ENVIS

Management of Plastics, Polymer Wastes and Bio-polymers and impact of Plastics on the Eco-system

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Indian Centre for Plastics in the Environment

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RECYCLING OF PLASTICS

Plastics have shown rapid and visible growth compared to other materials. This is primarily because of substitution of other materials with plastics as well as its application in new areas. This is because of the materials' durability and versatility. The world's annual consumption of plastic materials has increased from around 5 million tonnes in the 1950s to nearly 150 million tonnes today.

Plastic Waste and the Indian Dimension

Item	World	India
Per capita consumption	18 kg	4 kg
Recycling (Machine, Industrial & Consumer waste)	15-20%	60%
Plastics in solid state	7%	0.5-2%

From the above table it is found that India is amongst the lowest in generation of waste. India also has amongst the lowest per capita consumption of plastics and consequently, the plastic waste generation is very low as seen in the table. The above table indicates that India has a minimal presence of plastics in solid waste. However, the recycling rate of plastics is amongst the highest in the world.

With growing environmental awareness and the public focused on the increasing amount of plastic waste as a result of increased usage, an effective recycling system is the need of the hour. Today, the recycling industry has also grown exponentially with the Indian Recycling Industry having a turnover of Rs 50 billion with approximately 2,300 recycling units employing 3 lakh people.

Proper disposal and collection of solid waste and management of that waste in an economically and environmentally sustainable way is a viable option in lieu of the traditional methods of landfills. Integrated Waste Management system includes value addition to the waste: energy produced from waste, variable rate charging to consumers, public education and shared responsibility. This requires the participation of producers, consumers and local governments. The results include increased recycling and energy recovery.

Any effective waste management technique usually involves:

Reduce : Source reduction
Reuse : Multiple use of products
Recycle : Mechanical recycling
Recover : Feedstock & energy

We are going to focus on Mechanical Recycling as a key step in dealing with plastic waste management in India.

Mechanical Recycling

The World Resources Foundation recommends that Mechanical Recycling is the best option for the developed world. India too can reap the benefits of recycling due to the following advantages:

- It provides employment opportunities
- No emission of gases or effluents
- Offers ample Business opportunities
- Economical Utility products and
- Low cost Supply Chain

How are plastics mechanically recycled?

They are collected, sorted and baled into like materials, which are then washed and shredded into flakes and then placed into an extruder. The plastic is melted, pushed through

India has one of the highest plastics recycling rates in the world with almost 60% of plastic waste being recycled for its intrinsic value.

the extruder, cooled and pressed through a die and chopped or pelletised into granules almost the same as virgin material.
It is then ready for remaking into new products.

Plastics recycling technologies are generally placed into four categories.
Primary
Secondary
Tertiary
Quaternary

Primary

Although much of clean thermoplastic manufacturing waste is recycled in a primary sense, remelted and reformed, primary recycling by these methods is at present not a viable economic option for the vast majority of post-consumer plastics or manufacturing wastes that are contaminated. Removing contaminants and separating similar plastic resins has been difficult and costly.

Secondary

This technology involves manufacturing of products, with material properties inferior to the original products.

Tertiary

Processes that utilize waste plastics by altering a polymer's chemical structure to manufacture monomers, basic chemicals, or fuels. Tertiary recycling is a range of technological approaches applicable to a wide range of plastic wastes, producing a variety of products that may be substituted for different materials. Tertiary recycling can be divided into three basic categories:

Depolymerization processes*: This requires clean, single-resin plastic wastes and produces monomers or other basic inputs that can be used in the production of new and stainless kind resins.*

Tertiary processes*: They are applicable to mixed and contaminated plastics waste streams and utilize waste plastics as a substitute for crude oil in refinery operations and as substitutes for basic chemicals in refinery recycling and pyrolysis.*

Dissolution processes*: These can be applied to mixed and contaminated waste streams to selectively remove individual resins or classes of resins for further processing and recycling.*

With the exception of Dissolution, Tertiary recycling achieves closed loop recycling. Most of these technologies are in the developmental stage, and with economic viability they will substantially advance recycling efforts. Some Tertiary technologies allow recovery of nearly pure polymers or their constituents from a waste mixture, and the reaction conditions destroy contaminants, allowing the recovered material to be used in food-packaging applications.

