Alexander parkes in Britain modified cellulose nitrate with camphor to produce the first man made plastic material - Celluloid.

The First Thermosetting Plastic material was invented in 1907 when Leo Bakeland, USA, made Phenol Formaldehyde(Backelite)

The History of Plastics

	Events	Applications
1862	Birth of Plastics - Alexander Parks	
1865	CN + Camphor (Plasticizer)	
1868	Commercial Success - Hyatt Brother (Celluloid)	Billiard Balls Spectacle Frames
1907	Phenol Formaldehyde - Leo Bakeland (bakelite) - First Truly Synthetic Plastic	Electrical Fittings Telephone Sets
1919	Casein	Buttons, Knitting Needles
1922	Macromolecule Concept - Hermann Standinger	
1924	Cellulose Acetate	Coating of Fabrics Used for Aircraft Wings
1927	PVC	Flexible Pipes, Wall Covering
1929	UF	Lighting fixtures
1931	Acrylic	Aircraft Canopy, Housewares
1937	Polystyrene	Tablewares
1939	MF PVDC	Cutlery
1939	Nylon - Carothers	Gears
1940	LDPE	HF Telecom Cables
1942	Unsaturated polyesters	Boat hulls and radar
1947	Epoxy Resins	Coatings
1948	ABS	Luggage
1954	Poly Urethane Foam	Foam Cushions
1956	Poly Acetal	Automotive
1956	HDPE	B/M Containers
1957	PP PC	Safety Helmets Transparent Sheet
1964	PPO	Industrial Comp
1970	PET	Electrical Comp
1973	LLDPE	Film in blend with LDPE
1991	Metallocene LLDPE Metallocene HDPE, Elastomers & Plastomers	High Performance /High Clarity Film, Injection and Blow Moulding Products
1993	Metallocene PP Syndiotactic PP Catalloy PP	High Performance / High Clarity Film, Injection and Blow Moulding Products.

Chapter 2: Resource Conservation

Resource conservation is the planned management of natural resources to optimise their utility, efficient usage in their original application, reuse, and recycling.

The aim is to minimise the energy consumed and wastes generated in all stages, from production through the life of the product right up to final disposal.

Properties of Plastics

Plastics are derived from natural resources - petroleum oil and natural gas. Plastic products have a fascinating, bewildering and even bizarre range of properties. They can be rigid, as well as flexible, they can provide retention (i.e. act as barrier) as well as selective tailor-made permeation, they are excellent insulators, but can also be made conductive. They can have memory and can be even optically active; they can be 'Instant' structural adhesives. They have high impact strength; they can have high abrasion and scratch resistance. The ease with which plastics can be processed into a variety of articles of every day use is truly remarkable, and has no parallel. Plastics are hallmark of conservation of energy compared to steel and glass, and have additional advantage of recycling.

Saving of our Forests

Natural Resources The wood used for furniture like tables & chairs, doors & windows, packing of tea, mangoes, grapes, apples etc, wooden crates for aerated water bottles, are now being replaced by plastics. An estimate indicates that if only 2% of the wooden boxes are changed over to plastic we would save 1,200 ha of forests involving 1,10,000 trees.Wooden plate & frame-filters used in chemical & allied industries can be completely replaced by plastic.

Yearly consumption of Plastic chairs and Plastic Crates in India 2000 AD was about 50 million and 15 million, respectively. At this rate saving over a period of 10 years would be close to 20 million trees.

Cork used in a variety of applications like caps of aerated water bottles can be replaced by plastic. The nursery for forestry also benefit from plastic films.

Cotton and jute, in most applications can be replaced in a very effective and profitable way by woven sacks made of high density polyethylene or polypropylene. A lot of wastage associated with use of packaging jute bags for cement, fertilizer, pesticides, etc can be avoided by using waterproof plastic sacks.

Plastics in Agriculture

Plastics are used in a host of applications in the field of agriculture e.g. plastic pipes in sprinkler irrigation systems, plastic films in green houses, plastic nets in horticulture, heavy duty flexible membrane lines for canal lining which prevents water seepage- (It has been reported that 0.75 mm PVC sheet provides a million times more permeation resistance than 1m of clay as canal, dam and lake liner). Super absorbent polymers in our arid, and semi-arid zones, all help substantially to conserve water - a precious natural resource, to a great extent.

Plastics for Fishing Industries

Fishing nets made of plastics have a long life. Even ropes are made entirely of polypropylene or polyamide, and these have a long life compared to other conventional ropes. FRP boats have made a definite impact in the fishing industry.

Plastics in Desalination of Sea & Brackish water

Polymeric membranes have made major impact in recent years in desalination of sea and brackish water. We now have large-scale plants providing drinking water to the public. Here the net consumption of energy, compared to multi-stage evaporator based system is very lower, and hence saving of energy is substantial. The availability of potable water in a number of arid and semi-arid areas in Rajasthan, Gujarat, Tamil Nadu, Andhra Pradesh, etc. is serious problem of society, and polymers' contribution in tackling the issue is very great.

Plastics in Cryogenic Operations

Many cryogenic operations, for e.g. pure or enriched nitrogen and oxygen, can now be based on polymeric membrane separations or hybrid systems resulting in enormous power savings.

Enriched oxygen can be supplied for industrial purposes like boilers, klins, furnaces etc. resulting in saving of substantial energy. Even in hospitals enriched oxygen is being supplied through membrane based modules.

Saving of Energy

Energy consumed on a functional basis, by a unit amount of plastic, (polymers like LDPE/HDPE/PP/PS) which have densities which is about one-seventh of that of steel, is very much lower than that required for steel, and aluminum (aluminum requires 13 times its weight in energy to produce 1 lb from ore, steel six times). Plastic do not need frequent painting. This is another saving. In many applications steel and aluminum can be safely and profitably replaced by plastic at lower cost and in saving Capital Investment, which we are always in short supply.

Plastics (HDPE) pipes can be conveniently and advantageously used for transportation of industrial gas, effluent pipelines where liquids may be acidic and corrosive, and avoid the aberration that we will have through the leakage of metal pipes.

Frictional losses in plastic pipes & fittings as a whole and pipes for sprinkler irrigation systems are less, which adds and to substantial saving of energy.

Replacement of asbestos and corrugated iron sheets by transparent/ translucent FRP sheets that provide daylight as well can result in saving electricity.

Another welcome change is replacement of blades of fans (ceiling, table & pedestal) with plastic based material, as it will save substantial energy.

Polymeric additives make fuels and engines more efficient in internal combustion engines and this helps in conserving scarce petroleum products

According to American sources only 4% of United States energy consumption is actually used to produce plastic raw materials including feedstocks. It takes less energy to covert plastics from a raw material into a finished product as compared to other products. E.G.

Plastic bags require only one-third of the energy required to make similar paper bags.

Foamed polystyrene containers take only 70% of the energy to make paperboard containers.

Fifty-three billion kilo watt-hours of electricity are saved annually by improvements in major appliances. Energy efficiency has been made possible by plastic applications.

Plastics being strong, yet light weight, require less material to make a certain package compared to other materials, resulting in saving of energy, eg

(a) Plastic film wrappers now used for large diaper packs need only 50% by volume, than previous packs.

(b) In the US 4 million students a day drink their milk or juice in flexible pouches which reduce weight by 80% and volume by 70% as compared to traditional cartons, reducing storage and trash disposal costs.

(c) Plastic grocery bags are lighter and create upto 80% less waste by volume than paper sacks, and are recyclable.

Because of durability, flexibility and increased life span, plastic bottles etc can be reused several times, eg. Packings for laundry products etc.

The lightweight nature of plastics helps to reduce transportation costs substantially. A truck that could carry only 5,00,000/- paper grocery bags can transport 2.8 million plastic grocery bags.

Container breaches, denting and product loss on the package lines during handling are substantially reduced because of plastics' superior resistant to breakage and denting.

Increased productivity by about 20-30% and reduced capital expenditure to the extent of 50% can be achieved due to highly superior manufacturing efficiency of plastics.

Corrosion resistance will increase the life of major appliances by about 40% resulting in substantial savings.

