Chapter 1

INTRODUCTION TO FOOD PACKAGING

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From the pre-historic times of hunting and gathering of food through farming and storing foodgrains upto today's impulse buying of food products stacked across supermarket shelves, man has come a long way with regard to ways of finding food for survival and gastronomic pleasure.

It is well recognized that globalization has now made it possible for goods produced in one corner of the globe to be available in another corner. Foods, despite their perishable nature, are no exception. However, what is not well recognized is the fact that it is the modern food preservation and packaging technologies, which are the underlying forces that make foods available thousands of kilometers away from the places of their origin and weeks, months and even years beyond the day of their harvest or production.

The safety and quality of the milk delivered at our doorstep in the humble milk sachet every morning are indeed taken for granted by all of us. We hardly realize that this would not have been possible without the development of refrigeration and pasteurization technologies, availability of cheap plastic-based packaging materials and high-speed form-fill-seal liquid packaging machines and, of course, the efficient logistics of procurement, transportation, storage and distribution. Thanks to the advent of unit packaging of edible oils in functional and cost-effective multilayer plastic pouches, polyjars and PET bottles, the Indian consumer is relieved of the problems of dangerous adulteration, underweighing and uncertain quality that were associated with the earlier practice of loose vending at retail store. The ultimate convenience of off-the-shelf ready-to-eat gourmet meal with assured hygiene and taste and without the hassles of cooking in the kitchen has become affordable due to the development of heat-resistant plastics and retort sterilization technologies.

Availability of safe and wholesome food in sufficient quantities to the burgeoning population is a major issue in a country like India, where nearly a third of the population lives below the poverty line and consequently, suffers either from malnutrition or under-nutrition. Though constant efforts are being made to increase food production, we have to contend with high levels of food wastages resulting from unscientific or inefficient storage practices and inadequate use of preservation and packaging technologies. Food wastage occurs through external contamination, consumption by pests and spoilage. Most of the fresh food supply is perishable because of its moderate to high water content and its nutritious nature. The storage life of juicy fruits, vegetables, fresh meat, seafoods and milk is hardly one to few days at room temperature. Only mature dry plant tissues such as foodgrains, dry peas, nuts, etc., can resist spoilage for extended periods of one year or more, but they are still susceptible to attack by numerous pests.

Food Preservation

Deterioration and spoilage of food are caused by growth of microorganisms, which is the most common cause of spoilage of foods with moderate to high water contents, contamination with external factors like filth, dust, absorption of off-odours, normal respiration in plant tissues, loss or gain of water, autolysis as in the case of fish, chemical reactions like oxidation, physiological disorders like scald in apples, chilling injury and anaerobic respiration of plant tissues and mechanical damage.

The basic aim of food preservation is to prevent undesirable changes in the wholesomeness, nutritive value, or sensory quality of food by economical methods which control growth of micro-organisms, reduce chemical, physical and physiological changes of undesirable nature and obviate contamination. Chemical, biological and physical methods of food preservation exist (Fig. 1.1). Chemical preservation involves the addition of substances like sugars, salts or acids or exposure of food to chemicals,