Quaternary

The incineration of plastics takes place with heat recovery, either as part of the municipal waste stream or as segregated waste.

Thermal Degradation of Plastics during Recycling

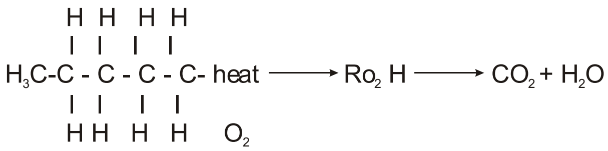
Plastics go through several heating processes during Mechanical Recycling. Different plastics react differently to thermal processes. Polymers get degraded in presence of heat and the presence of oxygen with heat further accelerates the degradation process. But during recycling, there is neither emission of any toxic gas nor any chemicals are produced. Thermal degradation of some common plastics like, PE, PP, PVC and PS happen in the following ways:

0 days | 30 days | 55 days

Photo Source: www.degradable.net/ retail/com

Polyethylene (PE)

Thermal degradation of Polyethylene mainly produces carbon dioxide and carbon monoxide. In the presence of atmospheric oxygen and heat, it initially produces hydro peroxides, which ultimately generate carbon dioxide and water.



Polypropylene (PP)

Polypropylene is more prone to thermal degradation as compared to Polyethylene but the degradation process and the end products are similar to PE. Mainly due to thermal degradation in the presence of oxygen, alkyl peroxides and hydro peroxides are produced which ultimately produce carbon dioxide.

Polyvinyl Chloride (PVC)

PVC is adequately stabilized to withstand significant thermal degradation during recycling. Inadequately stabilized PVC releases Hydrochloric Acid during thermal degradation process while recycling. The degraded product exhibits reactions typical of unsaturated Hydrocarbons, and this may be considered as the result of the ejection of chlorine, together with an adjacent hydrogen atom. Thus, it is the polyene structure with conjugated double bonds (dienes) which is generally accepted as the degraded product.

$$(-CHCl-CH2-)_m \longrightarrow -CHCl-CH2-(-CH=CH-CH=CH-)-CHCl-CH2-$$

The liberation of hydrogen chloride (HCl) is twice as great in stationery air compared to that in a current of air. Alongwith HCl, also liberated is water, carbon dioxide and small amount of Hydrogen.

The formation of polyene structure is indicated by a change in colour and results in a great loss of mechanical properties.

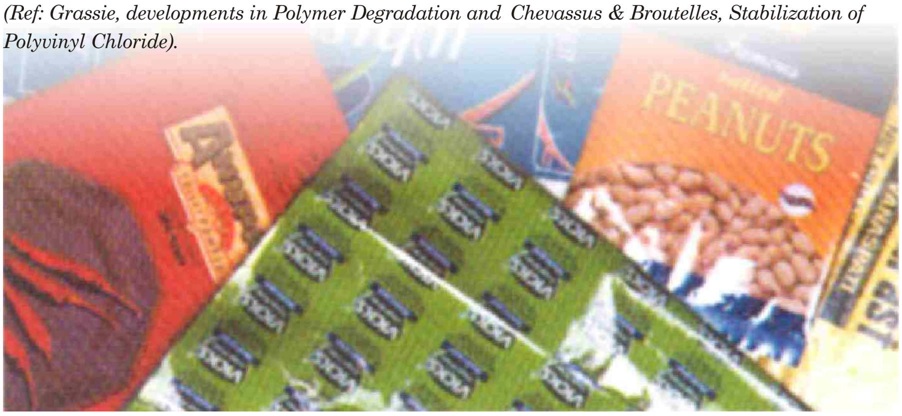
Properly stabilized PVC does not undergo such degradation process.

There is no evidence of cyclisation during processing or recycling of PVC and no chance of formation of Dioxin or any other chemicals.

Polystyrene (PS)

The thermal degradation of Polystyrene proceeds by a free radical chain mechanism. In the absence of oxygen mainly disintegration of polymer chains occurs, which lead to oligomer or monomer. But the amount of monomer emission at <3000C is negligible.