The automotive industries choose plastics for their durability, corrosion resistance, ease of colouring and finishing, resiliency, energy efficiency and lightweight, which reduces handling and transportation costs. Ease of fabrication and outstanding thermal insulation, reducing energy consumption are the prime considerations for major appliances manufactures for using plastic.

Aesthetic appearance, durability, ease of installation and energy efficiency are the prime factors for the building and construction industries to use plastic.

Some of the experiences of the US plastic industries as reported are: **Less waste** - Plastics often help product manufactures to do more with less material, which is known as 'resources efficiency' or 'source reduction'. Source reduction is the process by which a package or product is made using fewer resources, creating less pollution and utilising fewer potentially toxic ingredients.

Manufacturers benefit by using less stuff, as their cost is less and this helps to keep their consumer prices down. This also results in resource conservation. The following quotations will clarify certain other points:

"Plastic Engineers have helped manufacturers make production using less material by lightening and thinning consumer product packaging. Just 2 lbs plastics can deliver 1,000 ounces - roughly 8 gallons - of beverage such as juice, soft drink, milk or water. In its place we will need 3 lbs of aluminum to bring home the same amount, 8 lbs of steel or 27 lbs of glass".

"Plastics help make packaging more efficient, thereby conserving resources. As a result, the consumer can buy larger, economy size products (eg: laundry detergents). It also means that it takes fewer trucks - and therefore less fuel - to get the products to the consumer. For example: It takes seven trucks to carry the same number of paper bags that fit in one truck load of plastic bags".

"Reuse provides another significant way to conserve resources. Plastic's durability allows many products and packaging to be reused over and over again. Not surprisingly, in a 1977 Survey, Wirthlin Worldwide found that more than 80% of Americans reuse plastic products and packaging for their homes. Plastics are durable, making it a material of choice for commonly reusable items, such as food storage containers and refillable sports bottles. Reuse of plastics reduces trash disposal costs, and extends landfill capacity. For example: as much as 40% of certain plastic parts from damaged or discarded cars are repaired and reused, reducing the amount of automotive components sent to landfills. Laundry products are also being packed in reusable plastic bottles and small refill packages of concentrated products - helping to reduce packaging waste".

"Many US businesses have made the decision to receive their supplies and ship their products in reusable plastic containers (RPSCs) rather than single use corrugated boxes. Over the past two years, the Ford Motor Company has eliminated more than 150 million pounds of wood and carboard packaging that would have gone to landfill, by asking its suppliers to use returnable plastic shipping containers and plastic rather than wood pallets. Returnable containers are also making major inroads in the produce and meat packaging industries".

Recovery of Energy

Burning of municipal solid waste (MSW) or garbage is an important source to generate energy. The heat thus generated is used to produce steam and electricity, and is called 'Waste to Energy' (WTE) facilities. According to American studies this process can reduce volume of MSW to be landfilled by as much as 90%. Comparative table of the heat energy that can be obtained by burning various MSW in special combustion chambers:

Type of MSW	Heat Energy btu/lb
Mixed Food Wastes	2,370
Mixed MSW	4,800
Mixed paper	6,800
News print	7,950
Mixed Plastics	14,100

Polystyrene	17,800
Polypropylene	19,850
Polyethylene	19,900

In the United States there are now 103 energy recovery plants operating spread over 32 states, generating enough electricity to meet the power needs of 1.2 million houses and businesses.

Plastics in Packaging and Environmental Benefits

Primary function of packaging is to help protect the quality of goods - all marketable products, viz., fresh meat and vegetables and prepared foods, industrial, equipment, sensitive electronics, etc, during shipping, handling and marketing. Because of the versatile nature of plastics they are most suitable for a wide range of packaging applications. Plastics offer best protection while using minimum resources, creating less wastage. As compared to other conventional packaging materials, plastics have minimum weight to volume ratio. Globally around 40%(which may shortly go up to 60%) of polymers are used in packaging. Polyethylene is the main polymer used for packaging. Plastic being so versatile, each resin has attributes that makes it best suited to a particular application. The following six resins account for nearly all plastics used in packaging.

PET (polyethylene terephtalate) is a clear, tough polymer with exceptional gas and moisture barrier properties. PET's ability to contain carbon dioxide (carbonation) makes it ideal for use in soft drink bottles.

HDPE (high density polyethylene) - Because of its excellent protective barrier properties it is used for milk, juice, and water containers. Its chemical resistance properties make it ideal for containers for household chemicals and detergents.

Vinyl (polyvinyl chloride) provides excellent clarity, puncture resistance and cling. As a film, vinyl can breathe just the right amount, making it ideal for packing fresh meats that require oxygen to ensure a bright red surface, while maintaining good shelf life.

LDPE (low density polyethylene) offers clarity & flexibility and is used to make bottles requiring flexibility. It is used to make grocery bags, garbage bags, shrink and stretch film making use of strength and toughness in film form of LDPE. It is also used as coating for milk cartons.

PP (polypropylene) - Because of it high tensile strength it is ideal for use in caps and lids that have to hold tightly onto threaded openings. PP has high melting point, can be hot-filled with products designed to cool in bottles, including ketchup, and syrup. It is also used for products that need to be incubated, such as yogurt.

PS (polystyrene) in its crystalline form is a colourless plastic that can be clear and hard. It can be foamed to provide exceptional insulation properties. Foamed or expanded polystyrene (EPS) is used for making meat trays, egg cartons, coffee cups etc and also used for packaging and protecting appliances, electronic and other sensitive products.

Plastics help make packaging more efficient thereby conserving resources.

Chapter 3: Waste Disposal

Waste Management - A Social Problem

Modern life-style with its emphasis on consumption and disposal has brought in its wake the acute problem of Solid Waste Management across the globe. The problem is aggravated due to pressure on land space on our planet. The urban solid waste consists of different materials - wet and dry. In a typical composition of Municipal Solid Waste (MSW), it is estimated that plastic waste, constitutes only 5-6 per cent.

Plastics are quite often, probably due to their bright colour and visibility, criticized for contributing to the waste problem, although, in reality plastics constitute a very miniscule percentage of urban solid waste both in volume and weight. Instead of singling out any one material our effort should be to streamline waste management system right from source reduction to collection, sorting, re-usage and recycling and finally disposal and incineration wherever applicable.

The Potential Of Recycled Plastics - A Second Life

Plastics' recycling takes place on a significant scale in India. As much as 60 per cent of both industrial and urban plastic waste is recycled. Plastic wastes have immense economic value. Almost all the plastic waste is converted into co-products and by-products. Most of it is mechanically recycled into products like containers, footwear, boards, partitions, profiles, pipes and other building and construction materials. Waste plastics are also recycled into lumber/wood products like rails, fencings, posts, benches, water pots, monofilaments etc. Plastic beverage bottle is being recycled into synthetic fibre for clothing and bedding applications.

Plastics are 100 per cent recyclable by various means. Technology is being continuously upgraded to improve the process of recycling, quality of recyclate and the quality and performance of the end products. Raw materials have a high value and are a precious resource, so to conserve both money and the environment the industry makes every effort to recover as much as possible.

It is often reported that burning of plastic bags releases toxic and carcinogenic elements into the environment while the truth is that plastic bags are made from polyethylenes which have basic building blocks of carbon and hydrogen. Burning of such bags provides only harmless carbon dioxide and water which are part of the natural atmospheric cycle.

Reclamation

The majority of municipal waste is still used as landfill, due to the very high cost of facilities for the sorting, separation and recycling of waste. As plastics are stable, both physically and chemically they in turn provide stability to the tips. This provides a safe and solid foundation upon which to build; thereby releasing land for development. However, as far as plastic waste is concerned, recycling and re-use is the answer or incineration at the end of it all.

Conserving The Environment

The plastics industry is concerned that it should take appropriate care of resources and the environment. The advantages of plastics over other raw materials are apparent from the beginning of their life cycle. Research shows that it often takes less energy to make products in plastics, and although most plastics depend on oil, coal or gas they are responsible for only a small fraction of the national consumption of these fuels. In addition, as plastics are lighter and easier to store and transport, energy savings are made. As well as developments in the recycling of plastics, there have been interesting advances in the production of degradable plastics for products that need only a limited life.

