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General Article

PLASTICS AND THEIR ROLE IN ECONOMIC DEVELOPMENT OF INDIA

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ABSTRACT

The first man made plastic was created by Alexander Parkes called Parkesine from cellulose. Plastics are usually synthetic, most commonly derived from petrochemicals but many are partially natural. A plastic is primarily made up of binder, plasticizer, fillers, pigments and additives. Plastics are of two types namely thermoplastics and thermosets. The one critical factor that plagues the Indian plastic industry is the common perception that plastics are not environmentally friendly. This is mainly due to poor awareness about the energy saving properties of plastics and the benefits to industries that utilize plastics. India is the highest recycler of plastics. The Indian plastic industry is promising industry and is creating new employment opportunities for people of India. The per capita consumption of plastic products in India is growing. The Government of India is trying to set up the economic reforms to elevate and boost the plastic industry by joint ventures, foreign investments and entrepreneurs are trying to provide high quality plastic products so that it becomes a booming industry.

Key words: Plastic, development, biodegradable and employment.
JEL Classification: F63, J21

INTRODUCTION

The first man-made plastic was created by Alexander Parkes who publicly demonstrated it at the 1862 Great International Exhibition in London. The material called Parkesine was an organic material derived from cellulose that once heated could be molded, and retained its shape when cooled. John Wesley Hyatt invented celluloid as a substitute for the ivory in billiard balls in 1868. However, the material was not strong enough to be used as a billiard ball, until the addition of camphor, a derivative of the laurel tree. The new celluloid could be molded with heat and pressure into a durable shape, later celluloid became famous as the first flexible photographic film used for still photography and motion pictures. By 1900, movie

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film was an exploding market for celluloid. After cellulose nitrate, formaldehyde was the next product to advance the technology of plastics. Around 1897, efforts to manufacture white chalkboards led to casein plastics. In 1899, Arthur Smith received British Patent 16275, for phenol-formaldehyde resins for use as an ebonite substitute in electrical insulation. However, in 1907, Leo Hendrik Baekeland improved phenol-formaldehyde reaction techniques and invented the first fully synthetic resin to become commercially successful, trade named Bakelite (Du Bois, 1972).The various times line precursors of plastics discovered from time to time are presented in Table 1 reveals the development of superior quality plastics.

Table 1: Timeline-Precursors of plastics

Year of discovery	Name of material	Scientist
1839	Natural Rubber- method of processing invented Polystyrene (PS) discovered	Charles Goodyear Eduard Simon
1843	Gutta-Percha	William Montgomerie
1856	Shellac	Alfred Critchlow, Samuel Peck
1856	Bois Durci	Francois Charles Lepag
1862	Parkesine	Alexander Parkes
1863	Cellulose Nitrate or Celluloid	John Wesley Hyatt
1872	Polyvinyl Chloride (PVC)	first created by Eugen Baumann
1894	Viscose Rayon	Charles Frederick Cross, Edward John Bevan
1908	Cellophane ®	Jacques E. Brandenberger
1909	First true plastic Phenol-Formaldehyde trade name Bakelite	Leo Hendrik Baekeland
1926	Vinyl (PVC)	Walter Semon invented a plasticized PVC
1927	Cellulose Acetate	-
1933	Polyvinylidene chloride or Saran (PVDC)	Accidentally discovered by Ralph Wiley, a Dow Chemical lab worker
1935	Low-density polyethylene (LDPE)	Reginald Gibson and Eric Fawcett
1937	Polyurethanes trade name Igamid for plastics materials and Perlon for fibers	Otto Bayer and co-workers discovered and patented the chemistry of polyurethanes
1938	Polytetrafluoroethylene (PTFE) trade name teflon	Roy Plunkett
1939	Nylon and Neoprene considered a replacement for silk and a synthetic rubber respectively	Wallace Hume Carothers
1941	Polyethylene Terephthalate (PET)	Whinfield and Dickson
1942	Unsaturated Polyester (PET)	Patented by John Rex Whinfield and James Tennant Dickson
1951	High-density polyethylene (HDPE) trade name Marlex	Paul Hogan and Robert Banks
1953	Saran Wrap	Dow Chemicals
1954	Styrofoam a type of foamed polystyrene foam	invented by Ray McIntire for Dow Chemicals
1970	Thermoplastic Polyester this includes trademarked Dacron, Melinex and Tetoron	*
1978	Linear Low Density Polyethylene	*
1985	Liquid Crystal Polymers	*