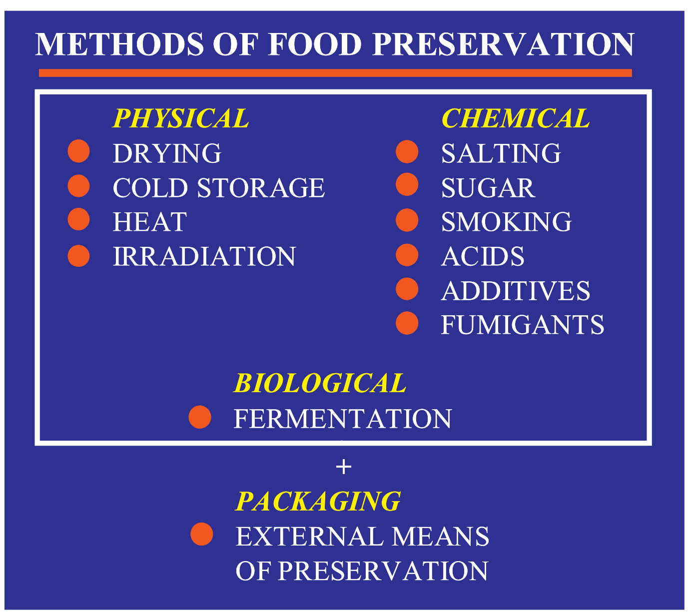

Fig. 1.1. Methods of food preservation

such as smoke or fumigants. Biological methods involve alcoholic or acidic fermentations as in the case of wines, beer and yoghurt. Physical approaches to preserving food include temporary increase in the product's energy level as in the case of heat sterilization and irradiation, controlled reduction of product's temperature (chilling, freezing), and controlled reduction in the product's water content, e.g., drying, concentration. Packaging can also be classified as a physical means of food preservation though it is essentially an external method.

Apart from being a stand-alone method in certain cases, packaging has to be used in combination with all other preservation methods to maintain whatever status that has been achieved in the latter. Thus packaging becomes an essential and integral component of all food preservation methods.

Food preservation and packaging perhaps went hand in hand as civilization progressed. While man learnt the use of salt or spices and techniques like drying, smoking or cooling for preserving food, he also learnt by experience that packaging could help preserve food by protecting it from harmful environmental factors such as air, moisture and light. Though shells, animal skins, earthen pots, ceramic, glass, metallic vessels, woven baskets, chests, kegs, barrels and woven cloth are some of the examples of early packages, modern food packaging as it is known today has its beginnings in the early 1800's with the development of the technique of canning by the French confectioner, Nicholas Appert. He was able to extend the shelf-life of many food products by packaging them into hermetically sealed glass jars and heating them in boiling water for certain time period. Metal cans instead of glass jars came into use soon afterwards. Though the technique was not scientifically understood at that time, it later became known, due to pioneering discoveries of Louis Pasteur, that heat destruction of microorganisms was responsible for the long shelf-life achieved by Appert.

The development of various other modern food preservation techniques such as pasteurization, refrigeration, freezing, use of chemical additives followed. Improved packaging materials such as metal-capped glass jars, tinned steel, enameled tin cans, corrugated paperboard, coated paper and aluminium foil also gradually became available. Plastic materials came into commercial use much later in the 1950's and the decades that followed.

Food Processing Industry and Packaging

In industralised societies, food industry is the largest user of packaging materials. Packaging forms an integral part of food manufacture providing the link between the processor and consumer. In fact, it plays a dominant role in the total manufacturing activity and in marketing. With packaging lines usually occupying 50% of the shop-floor area, packaging and related operations engage about 60% of the work force of 14 million in Indian food industry.

The impetus to food processing industry in India came in the 1970's and 80's. It was during this period that a variety of processed food industries came into being, resulting in the proliferation of packaged foods and changing the face of the neighbourhood grocery store. Commodities stocked in bulk, weighed or measured on the spot and sold started giving way to unit packs – attractively packaged and branded by the manufacturer or simply pre-packed by the grocer himself. Secondary processing came to the fore with many intermediate processed products receiving large patronage from middle income population seeking convenience. The industry was able to grow due to the introduction of plastics based packaging, especially the flexible forms, with diverse functional characteristics and low cost.

The post-liberalisation period of 1990's has seen the most significant development of food industry in India, facilitated by opening up of the economy that encouraged foreign direct investment, eased import restrictions on materials and machinery, which led to setting up of state-of-art packaging and processing industries. This period was also a witness to the growth of organized retailing which in turn provided increased market access to the manufacturing industry, especially the packaged foods. The supermarket culture in which products come to be identified by the packages could penetrate the Indian psyche owing to the developments in packaging technologies especially the plastics-based ones which are highly cost-effective compared to other alternatives. The food processing sector had a market size of Rs 4,60,000 crore in 2003-04 and is expected to grow at 7.3% in the next five years. Food packaging, which is at the very heart of the modern food industry, will probably see a corresponding growth in the coming years.