The Future

Plastics recycling are in the growth phase as the whole industry is still relatively young. A further development in recycling, which is being researched, is the recovery of the individual chemical components of plastics for re-use as chemicals, or for the manufacture of new plastics. ICPE is committed to encouraging industry to exploit the potential of plastics for recycling. It recognizes that many of the measures that could be taken to increase recycling ventures are inhibited by both cost and practicalities. The ICPE proposes to hold seminars on recycling issues, to ensure innovation and development within the plastics industry.

Plastic recycling industry in Indian is of tremendous economic importance. Besides providing gainful employment to thousands of skilled and unskilled people it provides cheap inputs for industry and also cheap, affordable consumer products for the middle class and poorer sections of the society.

A Source Of Energy

Material recovery is by no means the only way to recycle plastics. Incineration is another option that also helps recover their thermal content, providing an alternative source of energy. An average typical value for polymers found commonly in house hold waste is 38 mega joules per kilogram (MJ/kg), which compares favourably to the equivalent value of 31 MJ/kg for coal. This represents a valuable resource raising the overall calorific value of domestic waste which can then be recovered through controlled combustion and re-used in the form of heat and steam to power electricity generators. This method is being put to use in Japan, the UK and in some of the European countries. However, it will take a long time before India could adopt the technology.

Chapter 4: Recycling

Recycling plastics significantly reduces energy and GHG emissions

A new study using life cycle inventory (LCI) conclusively shows that the recycling of plastics, specifically PET and HDPE, translates into significant savings in energy and greenhouse gas (GHG) emissions. Source :Canadian Plastics Industry Associations (CPIA)

Recycling

The most environmentally friendly alternative for plastic waste disposal - is the process by which we can re-utilize the energy content of the polymer in an ecologically acceptable way. The other two alternatives are Land filling, and Incineration, which have, amongst others, the following constraints, especially because of increasing rapid accumulation of plastic wastes:

(i) Lack of adequate and suitable sites for landfilling.

(ii) The feared toxic emissions from inadequate equipment and inappropriate incineration conditions, and the resultant public resistance.

Types of Recycling

(a) Material Recycling - This practice of recycling post-manufacturing waste has been in vogue since the last many years. But problems are encountered in case of post consumer waste such as great inhomogeneity of different polymers present such as PE/PP, PS, PVC etc. Further the incompatibility of the components mixed, chemically different polymers present pose difficulties in processing and inferior material properties. It is therefore necessary to separate various polymers to boost their value. The separation works based on the principle of sorting by a centrifugal force field, using density difference of the various polymers is one possible solution. Prior to separation, it will be necessary to clean the polymer waste to remove contamination like dirt, food leftovers, paper etc.

(b) Chemical Recycling - Converting polymers back into short chain chemicals for re-use in polymersation or other petro-chemical processes: e.g. - Cracking, Gasification, Hydrogenation and Pyrolysis. Investigations and studies are going on.

Recycling of Heterogeneous Plastics

Degradation of polymers during different processing steps is the main problem in post consumer plastics recycling. Incompatibility among the different phases also poses major difficulty in the recycling of heterogeneous waste.

Recycling of used plastic containers for liquids

Incompatibility between component polymers (PE, PVC and PF) and degradation of components during the heterogeneous reprocessing results in poor quality of mechanical properties of such secondary plastic materials.

The use of different classes of additives, such as stabilizers, inert fillers, elastomeric modifiers and compatibilizers can improve the processability enhancing the thermo-mechanical resistance of the polymers and the mechanical properties.

To reduce cost, inert fillers can be used, by which mechanical properties will be enhanced, though not to the expected level. Elastomers will improve mechanical properties substantially. Functionalised polyethylene and styrene butadiene-styrene rubber and CaO coated with organo - titanates will help in some compatibilising actions. For blends produced from this mixture and recycled polyethylene good results can be expected.

Recycling - Effects of contamination

In polymers used for recycling, contamination is omnipresent, resulting in reduction of the quality of recycling. It can be in the form of dirt, printing inks, paper, metals, foil, additives, pesticides, partially oxidized polymers, contamination by foreign bodies can be noticed even in PET and HDPE bottles collected from roadsides. In very old scraps of building products, electrical and electronic system, vehicles, furniture etc., which now come for recycling may contain very high concentration of additives in particular, fire retardants, which are now banned. Contamination can be reduced if consumers can be organized to segregate polymer products before disposal. However accidental or unintentional mixtures, multi-component products etc do pose problems.

Common contaminants in recycled polymers:

Polymer	Recycle source	Contamination
PET	Beverage bottles	PVC, green PET, Al, water, glue, oligomers

HDPE	Milk/water bottles	PP, milk residue, pigments, paper, EPS, cork
LDPE	Greenhouse films	Insecticides, soil, Ni, oxidation products
LDPE	Shopping bags	Paper receipts, printing ink, food scraps
PP	Battery cases	Pb, Cu, acid, grease, dirt
HDPE	Detergent bottles	Paper, glue, surfactants, bleach, white spirit
PET	Photographic film	Silver halides, gelatin, caustic residues
Phenolic	Circuit boards	Cu, tetrabromobisphenol A
LDPE	Multilayer film	Ethylene vinyl alcohol, polyamide, ionomer
PVC	Beverage bottles	PET, PE, paper, Al foil, PP
ABS	Appliance housings	Polybrominated flame retardants
SBR	Automobile tires	Steel wire, fiber, oil extender
LDPE	Mulch film	Soil (up to 30%), iron (up to 3% in soil)

The simple and widely used process for separation is by using differences in density, e.g. HDPE cups and PET bottles.
Separation and purification by chemical reaction process will give better results.

Mixtures of solvents allowing selective dissolution can be used for multi component plastic products.

Different Post Consumer Plastics for Recycling

In the plastic industry, in terms of volume, polyethylenes are the largest group, followed by PVC (Poly vinyl chloride) in the second place.

HDPE (High density Polyethylene) products:

Generally available in bales, low cost.

Products: milk jugs and detergent bottles. High-density polyethylene - almost as dense as water, natural in colour, transparent, white, without any pigment. During recycling any colour can be mixed.

Process of recycling is very simple - Grind into small flakes approx. 1 cm., wash, float and remove heavy contaminant, dry the clean flakes in a stream of hot air, pack in boxes - ready for sale.

Reheat the flakes, add pigments of choice, colour and run through a pelletizer. By using injection moulding presses new products can be made out of the little beads that may be formed in the process of pelletizing.

End uses: Pipes, lumber, flowerpots, trashcans, and non-food application bottles.

LDPE (Low Density Poly Ethylene)

LDPE available in bales - low cost. Chemically similar to HDPE but less dense and more flexible., e.g. Polyethylene films used for plastic bags and in grocery sacks.

Process is similar to HDPE, and special grinders are used when thin films are required.

End use - Plastic trash bags grocery sacks, tubing, agricultural films and lumber.

PET (Poly Ethylene Terephthalate)

A thin strong polyester film, extremely tough. Used for softdrink and water bottles, jars, clamshell packages like cooking containers or trays etc.

Process: - Similar to the process for Polyethylene. Sort out based on colour, grind & wash. PET sinks in the wash water when plastic caps and labels will float. The clean flake is dried and often repelletized.

End use: Largest usage is in Textiles. Carpet companies often use 100 % recycled resin to manufacture Polyester carpet in different colours and textures, fibre filling for pillows, quilts and jackets clear sheets or ribbon for VCR and audio cassettes. A good quantity goes back into the bottle market. Cost varies widely with supply.

PVC (Poly Vinyl Chloride):

PVC is a versatile and universal polymer, low cost.

PVC can be compounded with variety of additives to make wide range of flexible and rigid forms and hence versatile. PVC is a universal polymer because it can be processed by various techniques like calendering, extrusion, injections, moulding and plastosol. Physical chemical, weathering properties of PVC are excellent.

End uses: - Pipes, Profiles, Floor coverings, cable insulation, roofing sheets, packaging foils, bottles and medical products, car interiors.