(Ref: Grassie, developments in Polymer Degradation and Chevassus & Broutelles, Stabilization of Polyvinyl Chloride).



Steps involved in the process of Mechanical Recycling

COLLECTION: Plastics are first recovered from the waste stream and are either brought to a centralized collection point or are picked up by a hauler from designated waste containers. Rag pickers also collect these from municipality dustbins from where they are taken to handlers.

HANDLING: Then, the handlers sort the plastics from the waste, code them and then densify them.

SORTING: Plastics are separated from other materials like steel, aluminium, rubber wastes etc. They are also sorted by resin types- e.g. PET and HDPE plastic materials are separated before they are processed further. This is done manually in India while in developed countries it is done by using an automatic separator that uses infra-red identification or X-ray to identify plastic waste by resin type or color. Labels, caps and rings too are separated from plastic bottles.

CODING: To combat the recycling problem posed by the need to separate different plastics, many manufacturers have adopted a coding system. Containers are stamped with a code indicating the type of plastic from which they are made. Coding makes it possible to sort containers in the recycling process, if they are made of a single type of plastic.

DENSIFICATION: It takes a small quantity of plastic to produce a large volume of items. To avoid the high shipment costs arising from the high Volume to Weight ratio of plastic products, the handlers densify the plastics. This is generally done using Baling and at times, by granulating or grinding the plastics depending upon the market specification.

RECLAMATION: This is when the sorted and densified plastic is converted to flakes or pellets that can be used to manufacture new items. The process of flaking involves granulating it to convert it into small uniform sized chips of material. However, for obtaining clearer material, these flakes are washed, dried and then pelletized. The process of pelletizing involves melting the plastic, extruding it into thin strands and then chopping them into small uniform pieces.

END-USE: The pelletized or flaked plastic can then be sold to the manufacturers of recycled products. From bottles and containers, clothing, automotive accessories, bags, bins, carpet, plastic lumber, film and sheet to hospital supplies, houseware, packaging, shipping supplies, toys are recycled.

Although the above process may seem very simple and straightforward, it poses unique recycling challenges. Recycling plastics is difficult because the plastic waste that comes through is a mix of plastics having different properties. Separating plastics poses problems for the recycling industry. Multi layer packaging also makes it difficult to isolate plastics of one kind as it involves layers of different plastics fused into one container.

India has many success stories in the use of recycled plastics for commercial uses. Thus conversion of automobile battery cases to moulded Luggage, milk film to Barsati film (hamlet covers), plastic woven sacks (PWS) to Niwar Patti are just a couple of the numerous applications made in a country famous for maximum plastics recycling in the world.

Sources of Plastic Waste for Recycling:

Sources of plastic waste can be in houses, industrial products and/or consumer waste.

Machine	Industrial	Consumer
Runners	Barrels	Milk Pouch
Flashes	Crates	Carry bags
Defective articles	Films	Cups/glasses
Purging	Jerry cans	Buckets/mugs
Sweepings	Rotomoulded tanks	Pens
	Cement bags	Mats
	Tarpaulins	Luggage
		TV cabinets
		Footwear
		Films from various consumer packs

Commercial Uses of Recycled Plastics

Name of plastic	Some uses of virgin plastic	Some uses of recycled plastic
PET	Soft drink and mineral water bottles	Multi-layer soft drink bottles, carpet fibres, fleecy jackets
HDPE	Raffia, knitted fabrics monofilaments, nets L-ring barrels, jerry cans, pressure pipes for potable water / gas, housewares, packaging film, luggage, toys	Waste bins, detergent bottles, crates, agricultural pipes, kerbside recycling crates. Plastic lumber, plant pots, traffic cones, toys, outdoor furniture
Rigid PVC	Potable water pipes / pipe fittings, doors and windows, office partitions, window profiles, calendered film for medical tablet packaging, bottles for toiletries	Detergent bottles, tiles, cooling tower frills
Flexible PVC	Wires & cables, shoes/ shoe soles, garden hoses, irrigation hoses, blood bags and medical tubings, upholsteries - tiles	Hose inner core, industrial flooring. shoes / shoe soles
LDPE	Heavy duty/general purpose, packaging bags, cable coating, extrusion coating, various substrates for packaging applications, wide width film for canal lining and cap covers for food storage, milk pouches	Packaging and plant nurseries, bags
PP	Raffia, monofilament, ropes, industrial mouldings, disposable syringes, automobile applications, automotive batteries, furniture, luggage, caps and closures, thermowares, integrally hinged boxes, washing machines	Composite bins, crates, niwar, straps
PS	Yoghurt containers, audio/ video Cassettes, plastic cutlery	Coat hangers, office accessories, rulers, video/CD boxes