Packaging, despite its key role in preserving food, preventing wastages and facilitating distribution and marketing of food, is sometimes regarded as a "necessary evil", an unnecessary cost, a drain on resources and an environmental menace. Such a view, undoubtedly an uninformed one, arose since packages are ultimately disposed off while using the product and one is hardly aware of the crucial role that a package plays in delivering the product to the consumer.

The Packaging System

In order to appreciate the place of packaging in the economy, one should try to understand what it is and how it functions. Fig. 1.2 shows the life-cycle of a package from the point of its manufacture through the point of sale upto the final disposal. Based on its functions, packaging can be defined in several ways:

"A coordinated system of preparing goods for transport, distribution, storage, retailing and end-use".

"a means of ensuring safe delivery to the ultimate consumer in sound condition at minimum cost."

"a techno-economic function aimed at minimizing costs of delivery while maximizing sales (and hence profits)".

All these definitions provided by the UK Institute of Packaging have an economic aspect that is of utmost relevance in these days of resource conservation. Packaging is also closely linked to marketing which is defined as identification, anticipation and satisfaction of customer need profitably.

As the definitions show, packaging is

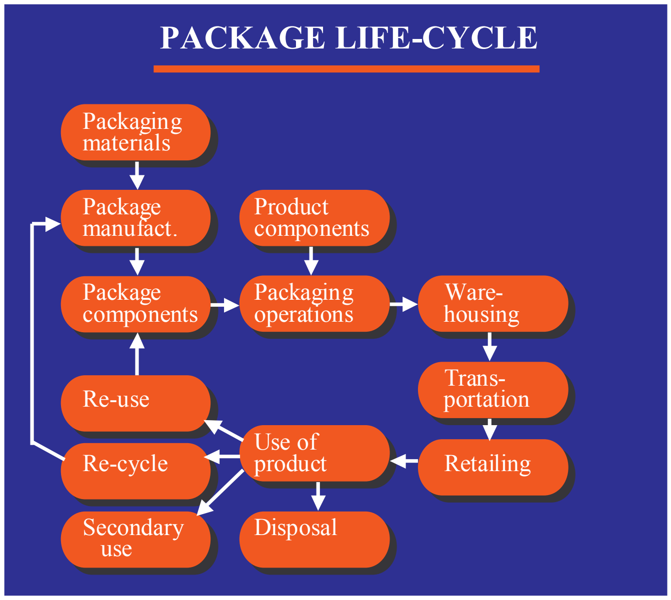

Fig. 1.2. Package life-cycle

much more than "packing" which is nothing but enclosing an article or several of them usually for shipping or delivery. Packaging functions at several levels. At the most basic level — occasionally it is most sophisticated one — is the primary package, which is in direct contact with the product. It provides the initial and usually the major protective barrier. Examples of primary packages include metal cans, glass bottles and plastic pouches. It is frequently the only primary package which the consumer sees and purchases at retail outlets and uses. A secondary package, e.g., a corrugated fibre-board case or shipping container, contains a number of primary packages. It is the physical distribution carrier and is sometimes so designed as it can be used in retail outlets for the display of primary packages. A tertiary package is made up of a number of secondary packages, the common example being a stretch-wrapped pallet of corrugated cases. In inter-state and international trade, a quaternary package is frequently used to facilitate the handling of tertiary packages. This is generally a metal container up to 12 m in length which can hold many pallets and is intermodal in nature. That is, it can be transferred to or from ships, trains, and flatbed trucks, by giant cranes. Certain containers can also have their temperature, humidity and gas atmosphere controlled and this is necessary in particular situations such as the transportation of frozen foods or fresh fruits and vegetables.