Advantages: Easy to clean, Water proof and resistant to corrosion.

Recycling of Plastics: Indian Context

Recycling of Plastics has been classified into 4 main categories:

Primary Recycling – conversion of waste plastics into products having performance level comparable to that of original products made from virgin plastics.

Secondary Recycling – conversion of waste plastics into products having less demanding performance requirements than the original material.

Tertiary Recycling – the process of producing chemicals / fuels / similar products from waste plastics.

Quaternary Recycling – the process of recovering energy from waste plastics by incineration.

The present article deals with the first two categories of Recycling.

The process of recycling of waste plastics into products of varying usefulness mostly involves the following essential steps:

Collection Segregation.

Cleaning & Drying.

Sizing / Chipping.

Agglomerating / Colouring

Extrusion / Palletisation

Fabrication into end Product.

Each of the above steps involves a series of operations.

Collection / Segregation:

The basic principle of plastic / polymer processing is that the polymeric materials under process are required to be compatible with each other, if more than one type of plastic materials are involved..

Certain polymeric materials are compatible with each other at all proportions.For example LDPE and Lldpe are generally compatible to each other at all proportions.

However, it is to be remembered that even differing molecular weight variety of the same polymer may not be compatible for useful purpose. For example phase separation may occur if a high molecular weight (low Melt Flow Index) grade of LDPE (e.g. heavy duty film grade) is processed with a very low molecular weight (high Melt Flow Index) grade of LDPE (e.g. high flow Injection Moulding grade).

The advanced technology of separating / segregating different types of waste plastics involves ‘Floatation Process’. In this process the property of the varying densities of different plastics is made use of for segregating different types of plastics.

However in the Indian Context, this separation or segregation process, in many cases, are done by manual process utilizing the availability of cheap and expert labour force.In case the waste is contaminated with embedded metals, proper method of separating the metals / other contaminants, is required.

Cleaning & Drying:

The scale of cleaning depends on the type of waste.

Generally, Industrial waste does not require significant cleaning operation, whereas, post-consumer waste requires proper cleaning.

Whenever a cleaning operation is involved, it is to be ensured that the water or any other cleaning material used, should be discharged after ascertaining that the discharge does not contain any objectionable substance. A proper Treatment Device may have to be deployed – like a water treatment plant / effluent treatment plant.

For drying, a suitably designed drier is used.

Many industries situated out side the metropolises, use open space for natural drying of the cleaned waste.

Sizing / Chipping:

The cleaned plastics waste is then required to be properly sized so that those may be fed into the extruders for processing and palletizing. The sizing operation depends on the type and shape of the waste plastics.

During this process, attention is required to separate any powdery material from the sized / chipped plastics.

Agglomerating / Colouring

In the next operation the sized plastics waste is mixed with colour master batch in high-speed mixers / agglomerators and the output is ready for extrusion into pellets.

Extrusion / Palletisation

This is the most important part of the process wherein the sized / chipped plastics are plasticised and regranulated to make the plastics material ready for fabrication next.

The type and size of the Extruder depend on the type and volume of the plastics waste.

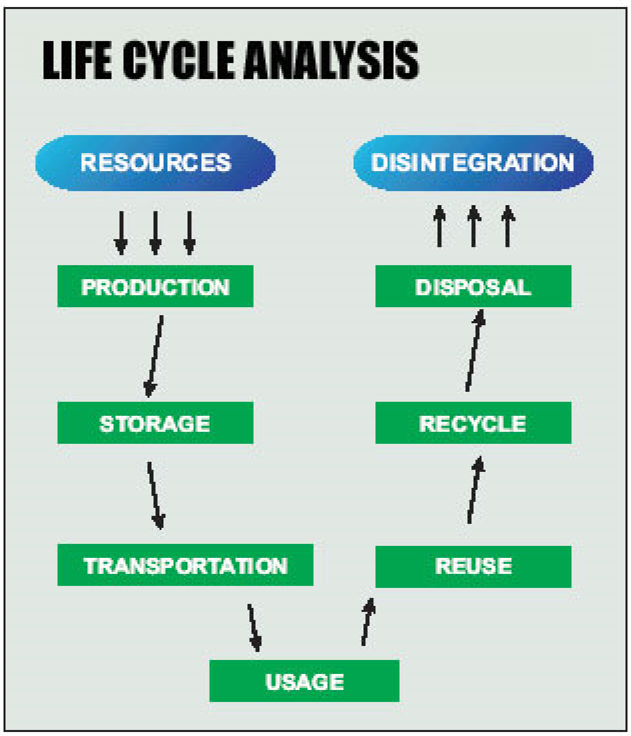
Fabrication into end Product

Finally the reprocessed plastics granules are used as raw material for producing end products using similar fabrication machines like Injection Moulding / Extrusion etc., depending upon specific requirement.

Chapter 5: Life Cycle Analysis

Life Cycle Analysis is an important environmental management tool to gauge the impact of a product on the environment from its manufacturing stage to its final disposal / disintegration.

The development of industries and the various man - made activities to fulfil the requirement of human race, has created an enormous impact on the environment. Any man-made product has some impact on the environment. To analyse the impact/effect of a particular product on he environment, one has to consider the life cycle analysis of the product which consists of the following aspects :



Life cycle analysis on following Plastics materials/proudts have been included in this document :

1) LCA of PP-HDPE Woven sacks vis-à-vis jute/paper
2) LCA of Plastics in Packaging

For - Milk
- Atta(Flour)
- Lube Oil

LCA of PP-HDPE Woven sacks VIS-a-VIS jute and paper bags

Packaging is both a symbol of society's consumption habits and reflection of its progress. The user expects it to have better strength, easier handling, to be lighter, more aesthetic, safer from a hygiene point of view, etc. The manufacturer undertakes research and development to meet these demands and to offer a high quality product. In addition to its standard attributes, today's packaging just also contribute to protecting the environment, and certainly must not damage it besides being friendly to human health. The packaging referred to in this document is used to pack and distribute bulk products, like cement, fertilizers, sugar, food grains, salt, chemicals, oilseeds etc. as opposed to the carry bags that vendors offer their customers for carrying various edible/non-edible items purchased in retail.

Today where there is a lot of controversy about different packaging materials and their environmental credentials, an ecological assessment as well as study of effects on human health is necessary. In view of this ICPE (Indian Centre for Plastic in the Environment, New Delhi) decided to carry out a Life Cycle Analysis (LCA) of bulk packaging materials (Jute Sacks, PP-HDPE woven Sacks and Paper Sacks) with a capacity of 50 kg or below. Life cycle analysis is an effective tool to measure the impact of a product or process on the environment. In this study, it covers the environmental and resource impact of PP-HDPE woven sacks in particular vis-à-vis Jute/Paper from the stage of raw material extraction, production, use and disposal, taking into account all the inputs such as materials, energy, capital equipment, man-hours, etc.) and the outputs like products, by-products, waste materials, emissions at every stage using "cradle to grave" approach.

Resource Consumption & Recovery

The analysis by steps identifies the production of jute and paper and subsequently manufacture of sacks as being responsible for the greatest consumption of energy (~ 669.6 Thousand GJ/MMT of packed product) in case of paper bag and 333 Thousand GJ/MMT of packed product in case of jute sacks as compared to PP-HDPE woven sacks (~ 226.8 Thousand GJ/MMT of packed product). Energy consumption related to transportation of bulk goods shows that transportation in jute sacks requires significantly excess amount of energy, being about 2036 GJ/MMT of packed product in case of jute sacks, and 928 GJ/MMT of packed product where paper is being used as packaging material (compared to transportation in PP-HDPE woven sacks).

Another major resource utilization is being demonstrated in terms of consumption of water. The manufacture of jute and paper sacks is found to be responsible for the overall greatest consumption of water; ~ 22 Thousand lakh litre/ (MMT of packed product) in case of jute bag production and ~ 18 Thousand lakhlitre/ (MMT of packed product) in case of paper bag production. This is about 10 (jute) and 7 (paper) times higher than that for PP-HDPE woven sack for one MMT of packed product.