News You Can Use

INDIA

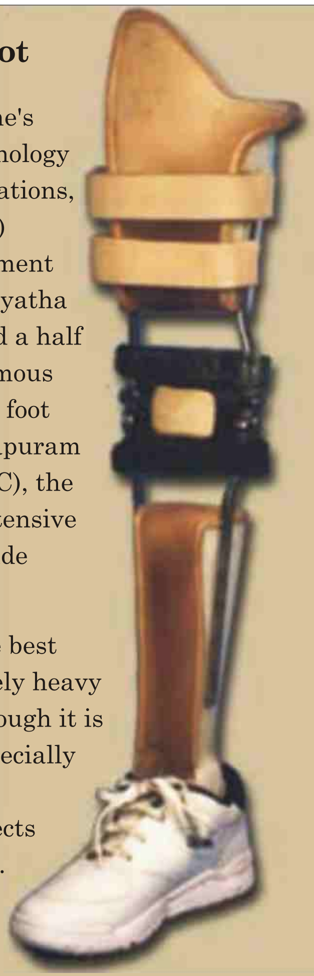
Biodegradable plastics a dream product for the environmentalists

The term 'plastics' covers a multitude of synthetic substances, which are lightweight and easy to mould into various shapes. While a majority of chemical compounds have small molecules, often containing less than ten atoms, plastics consist of molecules containing tens of thousands of atoms. These are very long chained compounds of carbon known as polymers. Their uses and applications are far too many and it would not be an exaggeration to state that each one of us uses several plastic polymer products in our daily life.

Besides other uses, it is their easy availability in transparent films, which have led to their tremendous popularity amongst the consumers and which may also be the source of a serious environmental hazard. Plastics per se are not harmful as they are inert and remain neutral to the elements in our environment. However, the threat to the environment is caused basically on account of lack of an efficient collection and disposal system. These days plastics are most commonly used in the form of carry bags and as packaging material, both of which are non-degradable.

However, in the absence of any proper collection and disposal system, they are usually strewn around, littering the surroundings and keep piling up on garbage heaps. It is this accumulation of multi-coloured plastic bags, which are non-degradable, and appearing as eyesores, which often choke the sewage pipes leading to unhygienic conditions besides causing accumulation of methane gas as a potential explosive.

Space research helps Jaipur Foot



In keeping with the Indian space programme's thrust on exploiting the fruits of space technology for national development in all its manifestations, ISRO (Indian Space Research Organisation) recently signed a technology transfer agreement with the Bhagvan Mahavir Vikalanga Sahayatha Samithi of Jaipur which for the last two and a half decades has been active in providing the famous Jaipur Foot to amputees, for Poly Urethane foot technology developed by the Thiruvananthapuram based Vikram Sarabhai Space Centre (VSSC), the largest Indian space establishment with extensive and sophisticated facilities for building a wide variety of launch vehicles.

Though Jaipur Foot is considered one of the best artificial limbs now in use, it is comparatively heavy and cumbersome to wear. Consequently, though it is acceptable for the lower limb amputees, especially for the poor in India and other third world countries, the Jaipur Foot is marred by defects and deficiencies, which need to be corrected. Moreover, its production process was naggingly slow and highly labour intensive. Because its manufacturing involves the use of substances like wood, pipes and tyre cord, it is not always possible to ensure uniform quality.