A total packaging system consisting of these different levels is designed based on inputs like product characteristics, availability and costs of various packaging materials and forms that can be fabricated, the nature of physical distribution environment, the needs of production line and the requirements of the consumer (Fig. 1.3). These considerations result in a

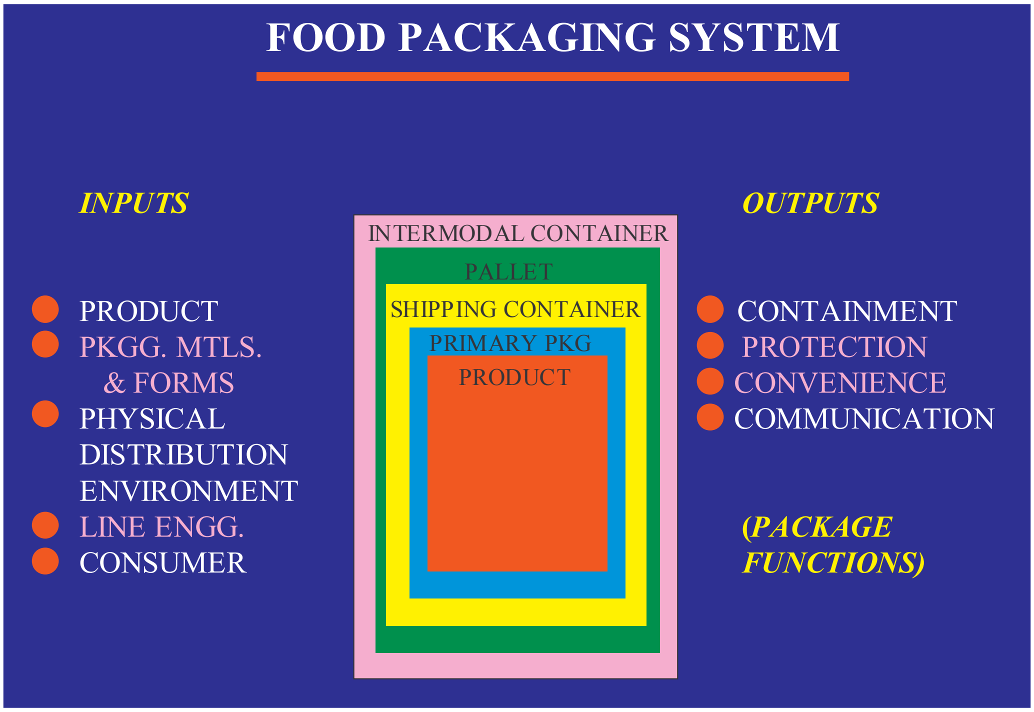

Fig. 1.3. Food packaging system

packaging system that performs the four major functions of containment, protection, convenience and communication.

Functions of Packaging

Containment, the most basic function of packaging is so obvious that it is usually overlooked. With the exception of large, discrete products, all other products — whether a litre of liquid milk or a kg of wheat flour — must be contained as a single unit before they are moved from place to place.

The function of protection is often regarded as the most important since the product has to be protected from outside environmental effects, be they water, water vapour, oxygen, odours, microorganisms, dust, shocks, vibrations, stack loads, etc. In case of food products, protection afforded by the package is often a part of the preservation process. For example, aseptically packaged juice in a carton cannot retain its shelf life, if the integrity of the package is breached.

Changing demographic trends such as urbanization, increasing incomes, more women in the workforce, nuclear families and single-person households have brought in their wake an increasing demand for convenience in consumer products — ready-to-cook and ready-to-eat foods and ready-to-drink beverages, foods and drinks that can be directly consumed from the packages, dispensers that facilitate use of products like sauces, etc. The convenience function designed to perform by the package allows products to be used conveniently.