Furthermore, both the production of jute and paper sacks requires utilization of chemicals in the tune of 258 ton/MMT of packed product (for jute) and 4647 ton/MMT of packed product (for paper) whereas almost negligible amount of chemicals of this nature are required at all for production of PP-HDPE woven sacks (0.014 ton/ MMT of packed product). The energy requirement and more particularly health hazards connected to these should be taken into consideration for comparison of the three materials for bulk packaging purposes.

More importantly attention is also given to two end-of-life cases i.e.,100% incineration (waste to energy) and/or 100% recycling with energy recovery/saving. According to this phase energy recovery due to incineration is about 95 Thousand GJ for PP-HDPE woven sacks used for packaging one MMT of bulk commodities as compared to ~170 Thousand GJ in case of paper sacks used for packaging one MMT of bulk commodities. Similarly energy savings due to recycling is found to be 47 GJ for PP-HDPE woven sacks used for packaging one MMT of bulk commodities while it is only 32 Thousand GJ for paper sacks used for packaging one MMT of bulk commodities. It should also be noted that in case of recycling of plastics the waste enters into a new life and if the waste management technique is taken into consideration the life cycle analysis of plastics can be termed as "Cradle to Cradle" approach instead of "Cradle to Grave". In this phase minimum or almost no recovery of energy is at all in practice for waste jute sacks.

Emission to Air

The emission of CO_2 for the materials has approximately the same profile. However, the analysis of input effects indicates remarkably high emission of CH_4 emission in case of production of jute bag. The comparative study on emission during transportation also shows significantly excess generation of CO, CO_2 and NO_x as compared to that in case of PP-HDPE woven sacks.

Emission to Water

The emission of CO_2 for the materials has approximately the same profile. However, the analysis of input effects indicates remarkably high emission of CH_4 emission in case of production of jute bag. The comparative study on emission during transportation also shows significantly excess generation of CO, CO_2 and NO_x as compared to that in case of PP-HDPE woven sacks.

Health Hazards to Human

The standard of living of PP-HDPE workers is much better, compared to those toiling in Jute and Paper in conditions far from congenial to human health. Jute farmers suffer from respiratory diseases, skin disorders, and certain cancers-- arising from nitrogen dioxide, hydrogen sulfide, ammonia, carbon dioxide and methane produced during its cultivation. Besides, the workers are required to remain for 6 to 10 hours in waist-deep water during retting of Jute. In addition, the Jute Batching Oil used during softening process of Jute remains in the final Jute sacks. Food substances packed in Jute sacks have the potential to jeopardize human health by causing several illnesses such as dizziness, headache, nausea and vomiting, etc.

The toxic chemicals released by Paper industry have enough potential to harm earth's life forms. In forests, where pulp mills sludge has been disposed, dioxins have accumulated in the tissues of field animals and have caused bio-chemical effects on birds. As dioxin resist natural breakdown processes, they build up over time in the environment and can undergo continual recycling through out the environment. Thus, even if production of dioxin ceases, levels already present in the environment will take long time to decrease. Finally, organo-chlorines are found in the paper products themselves.

The study of mortality rate of these workers is absolutely necessary to study and direct weightage to be given while considering the total impact assessment. Needless to mention such health hazards are non-existent for PP-HDPE woven sacks, both at raw material stage as well as at sack manufacturing stage.

Conclusion

Though plastics like PP-HDPE are relatively newcomers, the use of it in packaging of bulk commodities adhere the basic tenets of sustainable development more than materials like Jute and Paper, if one considers the consumption of energy, emission of gases and the use of chemicals. An analysis of the comparable life cycle with jute and paper clearly tells that plastics are economically affordable, socially acceptable and environmentally effective. Health hazards for workers in jute and paper are very high while those employed in plastics are almost free from such health hazards.

While documenting the stages of procuring raw material for jute, PP-HDPE and paper, it highlights the facts that were hitherto kept under the wrap, such as the hazards on workers and environment caused by massive use of fertilizers, insecticides and chemicals in jute and paper. On the contrary, the use of PP-HDPE is not only safe, but as a whole actually saves more oil than needed for their manufacture.

The recording of the stages of production of jute sacks, PP-HDPE woven sacks and paper sacks give a complete picture of the consumption of energy, water and gases in all the three materials and remove the prevailing notion that jute and paper are more environment- friendly than PP-HDPE.

Another sensitivity in the study results in discovering the effects of the weight of the jute vis-à-vis PP-HDPE woven sacks on the overall loss to environment through transport of commodities.

Managing waste help to produce more from fewer resources, while generating less pollution and waste. The measures to reduce the amount of solid waste produced, either as industrial, commercial or domestic waste, in essence are improvements in efficiency. Jute and paper as bulk packaging material cause more stress on waste management than PP-HDPE woven sacks. The residual plastics at less than 10 percent by weight of Municipal Solid Waste can provide 20 per cent of the fuel value for a local WTE plant.

PP-HDPE-based bulk packaging is a vehicle for sustainable development, and is fully renewable and recyclable

Life Cycle Analysis of Plastics in packaging in terms of "Cradle to grave" Aproach

❖ Plastic Pouch vis-a-vis Glass Bottle for Milk Packaging

Life Cycle Analysis of Plastics in Packaging in Terms of "Cradle to Grave" Approach

Life cycle analysis is an effective tool to measure the impact of a product or process on the environment. The present study covers the environmental and resource impact of plastic pouches vis-à-vis glass bottles used for packaging 'Milk'; plastic film bags vis-à-vis jute bags used for packaging 'Atta'; HDPE cans vis-à-vis tin cans used for packaging 'Lube Oil', from the stage of raw material extraction, production, use and disposal, taking into account all the inputs such as materials, energy, capital equipment, man-hours, etc., and the outputs like products, by-products, waste materials, emissions at every stage.

This report documents the journey of the packaging materials from the time they are born to the end of their utility in the hope that environmental safeguards could be incorporated without hampering plastics progressive role that it has been playing in sustainable development.

The basis of this study has been considered as one lakh (1,00,000) litres of 'Milk', one lakh metric tons of 'Atta' and one million metric tons of 'Lube Oil' respectively in keeping with the view of the consumption in order of magnitude.

Plastic Pouch vis-à-vis Glass Bottle for Milk Packaging

The study discloses that for producing plastic pouches for packaging of one lakh litres of milk, the plastic raw material required is only 0.40 MT. But for packaging of same quantity of milk with glass bottles, the raw material required is 45.4 MT of glass. The results of this analysis are organised in two categories: resource utilisation and atmospheric emission.

Emission to Air

The emission of CO_2 for the materials has approximately the same profile. However, the

analysis of input effects indicates remarkably high emission of CH_4 emission in case of production of Glass. The comparative study on emission during transportation also shows significantly excess generation of CO, CO_2 and NO_x as compared to that in case of plastic pouches.

Table I: Life Cycle Data for Different Materials Used for Packaging One Lakh Litres of Milk

	Glass		Plastic Pouches	
Material Required (MT)	45.4		0.40	
	Energy*	Water*	Energy*	Water*
Phase I: Production of Raw Material	671.92	1608.0	32.22	25.6
Phase II: Production of Bottles/Pouches	530.27		4.56	
Total	1202.19	1608.0	36.78	25.6

	Glass		Plastic Pouches	
Phase III: Filling and Distribution	Fuel*	Energy* Single [Return]	Fuel*	Energy* Single [Return]
	2049	114.75 [213.43]	1120	62.73 [106.64]

*Units: Energy (GJ), Water (Thousand Litres), Fuel (Litres)

(Table - I contd on page 2)

❖ Plastic Bag vis-a-vis Jute Bag for Atta packaging(Flour)

Phase IV: Waste Management	Glass		Plastic Pouches	
Recycling Percent	Energy Consumption*		Energy Consumption*	
100%	501.67		4.56	
80%	401.34		3.65	
60%	301.00		2.74	
50%	250.83		2.28	
Reuse (Including Transportation)	Energy Consumption	Water Consumption	Energy Consumption	Water Consumption
95%	277.8	509.1	143.4	25.6
80%	457.5	675.4	(New Plastic	(New Plastic
60%	697.0	897.2	Pouches)	Pouches)
Incineration	Energy Recovered		Energy Recovered	
100%	Not Applicable		20.73	
80%			16.58	