Information not available

A plastic material can be synthetic or semi-synthetic organic solids that are moldable. Plastics are typically organic polymers of high molecular mass, but they often contain other substances. They are mostly derived from petrochemicals, but many are partially natural. The term was derived from the Greek plastikos, which means fit for molding. Plastics are a wide variety of combinations of properties when viewed as a whole (Angell 1991). They are used for shellac, cellulose, rubber, asphalt and synthetically manufacture items such as clothing, packaging, automobiles, electronics, aircrafts, medical supplies, and recreational items. One way plastics changed the world was in cost. It was so much cheaper to manufacture than other materials and the various ways it could be used was staggering. For instance, the use of polymers, which are substances with a higher molecule mass and which have a large number of repeating units, is common today. There are naturally occurring polymers, which include starches, cellulose, proteins, and latex. Polymers are molecules that join together like a chain with one or more monomers. The polymers are changed depending on the incorporation of these monomers. If the atoms in the monomers are combined to form the polymer, it is called an addition polymer. When some of the atoms of the monomers are released into small molecules, as in liquid, then the polymer is called a condensation polymer. A double bond between carbon atoms is most common in addition polymers (Arnold, 1968).

Composition

Almost invariably, organic polymers mainly comprise plastics. The vast majority of these polymers are based on chains of carbon atoms alone or with oxygen, sulfur, or nitrogen as well. The backbone is that part of the chain on the main "path" linking a large number of repeating units together. This fine tuning of the properties of the polymer by repeating units molecular structure has allowed plastics to become an indispensable part of twenty first-century world. A plastic is principally made up of binder, plasticizers, fillers and pigments and other additives. The binder gives a plastic its main characteristics and usually its name. Thus, polyvinyl chloride is the name of a binder as well as the plastic into which it is made. Binders may be natural materials, for example cellulose derivatives, casein, or milk protein, but are more commonly synthetic resins. In either case, the binder materials consist of very long chainlike molecules called polymers.

Classification

Thermoplastic polymers and thermosetting plastics are two types of plastics. Thermoplastics do not undergo chemical change in their composition when heated and can be moulded again and again. Examples include polyethylene, polypropylene, polystyrene, polyvinyl chloride, and polytetrafluoroethylene. The common thermoplastic ranges from 20,000 to 500,000 amu (Ungar, 1993). They are usually rigid glasses at low temperature and flexible elastomers above Tg (the glass transition temperature); and they may actually melt at a still higher temperature. Their properties like tensile strength, elongation at break and flexural modulus and uses (Miller and Dekker, 1996) are determined partially by whether Tg is above or below the temperature during use (Table 2). Thermosets are assumed to have infinite molecular weight. These chains are made up of several thousand repeating molecular units. Thermosets can melt and take shape once after they have solidified. In the thermosetting process, an irreversible chemical reaction occurs for instance the vulcanization of rubber. Before heating with sulfur, the polyisoprene is a tacky, slightly runny material, but after vulcanization the product is rigid and non-tacky. The biodegradable plastics are plastics that will decompose in natural aerobic (composting) and anaerobic (landfill) environments (Anonymous, 2013).