It was against this backdrop that ISRO hit upon the idea of using Poly Urethane polymers (used in the production of rocket fuels and cryogenic insulation) as a durable and more efficient substitute for rubber and wood in the ankle block of the Jaipur Foot. Incidentally, Jaipur Foot can easily be produced by reacting a polyol and isocyanate.

According to sources in ISRO, the improved Jaipur Foot which has the rubber and wooden ankle substituted by the more durable Poly Urethane micro cellular foams is light, and could be produced in large numbers in a short period with improved quality, providing added comfort, gait and durability for the amputees.

Poly Urethane packed Jaipur Foot has been found to be biomechanically advantageous as far as comfort and injury prevention are concerned. Moreover, this modified artificial foot has a high slip resistant feature in comparison to conventional artificial fittings. This means that the amputees using a Poly Urethane fortified Jaipur Foot can walk safely on any type of surface. This foot moulded with cosmetically attractive covers mimicking skin has been found to be readily acceptable to amputees. With the Bhagvan Mahavir Vikalanga Sahayatha Samithi getting the technology free of cost, production of Poly Urethane based Jaipur Foot could be taken up on a large scale for the benefit of poor amputees in India and other Third World countries.

(Source: The Tribune, New Delhi)

We now have biodegradable plastics, which are completely identical to the conventional plastics. A minor change has been introduced in their chemical structure, which helps in their decay on being left in the open and exposed to natural elements over a period up to three months.

Development of biodegradable plastics is a frontier area of technology and has been found to be particularly useful for manufacture of polybags, carry bags and other similar packaging material. What is important is that these biodegradable polybags, made out of the specially developed films, have the same tensile strength, the same transparency, and the same feel as that of the conventional polybags. They have been recently introduced in India and are finding encouraging responses from amongst environmentally conscious bodies. Also available in food grade quality, they have been certified to be so by the National Institute of Toxicology at Pune as also the National Chemical Laboratory, Pune. In Europe, advanced and environmentally conscious countries like Sweden and Germany have taken to the use of Biodegradable Plastics in a big way. These have also been introduced in US, Canada and Japan. Since the degradation and ultimate composting of the biodegradable plastic film takes place through a photo oxidation process in sunlight, over a period of three months, the plastic bags have a limited shelf life, but then they are designed to be so. In India they have already been introduced commercially in the market, but it may take some time before the change over to the new technology takes place-but once it does, we are bound to have a far healthier and a cleaner environment. *(Source: www.tribuneindia.com)*

Eco-friendly domestic fuel from plastics

Scientists from Sriram Institute of Industrial Research (SIIR) have developed an environment friendly domestic fuel, which has a higher heating value than wood, coal and other biomass fuels.

Called 'Uplas' (cow dung cake), the fuel burns with no toxic gas emissions and gives uniform flame, and it can be used in the conventional ovens (chulhas) and tandoors. Plastic 'uplas' have been found to be very cost effective and efficient for utilisation in the domestic sector in rural areas. They are marketable solid fuel products made of plastics, unsuitable for recycling, mixed with cow dung or other combustible material.

Since plastics are derived from petroleum products, they are a good reservoir of energy and burning of most of them has been found to be environment friendly. This conversion is an economically attractive option for plastic scrap utilisation. Utilisation of non-recyclable plastics can help a great deal in solid waste management, say scientists.

(Source: Newstime, Hyderabad, July 3, 2003)

INTERNATIONAL NEWS

Carnegie Mellon University(CMU) team's work could lead to a new plastic that breaks down

Few things made by humans are quite so long-lived as plastic. Sure, some items end up in the recycling bin, but the vast majority of plastic cups, bags, auto body parts, computer housings and DVDs will be around for the long haul. Chemists at Carnegie Mellon University, however, are exploring a new method of making polymers that promise to be rapidly degradable by light, by acids and bases in water and, presumably, by bacteria.

It's a method applicable to virtually anything made by the process known as radical polymerization, which accounts for about half of all polymers in use today, including plastic foam, vinyl, latex paints, grocery bags, Plexiglas, and automobile coatings. Studies are just beginning, however, on questions about how easily degradable these polymers might be and the cost of making them, at least initially, may limit them to specialized applications.