*Units: Energy (GJ), Water (Thousand Litres), Fuel (Litres)

Table II: Emissions during Phase I and Phase II for One Lakh Litres of Milk

		Glass	LDPE
Air Emissions			
CO	kg	54.3	0.6
CO_2	kg	6610.2	760.0
SO_x	kg	134.8	5.2
NO_x	kg	68.1	4.8
CH_4	kg	39.5	3.2
HCl	kg	5.3	0.0
Dust	kg	67.6	1.4
Water Emission			
Suspended Solids	kg	352.3	0.2
Chlorides	kg	4535.5	0.1

Table III: Emissions during Phase III for One Lakh Litres of Milk

Emissions	gm/km	kg/lakh litres		Excess for
		Bottles	Pouches	Glass Bottles
CO_2	781	4881.3	2668.7	2212.6
CO	4.5	28.1	15.4	12.7
HC	1.1	6.9	3.8	3.1
NO_x	8	50.0	27.3	22.7
HC+ NO_x	9.1	56.9	31.1	25.8
Particulates	0.36	2.3	1.2	1.1
Total Regulated Tail Pipe Emission	13.96	87.3	47.7	39.6

Plastic Bag vis-à-vis Jute Bag for 'Atta' Packaging

The study discloses that for producing packaging with plastic film bags for one lakh tons of 'Atta', the raw material required for packaging is only 680 MT. But for the same quantity of packaging with jute bags require 1960 MT of packaging material. The results of this analysis are organized in two categories: resource utilization, water and atmospheric emission.

Emission to Air

Phase I of jute involves absorption of CO_2 from the atmosphere but phase II involves emission of CO_2. This benefit of phase I is lost during the transportation phase, where because of excess weight it leads to consumption of excess fuel resulting in severe atmospheric pollution. The emission of CO_2 for plastic film bags are higher in phase I but leads to overall less CO_2 emission because of its light weight during the transportation phase. The analysis of input effects indicates remarkably high emission of CH_4 emission in case of production of jute. The comparative study on

2

❖ HDPE Cans vis-a-vis Tin cans for Lube Oil Packaging

Table I: Life Cycle Data for Different Materials Used for Packaging One Lakh Tons of 'Atta'

	Jute Bags		Plastic Film Bags	
Material Required (MT)	1960		680	
	Energy (Thousand GJ)	Water (Thousand Tons)	Energy (Thousand GJ)	Water (Thousand Tons)
Phase I: Production of Raw Material	21.50	1677	38.36	264
Phase II: Production of Bags & Liners	47.19	1506	24.22	296
Total	68.69	3183	62.58	560

Phase III:	Jute Bags		Plastic Film Bags	
Distribution	Fuel (Tons)	Energy (GJ)	Fuel	Energy
	4663	261.29	Taken as Basis	

Phase IV: Waste Management	Jute	Plastic Film Bags
Recycling Percent	Energy Savings	Energy Savings (Thousand GJ/680 tons)
100%	Not Applicable	17.20
80%		13.76
Incineration	Energy Recovered	Energy Recovered (Thousand GJ/680 tons)
100%	Not Applicable	35.24
80%		28.12

Table II: Emissions during Phase I and Phase II for Packaging One Lakh Tons of 'Atta'

For One Lakh Tons of 'Atta'		Jute	LDPE
Air Emissions			
CO	kg	54.3	0.6
CO_2	kg	6610.2	760.0
SO_x	kg	134.8	5.2
NO_x	kg	68.1	4.8
CH_4	kg	39.5	3.2
HCl	kg	5.3	0.0
Dust	kg	67.6	1.4
Water Emissions			
Suspended Solids	kg	352.3	0.2
Chlorides	kg	4535.5	0.1

emission during transportation also shows significantly excess generation of CO, CO_2 and NO_x in case of jute bags as compared to that in case of plastic film bags.

Emission to Water

As shown in the different tables, BOD and COD to water are unmistakably of highest amount in case of production of jute bags. While these values are negligible for plastic film bags. The COD and BOD values are at least 15-20 times larger in the case of jute bags leading to dangerous environmental impact apart from health hazards.

HDPE Cans vis-à-vis Tin Cans for 'Lube Oil' Packaging

The study discloses that for producing packaging with HDPE cans for one million tons of 'Lube Oil', the raw material required for packaging is only 63,218 MT. But for the same quantity of packaging with tin cans require 86,207 MT of packaging

Table III: Emissions during Phase III for Packaging One Lakh Tons of 'Atta'

Emission	gm/km	Excess Emission for Jute Bags (kg)	Plastic Bags
CO_2	781.0	11107.3	Taken as Basis
CO	4.5	64.0	Taken as Basis
HC	1.1	15.6	Taken as Basis
NO_x	8	113.8	Taken as Basis
$HC+NO_x$	9.1	129.4	Taken as Basis
Particulates	0.36	5.1	Taken as Basis
Total Regulated Tail Pipe Emission	13.96	198.5	Taken as Basis

Table I: Life Cycle Data for Different Materials used for Packaging One Million Tons of 'Lube Oil'

	Tin cans	HDPE cans
Material Required (MT)	86207	63218
	Energy (Thousand GJ)	Energy (Thousand GJ)
Phase I: Production of Raw Material	3846.02	5052.87
Phase II: Production of Cans & Liners	3638.54	1472.99
Total	7484.55	6525.86

Phase III: Distribution	Tin cans		HDPE Film Bags	
	Fuel (Tons)	Energy (GJ)	Fuel	Energy
	83770.49	4691.1	Taken as Basis	

Phase IV: Waste Management	Tin	HDPE cans
Recycling Percent	Energy Savings (Thousand GJ/86,207 tons)	Energy Savings (Thousand GJ/63,218 tons)
100%	1602.586	1620.287
80%	1282.069	1296.230
Incineration	Energy Recovered	Energy Recovered (Thousand GJ/63,218 tons)
100%	Not Applicable	3276.61
80%		2621.29

material. The results of this analysis are organized in two categories: resource utilization, water & atmospheric emission.

Emission to Air

During the transportation phase excess weight of the tin cans leads to consumption of excess fuel resulting in severe atmospheric pollution. The emission of CO_2 for HDPE cans is higher in phase I but leads to overall less CO_2 emission because of its light weight during the transportation phase. The analysis of input effects indicates remarkably high emission of CH_4 emission in case of production of Tin. The comparative study on emission during transportation also shows significantly excess generation of CO, CO_2 and NO_x in case of tin cans as compared to that in case of HDPE cans.

Emission to Water

As shown in the different tables, BOD and COD to water are of a slightly higher amount in case of production of Tin cans than in case of HDPE cans.

CONCLUSIONS

Though plastics are relatively newcomers, their use in packaging of milk/atta/lube oil commodities adheres to the basic tenets of sustainable development more than alternative materials like glass, jute, tin, if one considers the consumption of energy and emission of gases. An analysis of the comparable life cycle with conventional materials clearly tells that plastics are economi-

Table II: Emissions During Phase I for Packaging One Million Tons of 'Lube Oil'

For 1 Million Tons of 'Lube Oil'		Tin	HDPE
Air Emissions			
CO	Ton	1352.997	51.839
CO_2	Ton	21721.094	107470.6
SO_x	Ton	453.435	885.052
NO_x	Ton	333.495	625.858
CH_4	Ton	789.858	372.986
HCl	Ton	6.318	3.034
Dust	Ton	102.389	183.332
Water Emissions			
Suspended Solids	Ton	28.888	132.757
Chlorides	Ton	1038.517	21.494

Table III: Emissions During Phase III for Packaging One Million Tons of 'Lube Oil'

Emission	gm/km	Excess Emission for Tin Cans (kg)	HDPE Cans
CO_2	781.0	199545.5	Taken as Basis
CO	4.5	1149.75	Taken as Basis
HC	1.1	281.05	Taken as Basis
NO_x	8	2044.00	Taken as Basis
HC+NO_x	9.1	2325.05	Taken as Basis
Particulates	0.36	91.98	Taken as Basis
Total Regulated Tail Pipe Emission	13.96	3566.78	Taken as Basis

cally affordable, socially acceptable and environmentally effective.