Table 2: Types of plastics, properties, products and applications of some commercially important plastics

Polymer family and type	Tensile strength (MPa)	Elongation at break (%)	Flexural modulus (GPa)	Typical products and applications
THERMOPLASTICS				
Carbon-chain				
High-Density Polyethylene (HDPE)	20–30	10–1,000	1–1.5	Milk bottles, wire and cable insulation, toys
Low-Density Polyethylene (LDPE)	8–30	100–650	0.25–0.35	Packaging film, grocery bags, agricultural mulch
Polypropylene (PP)	30–40	100–600	1.2–1.7	Bottles, food containers, toys
Polystyrene (PS)	35–50	1–2	2.6–3.4	Eating utensils, foamed food containers
Acrylonitrile-Butadiene-Styrene (ABS)	15–55	30–100	0.9–3.0	Appliance housings, helmets, pipe fittings
Polyvinyl Chloride, Unplasticized (PVC)	40–50	2–80	2.1–3.4	Pipe, conduit, home siding, window frames
Polymethyl Methacrylate (PMMA)	50–75	2–10	2.2–3.2	Impact-resistant windows, skylights, canopies
Polytetrafluoroethylene (PTFE)	20–35	200–400	0.5	Self-lubricated bearings, nonstick cookware
Heterochain				
Polyethylene Terephthalate (PET)	50–75	50–300	2.4–3.1	Transparent bottles, recording tape
Polycarbonate (PC)	65–75	110–120	2.3–2.4	Compact discs, safety glasses, sporting goods
Polyacetal	70	25–75	2.6–3.4	Bearings, gears, shower heads, zippers
Poly ether ether ketone (PEEK)	70–105	30–150	3.9	Machine, automotive, and aerospace parts
Polyphenylene Sulfide (PPS)	50–90	1–10	3.8–4.5	Machine parts, appliances, electrical equipment
Cellulose Diacetate	15–65	6–70	1.5	Photographic film
Polycaprolactam (Nylon 6)	40–170	30–300	1.0–2.8	Bearings, pulleys, gears
THERMOSETS				
Heterochain				
Polyester (Unsaturated)	20–70	<3	7–14	Boat hulls, automobile panels
Epoxies	35–140	<4	14–30	Laminated circuit boards, flooring, aircraft parts
Phenol Formaldehyde	50–125	<1	8–23	Electrical connectors, appliance handles
Urea and Melamine Formaldehyde	35–75	<1	7.5	Countertops, dinnerware
Polyurethane	70	3–6	4	Flexible and rigid foams for upholstery, insulation

Biodegradation of plastics occurs when microorganisms metabolize the plastics to either assimilable compounds or to humus-like materials that are less harmful to the environment (Birley *et al*., 1988). They may be composed of either bioplastics (Watimo *et al*., 2001), whose components are derived from renewable raw materials, or petroleum-based plastics which contain additives. Biodegradable plastics degrade upon exposure to sunlight, water, bacteria, enzymes, wind abrasion, and in some instances rodent pest or insect attack are also included as forms of biodegradation or environmental degradation.

Table 3: Different types of polymers and their uses

Name and Description	Uses
Polyglycolic acid (PGA) -Hydrolysable polyhydroxy acid	Controlled drug releases; implantable composites; bone fixation parts
Polylactic acid (PLA)-Hydrolysable polyhydroxy acid; polymers derived from fermenting crops and dairy products; compostable	Packaging and paper coatings; other possible markets include sustained release systems for pesticides and fertilizers, mulch films, and compost bags
Polycaprolactone (PCL)-Hydrolysable; low softening and melting points; compostable; long time to degrade	Long term items; mulch and other agricultural films; fibers containing herbicides to control aquatic weeds; seedling containers; slow release systems for drugs
Polyhydroxybutyrates (PHB)-Hydrolysable; produced as storage material by microorganisms; possibly degrades in aerobic and anaerobic conditions; stiff; brittle; poor solvent resistance	*
Polyhydroxyvalerate (PHBV)-Hydrolysable copolymer; processed similar to PHB; contains a substance to increase degradability, melting point, and toughness; compostable; low volume and costly production	Films and paper coatings; other possible markets include biomedical applications, therapeutic delivery of worm medicine for cattle, and sustained release systems for pharmaceutical drugs and insecticides
Plastic Type	
Vinyl Poly vinyl alcohol (PVOH)-Water soluble; dissolves during composting.	Packaging and bagging applications which dissolve in water to release products such as laundry detergent, pesticides, and hospital washables
Polyvinyl acetate(PVAC)-Water soluble; predecessor to PVOH; has shown no significant property loss during composting tests	*
Polyenlketone (PEK)-Water soluble; derived from PVOH; possibly degrades in aerobic and anaerobic conditions	*