Another aspect of package convenience that is usually ignored is the apportionment function. The package containing the net quantity of the product reduces the output from industrial production to manageable, desirable consumer size, e.g., 1 litre of sunflower oil, 25 g portion pack of butter, etc. Put simply, the large scale production of products with its associated economies of scale could not have succeeded without the apportionment function of packaging to deliver product quantities convenient to use by the consumer. Besides convenient sizes, the relative proportions of the dimensions of the packages are designed to achieve efficiency in building into secondary and tertiary packages, such as corrugated cases and pallets and, occasionally, even the quaternary package of intermodal container. With optimal dimensions in primary and secondary packages, maximum space available on pallets and in intermodal containers, which are of standard sizes, can be used. As a consequence of this function, material handling is optimized since only a minimal number of discrete packages or loads need to be handled.

Finally, packaging plays an important role in marketing products through the communication function. The modern methods of consumer marketing would fail without a package communicating various messages to he ultimate consumer. The package through its distinct form, style and surface graphics, identifies the brand, the category and the product features and even motivates the buyer in supermarket environments, which function on self-service basis without the help of a salesman to promote the product. It is no exaggeration that a package has been dubbed the 'silent salesman'. Besides, modern retailing extensively makes use of barcodes printed on the packages through scanning at checkout counters for efficient store operations.

A knowledge of these functions of packaging and the ambient, physical and human environments in which packaging has to perform will lead to optimized packaging design and the development of real, cost-effective packaging.

Plastics as Alternatives

Development of materials for food packages occurs in response to the needs, and the needs have always been defined by the shortcomings of the materials in use at a given time. Packaging materials available prior to industrial revolution such as plant fibres, pottery and glass had the advantage of ready availability, but fell short of needs. Plant fibres were damaged by moisture and harboured pests. Pottery was heavy and brittle. Paper and paperboards which are made from plant fibres have low strength and high permeability to moisture and gases, and not ideally suited for food packaging. Glass has the advantages of transparency, imperviousness and inertness, but its fragility and high weight-to-strength ratio are limiting factors. Metal containers that came into use during 1700's for food packaging, have excellent strength besides being retortable, the main disadvantage being their shape limitations.

Plant based fibres, paper and paperboard, glass and metal dominated packaging applications till the middle of the last century. Though they continue to have significant share in present day packaging, the advent of plastics has revolutionized the whole area of food packaging especially during the last quarter of the 20th century.

Some important developments in plastics with applications in food packaging are listed in Table 1.1. Plastics come into use in food packaging in three phases: substitution, accommodation and innovation, differentiated by the extent to which designers take advantage of the performance properties plastics offer.

Table 1.1. Important developments in plastics and their use in food packaging

Period	Developments	Contemporary food uses
1900s	Modified alkyd resin solutions	Can coatings
	Vinyl acetate polymers	Adhesives, films
1910s	Phenol-formaldehyde resins	Closures (e.g., screw caps)
	Cellophane, casting (uncoated)	Lamina in multilayered films
	Viscose	Castings for processed meat
1920s	Coated "moistureproof" cellophane	Pouches, dry foods
	Rubber hydrochloride	Films; now in minimal use
	Vinyl chloride polymers, copolymers	Films, blown bottles, can coatings
1930s	Polystyrene	Trays, tubs, lids, foams
	Polyamide (nylon) resins	Barriers in films, sheets, moldings
	Ethylcellulose	Frozen foods, hot melt paper coating
	Methylcellulose	Edible films for internal moisture control in foods
	Polyethylene	Films, bottles, thermoforms, heat seals
	Polyvinylidene chloride (PVDC)	Barrier films, multilayer thermoforms
1940s	Impact polystyrene	Tubs, trays, thermoforms
	Thermoforming of sheet	Trays, tubs; form-fill-seal
	Injection blow molding	Bottles, jars; with threaded closures
	Extrusion blow molding	Large containers, threaded
	Nylon films	Processed meat packs
	Styrene-butadiene latexes	Paper coatings, primers
	PVDC lacquer coatings	High barrier cellophane
1950s	Polypropylene	Bottles, structure layers
	Extrusion coating PE on paperboard	Milk, juice, and frozen food cartons
	Coextrusion	Barrier containers of multilayer construction