From this study we can claim that the overall loss to environment from plastic pouches is less than that from alternative materials. The difference seems significant. The choice of product end-of-life (work) management even strengthens this assessment.

The need of the hour is educating the public of what to do with such waste packaging materials and how to dispose them for recycle – to lessen the stress on waste management and to give proper justice to resource management.

Chapter 6: Biodegradable Plastics

Bio plastics are biodegradable plastics, whose components are derived from renewable raw materials. These plastics can be made from abundant agricultural/animal resources like cellulose, starch, collagen, casein, soy protein polyesters and triglycerides. Large scale use of these would help in preserving non-renewable resources like petroleum, natural gas and coal and contribute little to the problems of waste management. Biodegradable Plastics degrade over a period of time when exposed to sun and air.

Though the demand for biodegradable Plastics is increasing, acceptance of biodegradable polymers is likely to depend on factors like

1) Customer response to costs.
2) Possible legislation by Governments
3) The achievement of total biodegradability

Immediate application areas identified in India for biodegradable plastics are Agricultural Mulch, Surgical implants, Industrial Packaging, Wrapping, Milk Sachets, Foodservice, Personal care, Pharmaceuticals, Medical devices, recreational etc.

Biodegradable Plastics highlights the Indian efforts in the direction, as well as activities at some of the major centers of developmental at USA/Canada, Germany, Scandinavian countries and Japan.

Plastics that break down

In an effort to overcome these shortcomings, biochemical researchers and engineers have long been seeking to develop biodegradable plastics that are made from renewable resources, such as plants.

The term biodegradable means that a substance is able to be broken down into simpler substances by the activities of living organisms, and therefore is unlikely to persist in the environment. There are many different standards used to measure biodegradability, with each country having its own. The requirements range from 90 per cent to 60 per cent decomposition of the product within 60 to 180 days of being placed in a standard composting environment.

The reason traditional plastics are not biodegradable is because their long polymer molecules are too large and too tightly bonded together to be broken apart and assimilated by decomposer organisms. However, plastics based on natural plant polymers derived from wheat or corn starch have molecules that are readily attacked and broken down by microbes.

Biodegradable plastics made with plant-based materials have been available for many years. Because of their higher cost they have never replaced traditional non-degradable plastics in the mass market.

Indeed, biodegradable plastic products currently on the market are from 2 to 10 times more expensive than traditional plastics. But environmentalists argue that the cheaper price of traditional plastics does not reflect their true cost when their full impact is considered. For example, when we buy a plastic bag we don't pay for its collection and waste disposal after we use it. If we add up these associated costs, traditional plastics would cost more and biodegradable plastics might be more competitive.

Biodegradable and affordable

If cost is a major barrier to the uptake of biodegradable plastics, then the solution lies in investigating low-cost options to produce them.The Cooperative Research Centre (CRC) for Food Manufacture and Packaging Science is looking at ways of using basic starch, which is economical to produce, in a variety of blends with other more expensive biodegradable polymers to produce a variety of flexible and rigid plastics. These are being made into 'film' and 'injection moulded' products such as plastic wrapping, shopping bags, bread bags, mulch films and plant pots.

Mulch film from biodegradable plastics

The CRC has developed a mulch film for farmers. Mulch films are laid over the ground around crops, to control weed growth and retain moisture. Normally, farmers use polyethylene black plastic that is pulled up after harvest and trucked away to a landfill (taking with it topsoil humus that sticks to it). However, field trials using the biodegradable mulch film on tomato and capsicum crops have shown that it performs just as well as polyethylene film but can simply be ploughed into the ground after harvest. It's easier, cheaper and it enriches the soil with carbon.

Pots you can plant

Another biodegradable plastic product is a plant pot produced by injection moulding. Gardeners and farmers can place potted plants directly into the ground, and forget them. The pots will break down to carbon dioxide and water, eliminating double handling and recycling of conventional plastic containers.

Different polymer blends for different products

Depending on the application, scientists can alter polymer mixes to enhance the properties of the final product. For example, an almost pure starch product will dissolve upon contact with water and then biodegrade rapidly. By blending quantities of other biodegradable plastics into the starch, scientists can make a waterproof product that degrades within 4 weeks after it has been buried in the soil or composted.

Composting the packaging with its contents

Compost may be the key to maximizing the real environmental benefit of biodegradable plastics. One of the big impediments to composting our organic waste is that it is so mixed up with non-degradable plastic packaging that it is uneconomic to separate them. Consequently, the entire mixed waste-stream ends up in landfill.

By ensuring that biodegradable plastics are used to package all our organic produce, it may well be possible in the near future to set up large-scale composting lines in which packaging and the material it contains can be composted as one. The resulting compost could be channeled into plant production, which in turn might be redirected into growing the starch to produce more biodegradable plastics.

An Olympic effort - recycling 76 per cent of waste

For anyone who thinks such schemes aren't feasible, you only have to look at the recycling success of the Olympics to see that where there's a will, there's a way. More than 660 tonnes of waste was generated each day at its many venues. Of this, an impressive 76 per cent was collected and recycled. Part of this success was due to the use of biodegradable plastics used in the packaging of fast food, making the composting of food scraps an economic proposition as it eliminated the need for expensive separation of packaging waste prior to processing.

With intelligent use, these new plastics have the potential to reduce plastic litter, decrease the quantities of plastic waste going into landfills and increase the recycling of other organic components that would normally end up in landfills

Chapter 7: Myths & Realities

YTH: Reusing plastic water bottles can cause them to break down into carcinogenic compounds.

"Many are unaware of poisoning caused by re-using plastic bottles. Some of you may be in the habit of using and re-using your disposable mineral water bottles (eg. Evian, Aqua, Ice Mountain, Vita, etc), keeping them in your car or at work. Not a good idea. In a nutshell, the plastic (called polyethylene terephthalate or PET) used in these bottles contains a potentially carcinogenic element (something called diethylhydroxylamine or DEHA). The bottles are safe for one-time use only; if you must keep them longer, it should be or no more than a few days, a week max, and keep them away from heat as well. Repeated washing and rinsing can cause the plastic to break down and the carcinogens (cancer-causing chemical agents) can leach into the water that YOU are drinking. Better to invest in water bottles that are really meant for multiple uses. This is not something we should be scrimping on. Those of you with family - to please advise them, especially children."

Reality: False.

This bit of plastic bottle scare lore is based upon a master's thesis from a University of Idaho graduate student, one which was unfortunately reported upon by the media despite its lack of peer review. According to The International
Bottled Water Association (IBWA):

The US Food and Drug Administration (FDA) regulates bottled water as a packaged food product and, for bottled water and all other foods and their packaging, FDA has determined that PET meets standards for food contact materials.

The basis for [the e-mail was] a college student's masters thesis that was not subject to peer review and did not reflect a level of scientific rigor that would provide accurate and reliable information about the safety of these products. Fortunately, FDA requires a much higher standard to make decisions about food contact packaging. DEHA, as mentioned in the email is neither regulated nor classified as a human carcinogen. Further, DEHA is not inherent in PET plastic as raw material, byproduct or decomposition product. DEHA has been cleared by FDA for food contact applications and would not pose a health risk even if present. DEHA is a common plasticizer used in many plastic items, many of which are found in the lab setting. For this reason, the student's detection (see comment above) is likely to have been the result of inadvertent lab contamination.

Also note that PET plastics used for bottled water containers are not unique to this product type and is the same as PET plastics used to package other common foods and beverages.

(No “diethylhexyl adipate” (DEHA) is used in PET manufacturing. For details pl. refer Pl. refer FAQ of this note.)