Information not available

Some modes of degradation require that the plastic be exposed at the surface, whereas other modes will only be effective if certain conditions exist in landfill or composting systems. Starch powder is mixed with plastic as a filler to allow it to degrade more easily, but it still does not lead to complete breakdown. Some researchers revealed that genetically engineered bacteria synthesize a completely biodegradable plastic, but this material, such as Biopol, is expensive at present (Bret *et al*., 2011 and Brandl and Puchner, 1992) The German chemical company BASF makes Ecoflex, fully biodegradable polyester for food packaging applications. Biodegradable plastics typically are produced in two forms: **injection molded** (solid, 3D shapes), typically in the form of disposable food service items, and **films**, typically organic fruit packaging and collection bags for leaves and grass trimmings, and agricultural mulch. Different types of biodegradable plastics are polyesters, polyanhydrides, polyvinyl alcohol, most of the starch derivatives like cellulose esters and renewable resource (Polylactic acid) which find use in pharmaceuticals, agriculture and packaging (Table 3). Polylactic acid (PLA) is another completely compostable biopolymer which can fully degrade above 60ºC in an industrial composting facility. Fully biodegradable plastics are more expensive, partly because they are not widely enough produced to achieve large economies of scale (Akiyama *et al.*, 2012).

Plastic Statistics

The one critical factor that plagues the Indian Plastic industry is the common perception that plastic is not environmentally friendly. This primarily is due to the low awareness about the energy saving property of plastics and the benefits to industries that utilize plastics. It is a little known fact that, while India has the lowest per capita consumption in the world, it is the highest recycler of plastics.

Table 4: Pattern of global consumption of plastics

Particulars	Kg per capita
World average	20
North America	90
West Europe	65
East Europe	10
Latin America	18
South East Asia	10
China	12
India	5.0

In India, we recycle 60 percent from both industry and urban waste as compared to the world average of 20-25 percent (Anonymous, 2011).The perusal of Table 4 revealed that world average per capita consumption of plastic was 20 kg. It was noticed that North America has highest consumption of plastics, followed by West Europe, Latin America and China. The corresponding figures are 65, 18 and 12 kg per capita respectively. The consumption in the case of South East Asia and East Europe was 10 kg each per capita. It was found that India has lowest per capita consumption of plastic (5 kg).

Indian Statistics

The Indian plastic processing industry is highly fragmented and comprises 25,000 firms. Barring 10-15 percent of the firms, which can be classified as medium scale operations, all the units operate on a small-scale basis. More than 95 percent of the firms in the industry are partnership, proprietorship or private limited companies. Further, these small companies get significant advantages in taxes.

Table 5: Statistics of plastics industries in India: Current status

Particulars	Unit	Amount/ Quantity
Major raw material producers	No.	15
Processing units	No.	25,000
Turnover (Processing industry)	₹ Crores	85,000
Capital asset (Polymer industry)	₹ Crores	55,000
Raw material Produced	Million metric tonnes	5.3
Raw material Consumed	Million metric tonnes	5.1
Employed Direct/indirect	Million (No.)	3.3
Export Value approx	$ Crores	190
Revenue to Government	₹ Crores	73000

Source: http://www.dnb.co.in

The perusal of Table 5 revealed that there are only 15 major raw material producers which produce 5.3 million metric tonnes of raw material meeting the demand for raw materials which is 5.1 million metric tonnes. There are 25,000 processing units in India which create employment for 3.3million people, exporting worth $190 crores plastic material thereby generating ₹73000 crores of revenue for the government. The processing industry turnover is ₹85000 crores and capital assets in polymer industry up to the tune of ₹55,000 crores. These firms thus provide significant level of competition to the organized sector companies, which combined together are making losses. The organized sector companies thus need to build up significant brand image to survive against the competition from the unorganized sector. The key organized sector players include Nilkamal Plastics Limited and Supreme Industries Limited.