All polymers are basically long, long chains of repeating chemical units, called monomers. The CMU team, headed by Krzysztof Matyjaszewski, essentially has found a way to introduce weak links into the chains and to space those links evenly through the chains. These added links are susceptible to degradation by both light and by water-based chemical processes, Matyjaszewski said. And if the spacing is done properly, the remaining bits of chain should be small enough to be seen as food by bacteria, making the polymer biodegradable.

Though it might be possible to make a plastic foam cup that, when tossed on a roadside, would degrade within weeks instead of remaining as litter, Matyjaszewski anticipates the more likely use, at least initially, will be for biomedical applications, such as drug delivery. The polymers might allow for precisely timed release of medications, or might be designed to target specific tissues. It should be possible to adjust the speed at which different products degrade, he said, with some items disintegrating within minutes or hours, while others might be designed to last a decade or more.

The most commercially notable to date is polylactic acid, or PLA, a polymer derived from corn. A joint venture of Dow Chemical and agricultural giant Cargill called Cargill Dow is now producing plastics made from PLA. DuPont also is working on a corn-derived plastic. The work at CMU has been under way for about a year now. Matyjaszewski, who directs the Center for Macromolecular Engineering, and Im Sik Chung, a postdoctoral associate, reported on one such degradable polymer this spring in the journal Macromolecules. They modified a clear, hard plastic polymer known as poly (methyl methacrylate) or PMMA, to chemists, but best known to consumers as Plexiglas or Lucite.

(Source: http://www.post-gazette.com/healthscience/20030721polymersci2p2.asp)

The History of Plastics


Alexander Parks

	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.

Director General of CIPET, (Chennai) Dr S K Verma's views on Plastics Recycling

What is the level of plastics recycling in India and how does it compare to developed countries as an organised industry?

Estimates reveal that around 2500 mechanical recycling industrial units are spread over the length and breadth of our country involving around 3 lakh people. About 1.2 million tonnes of polymers are recycled in India every year.

In the developed countries the recycling industry is better organised and scientific technologies of recycling with the use of proper recycling machinery are practiced, as compared to India mainly due to the following reasons:

- Methodical collection of plastics waste, segregation of waste at source
- Organised clusters of recyclers
- Disciplined society - no litter of plastics waste
- Low density of population, better infrastructure for waste management of all type of wastes.

Employment opportunities-What the future has to offer?

The global consumption of all types of polymers, which was around 70 million tonnes in 1990, has increased to around 145 million tonnes in the year 2001 and in India, the consumption of plastics has increased from 400 KT to 4 million tonnes in the last decade.

It is expected that the demand for plastic products will increase substantially in areas of packaging, automotive, electrical & electronic goods, telecommunication & IT, consumer/household goods and toys, medical and healthcare, agriculture and building construction.

Reckoning the tremendous potential that exists, it would not be exaggerated to state that the plastics sector offers a plethora of opportunities for self employment as well as carrier opportunities in the various disciplines of plastics engineering and technology not only in India, but also globally.

Today, the plastics industry is considered as the 'Sunrise Industry' and has maintained its growth in the last three decades. The plastics sector has emerged next to the information technology sector, and plastics technology has played the role of cog in the wheel in the development and sustainable growth of information technology too.

RECENT DEVELOPMENTS

Now, Blankets from used PET bottles

Plastic bottles are being used ubiquitously for packaging cosmetics, pharmaceuticals, edible oils, liquors, food etc. Many more products are being added to the list by the day. But not many are aware that these so called plastic bottles are made from a polymer similar to the ones used in making the polyester fibres, which we all have been using in clothing ourselves for the last few decades.

SASMIRA (Silk & Art Silk Mills' Research Association), Mumbai has been working on a technology that would convert used PET bottles - which have become so abundant and necessary in our lives today - into blankets which are 30% warmer. The PET bottles can be converted directly into spinnable flakes and do not need to be pelletised. These blankets have been found to be…

- Cost effective - at least 50-60% cheaper
- Warmer - 30% more than acrylic blankets
- Durable - Expected to last 4-5 seasons because their colour, fastness to light, water and rubbing is excellent
- Weight - range of weights are available
- Production on a large-scale is possible