The Environmental Protection Agency (EPA) at one time included DEHA on the list of toxic chemicals maintained under the federal Emergency Planning and Community Right-to-Know Act (EPCRA), but they have since removed it from the list because DEHA "cannot reasonably be anticipated to cause cancer, teratogenic effects, immunotoxicity, neurotoxicity, gene mutations, liver, kidney, reproductive, or developmental toxicity or other serious or irreversible chronic health effects." And, according to the International Agency for Research on Cancer (IARC), diethylhexyl adipate "is not classifiable as to its carcinogenicity to humans."

Some organizations (including the IBWA) do recommend that plastic water bottles be used only once before recycling, but not because re-use is likely to cause carcinogenic compounds to leach from the plastic bottles into the liquids they hold. The concern is that people (particularly children) can too easily spread and ingest bacteria from their hands and mouths by re-using bottles
without properly washing them or allowing them sufficient time to dry.

FREQUENTLY ASKED QUESTIONS (FAQ) on PET

Will a plastic bottle leach harmful substances into water if I reuse it?

Most convenience-size beverage bottles sold in the U.S. are made from polyethylene terephthalate (PET). The FDA has determined that PET meets standards for food-contact materials established by federal regulations and therefore permits the use of PET in food and beverage packaging for both single use and repeated use. FDA has evaluated test data that simulate long-term storage and that support repeated use.

The toxicological properties of PET and any compounds that might migrate under test conditions have also been well studied. The results of these tests demonstrate that PET is safe for its intended uses. (For details, see The Safety of Polyethylene Terephthalate.)
What about the student project that claimed to have found unhealthy compounds in water samples from reused bottles?

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The subject of a widely circulated e-mail hoax, these claims stem from a University of Idaho student's masters thesis that was promoted in the media but was not subject to peer review, FDA review or published in a scientific or technical journal.

While the student project may have been suitable work for a masters thesis, it did not reflect a level of scientific rigor that would provide accurate and reliable information about the safety of these products. Fortunately for consumers, FDA requires a much higher standard to make decisions about the safety of food contact packaging.

But I read that the student's project found carcinogens?
The student's thesis incorrectly identifies di(2-ethylhexyl) adipate (DEHA), a plastics additive, as a human carcinogen. DEHA is neither regulated nor classified as a human carcinogen by the U.S. Occupational Safety & Health Administration, the National Toxicology Program or the International Agency for Research on
Cancer, the leading authorities on carcinogenic substances.

In 1991, on the basis of very limited data, the U.S. Environmental Protection Agency classified DEHA as a "possible human carcinogen." However, in 1995, EPA again evaluated the science and concluded that "...overall, the evidence is too limited to establish that DEHA is likely to cause cancer."

Further, DEHA is not inherent in PET as a raw material, byproduct or decomposition product. DEHA is a common plasticizer that is used in innumerable plastic items, many of which are found in the laboratory. For this reason, the student's detection of DEHA is likely to have been the result of inadvertent lab contamination. This is supported by the fact that DEHA was detected infrequently (approximately 6% of the samples) and randomly, meaning that the frequency of detection bore no relationship to the test conditions.

Moreover, DEHA has been cleared by FDA for food-contact applications and would not pose a health risk even if it were present.

Finally, in June 2003, the Swiss Federal Laboratories for Materials Testing and Research conducted a scientific study of migration in new and reused plastic water bottles from three countries. The Swiss study did not find DEHA at concentrations significantly above the background levels detected in distilled water, indicating
DEHA was unlikely to have migrated from the bottles. The study concluded that the levels of DEHA were distinctly below the World Health Organization guidelines for safe drinking water.

Is it true that the U.S. Food and Drug Administration (FDA) only allows plastic beverage bottles, such as those made with polyethylene terephthalate (PET), for one-time use?

No, FDA allows PET to be used in food-contact applications, including food and beverage packaging, regardless of whether the packaging is intended for single or repeated use. PET beverage bottles sold in the United States are designed for single use for economic and cultural reasons, not because of any safety concerns with PET.

In fact, refillable bottles made with the same PET resin as single-use bottles are safely reused in a number of other countries. The only difference is that refillable bottles have thicker sidewalls to enable them to withstand the mechanical forces involved with industrial collection and commercial cleaning and refilling operations.

Can freezing a PET beverage bottle cause dioxins to leach into its contents?

This is the subject of another e-mail hoax. There simply is no scientific basis to support the claim that PET bottles will release dioxin when frozen. Dioxins are a family of chemical compounds that are produced by combustion at extremely high temperatures. They can only be formed at temperatures well above 700 degrees
Fahrenheit; they cannot be formed at room temperature or in freezing temperatures. Moreover, there is no reasonable scientific basis for expecting dioxins to be present in plastic food or beverage containers in the first place.

Compiled by :
PET Marketing Technical Services
technical_petmkt@ril.com
Phone: 022 –3032 22012 / 2251 / 2252

Source: http://www.plasticsinfo.org/beveragebottles/faq.html

POINT: Plastics / plastic bags are harmful to plants & the soil

Counter Point:

Plastics protect plant life in multiple ways

Plastics prevent massive deforestation by offering wood substitutes. eg. Furniture, building materials, crates

Plastic pipes are used extensively in Irrigation & Water Management

Flood Irrigation, Sprinkler Irrigation, Micro Irrigation (Drip/Trickle) etc

China uses One million tonnes of PE in agricultural application.

POINT: Plastics are not recyclable

Counter Point: Plastics are 100% recyclable via various routes :

Mechanical recycling : Plastics can be recycled several times into economically useful low cost products eg. Footwear, mats, sewer pipes etc.,

Waste plastics are also recycled without sorting into synthetic lumber / wood products like rails, fencings, posts, benches and land scaping products.

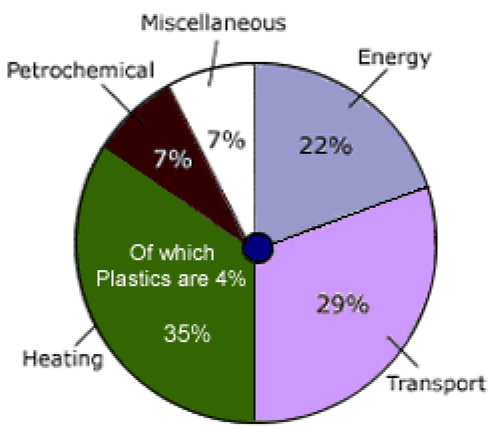
Plastics can be thermally recycled / incinerated to recover energy

Plastics can be chemically recycled to recover monomer for reuse.

In India we already recycle 60% of plastics from both Industry and urban waste streams Vs world average of 20-25%.

POINT: Plastics deplete precious & scarce fossil fuel

Counter Point: The different uses of commercially produced oil.



Plastics use globally only 4% of commercially produced oil. The rest being accounted by transport, energy and others. Infact plastics add value and extend life of fossil fuel instead of burning it directly.

POINT: Plastics are toxic and are not safe for usage

Counter Point: Plastics are used worldover safely for personal care products, packaging of food & medicine, in-vitro medical applications and for child care products.

Toothbrush, toothpaste tubes, shampoo bottle

Milk pouch, edible oil container, ice cream pack

Blister packing - tablets and capsules

Medical disposables - IV bags, blood bags, gloves

Heart valve, hip joint

Toys, diapers

Food and drugs authorities worldwide permit use of different plastics in various applications. Industry needs to adhere to prescribed standards.

POINT: Plastic bags contain plasticizers

Counter Point:

Plastic bags are made from Polyethylene (PE) which is a polymer of pure Carbon & Hydrogen. The material by itself is soft in nature. No plasticizers are used / required for any Polyethylene application including Poly Bags.

The campaign that Plastic bags contain plasticizers is a malicious canard

Plasticizers are used only in PVC Products.

POINT: Plastic bags contain titanium dioxide and lead based components which are toxic & Dyes used in coloured bags cause severe health hazards.

Counter Point:

Most of the pigments used for making bags are organic in nature. Use of lead or cadmium based compounds does not arise at all.

The inorganic pigments used in plastics do not contain lead or cadmium.

Organic pigments which are used are compatable with the polymer to get bonded. They cannot leach out.

Industry has accepted to use natural unpigmented carry bags for food contact applications. Recycled bags will be coloured (using BIS approved pigments) for other applications.