Growth rate of Indian plastic industry

The plastic industry in India symbolizes a promising industry and is creating new employment opportunities for the people of India. The per capita consumption of plastic products in India is growing and is moving towards 2.5 times GDP growth. This potentiality of the market will surely actuate the entrepreneurs to invest in this industry. The Government of India is trying to set up the economic reforms to elevate and boost the plastic industry by joint venturing, foreign investments and entrepreneurs are trying to provide high quality plastic products, so that it becomes a booming industry.

The overall turnover of the plastics processing industry that currently stands at ₹85,000 crores is expected to touch ₹1, 33,245 crores in the year 2015 on the basis of the expected growth of the demand potential to 12.50 MMT from the current 9 MMT. The number of processing units from the current 30,000 is expected to increased to 40,000, a 33 percent growth which will in-turn also increase the employment potential of the sector. Independent studies show that the industry that currently hires more than 3 million people, directly and indirectly, is expected to employ 7 million people by the year 2015.

The growth of the plastics industry has seen the increase in the number of processing units. The exponential growth anticipated over the next three years will see this number go up to 40,000 units in 2015. As of today, just about 10 to 15 percent of these units can be classified as medium scale operations and the rest all operate on a small scale basis. Over 70 percent of the industry is in the unorganized sector.

The plastic industry chain can be classified into two primary segments, viz., the Upstream which is the manufacturing of polymers and the Downstream which is the conversion of polymers into plastic articles. The Upstream polymer manufacturers have commissioned globally competitive size plants with imported state-of-art technology from the world leaders. The Upstream petrochemicals industries have also witnessed consolidation to remain globally competitive. The downstream plastic processing industry is highly fragmented and consists of micro, small and medium units. Presently, 75 percent are in the small-scale sector. The small-scale sector, however, accounts for only about 25 percent of polymer consumption. The industry also consumes recycled plastic, which constitutes about 30 percent of total consumption.

Despite the industry's high growth spanning over a period of over 2 decades and crossing several milestones, Indian plastics industry is yet to realize its full potential. The low level of per capita plastics consumption in India is indicative of the massive growth potential of the plastic industry. India has the advantage of high population and is expected to maintain high economic growth. This should propel India's plastics consumption to new levels in coming years. The consumption of plastic polymers is going to increase from 4.7 to 18.9 million tonnes, turnover of plastic industries from ₹35000 to ₹133245 crores and employment from 2.5 to 9.5 million (Table 6).

Table 6: Vision 2015: Indian Plastic Industry

Particulars	**Unit**	**2005**	**2015**
Consumption of Plastic Polymer @ 2.15 % CARG	Million tonnes	4.7	18.9
Turnover of Plastic Industries	₹ Crores	35000	1,33,245
Employment In Plastic Industry (Direct+ Indirect)	Million (No.)	2.5	9.5
Export of Plastic Products @ 30% CARG	US$ Millions	1900	10215
Contribution of Polymers and Plastic Products to the Exchequer	₹Crores	6200	15990
Requirement of Additional Plastics Processing Machines	No.	45,000	68113

The export of plastic products is going to increase from $1900 to $10215 million and contribution of polymers and plastic products to the exchequer from ₹6200 to ₹15990 crores. There will be additional requirement of plant processing machines in near future. The next two decades are expected to offer unprecedented opportunities for the plastic industry in India. According to a CRISIL the world plastics trade has touched 140 MMT in 2012 and provides a lucrative opportunity for India, but with just a 1.5 percent share in world export volumes, India is not in a position to capture this opportunity.

CONCLUSIONS

The Indian plastic Industry going forward, needs to consolidate and enhance capacity, upgrade facilities and improve productivity and increase utilization of critical plastic applications. India has the advantage of high population and is expected to maintain high economic growth. Last but not the least, the various associations need to come together and put in a concerted effort to join hands to enhance the image and the growth of the Indian plastic industry, create opportunities to demonstrate the industry's capabilities, educate all segments of the society about the benefits of plastics. The associations need to create a positive policy framework with all statutory entities and increase per capita consumption of plastics, encourage exports thereby significantly contributing to national growth.

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