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	Polycarbonates	Structures, food bottles, potable water
	Metallized films	Gas and light barrier pouches
	High barrier PVDC coextrusion resins	Multilayer coextrusions of films, thermoformable sheet
	Epoxy-phenolics	Can coatings for many foods
1960s	Polyethylene imine	Dual oven ware; composited with polycarbonates
	Styrene-butadiene resins	Potable water
	Ionomers	Films, coatings, heat seals
	Ethylene copolymers	Films, coatings, sealant layers
	Polysulphones	Dual ovenware
	Multilayer coextrusion and thermoforming	High barrier food tubs, trays
	Injection mold, reheat and blow process	Pressurized beverage bottles
1970s	Modified polypropylene resins	Multilayer coextrusion adhesivs
	Ethylene-vinyl-alcohol (EVOH)	Barrier layer in films, thermoforms
	Acrylonitrile resins	Bottles, thermoforms
	Polyethylene terephthalate (PET)	Food bottles, jars, dual overware, paperboard trays coatings
	VDC-methyl acrylate copolymers	High barrier multilayer films, containers
	Coinjection blow molding	Retortable barrier tubs
	Ethylene-acrylic acid copolymers	Films, adhesives
	Linear low density polyolefins	Moisture barrier films
1980s	Glycol modified PET	Extrusion blow molded food jars
	Crystallized PET	Dual oven trayware
	Tortuous path barrier blends	Bottles, films
	Amorphous polyamide	Barrier films, cotnainers
	Polyarylamide resin	Barrier films and multilayers; alloys and blends
	Liquid crystal polymers	High temperature, high barrier uses
	Poly (ethylene 2,6 napthalene) dicarboxylate) [PEN]	Monolayer barrier bottles
	Ultra low density polyethylenes	Thin, tough films, e.g, for bag-in-box

Adapted from Brown, WE (1992).

"Substitution" involves direct replacement of traditional materials with virtually no change in design. Early attempts to replace glass with shatter-resistant plastics is an example. Such approaches may not result in optimum designs. When a design is made taking advantage of the performance capabilities of plastics but without going beyond the design limitations for traditional materials, the approach is termed "accommodation". For example, bottles remain bottles, but with new dimensions, shapes and sizes. In the third approach, viz., "innovation", form follows function, and entirely new design concepts are built around the capabilities of the new material. With large body of data related to the properties and performance capabilities of plastics presently available, efforts are increasingly directed towards this approach that takes into account both package and user functions.

The use of plastics in food packaging has gone up several folds during the last two to three decades owing to the several advantages offered by them as compared to other materials. The most important advantages of plastics are their formabilities into practically unlimited range of shapes and forms and the broad range of their properties that enable design of packages with tailor-made functionalities. Plastics being synthetic organic polymers, their properties can be adjusted, modified or enhanced by formulation, by adaptation in manufacture and by deploying such processing steps as orientation.

One of plastics' largest contributions to the packaging industry is its ability to be made into very thin films and containers. In fact, packagers are increasingly substituting plastics for alternative packaging materials because they can achieve significant reductions in packaging weight, volume and cost for the same amount of product delivered.

A major advantage in using plastics for packaging purpose is that most polymers possess excellent physical properties such as strength and toughness, combined with low weight and flexibility, as well as resistance to cracking.

As a consequence of the diversity of packaging applications in the food industry, a wide range of polymer materials has been developed over the years. The basic material (with additives as necessary) is then converted into film, powder or sheet and moulded, or further processed into containers. e.g., trays, tubs, bags, pouches, sachets, blister packs or shrink wraps. Frequently, no one material possesses all the desirable properties required and hence, copolymers or even laminated materials consisting of two or more layers of different polymers (having different properties) cemented together, may have to be used.

The stability of packages in ambient and even hostile environments is reflected in their ability to retain their properties and functionality during the life of the package. Plastics are finite barriers to permeation and this property manifests in the form of oxygen transfer, gain or loss of moisture and sorption of flavour or aroma bodies. This property can often be used to advantage to control gas and moisture transfer as in the case of modified atmosphere packaging. Most fresh foods need to 'breathe' and hence the packaging material used must allow ingress of oxygen and expiration of carbon dioxide. Where the material chosen does not permit sufficient gas transfer, the problem can often be solved by incorporation of a few holes punched onto the film. Fresh meat also requires ingress of oxygen to maintain a satisfactory surface colour. On the other hand, foods with a high fat content (dairy products, bacon, crisps, etc.) become rancid on exposure to oxygen and are often vacuum packed, or packaged in an inert atmosphere, using a material of very low permeability. Low permeability materials are also useful for the packaging of fish or coffee, where the odour must be contained strictly within the package. Foods prone to atmospheric oxidation are often protected by the addition of an antioxidant, such as BHA or BHT. Some products like cereals and crisps are delicate, and need to be loosely packed. This increases the air inside the package and coupled with the high surface area of such products, can lead to rancidity. Additional protection and longer storage life, can be obtained by addition of antioxidant to the packaging materials itself as well as to the food. This reduces the concentration of antioxidant required in the food since only the surface of the food needs protection. Furthermore, consumers are likely to prefer addition of preservatives to the packaging materials rather than to the food itself, although migration of the antioxidant from the package to the food may still occur.

The compatibility of the package with the method of preservation selected is also essential. For example, if the food is being thermally processed after packing, then the packaging must obviously be able to withstand the thermal process. Likewise, if the food is to be stored at freezer temperatures after packing, then the packaging must be able to withstand these low temperatures.

The nature and composition of the specific packaging material and its potential effect on the intrinsic quality and safety of the packaged food as a consequence of the migration of components from the packaging material into the food needs to be looked into. The latter consideration, namely, the migration of potentially toxic moieties from the packaging material to food is of major concern in the selection and use of plastic packaging materials for food packaging.

Plastics and the Environment

Each year about 100 million tons of plastics are produced worldwide. In India, demand for plastics was about 4.3 million tons in 2001-02 and is expected to increase to 8 million tons by 2006-07. Currently however, the per capita consumption of plastics in India is only about 3 kg compared to 30-40 kg in the developed countries. The present market in India is about Rs 25,000 crore. Most of these plastics used today are synthetic polymers produced from petrochemicals. Most abundantly used plastics in food packaging are polyethylene, polypropylene, polyvinyl chloride, polystyrene, nylon and polyesters. As these conventional plastics are persistent in the environment, their improper disposal may become a significant source of environmental pollution in coming future.

Hundreds of communities and businesses across the world today collect plastics as part of their recycling programs. To obtain maximum scrap value, the plastics should be separated by type. If the plastics are not separated and remain mingled, some recycling operators can use them to produce lumber-substitutes for numerous outdoor applications.

Materials that are landfilled should be physically stable, non-degradable, and not contribute to groundwater contamination or gas generation. Plastics meet these criteria and behave as "model citizens" in a landfill environment. As people become better informed about solid waste issues, the focus of attention will shift away from the degradability myth toward real solutions like source reduction (making less), reuse (where appropriate), resource recovery (including materials recovery through recycling and energy recovery) and, finally, retention in landfill.

Biodegradable plastics, derived from renewable raw materials, can be made from abundant agricultural/mineral resources like cellulose, starch, collagen, casein, soya protein, microbially produced polyhydroxy alkanoates (PHA). Large scale use of these plastics would also help in preserving non-renewable resources like petroleum, natural gas and coal and contribute to the problems of waste management. Though the demand for biodegradable plastics is increasing, acceptance of biodegradable polymers is likely to depend on factors like customer response to costs, possible legislation by governments and the achievement of total biodegradability.

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