Chapter 3

Degradable Plastic Recycling

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Abstract

The public demand of plastics for food, drinks, consumable and packaging is increasing enormously all over the world. Due to limited available plastic resources, it is challenging to meet the stipulation of the massive population. The contribution of the synthetic plastic industry is encouraging to cope with these challenges. However, it is not only restricted towards production, but the degradation of its waste is also equally arduous and even more complicated to a large extent. A useful solution to this problem is recycling instead of degradation. In order to optimize the utility of recycling, various techniques are in progress. Plastic recycling is an acceptable technique to keep the economy in circulation. Moreover, it is an effective way to reduce the environmental pollution and to promote green environment.

Keywords

Plastic Industry, Global Warming, Economy Circulation, Environment, Reusability

Contents

1.	Introduction to degradable & biodegradable plastics	82
2.	Petroleum based plastics	85
2.1	Biobased Polypropylene	85
2.2	Biobased polyethylene terephthalate (PET)	86
3.	Recycling.....	86
3.1	Recyclable bioplastics	89
3.2	Reusable plastic bag	89

3.3	Recycling issues related to biodegradable plastic	89
3.4	Marine plastic debris recycling.....	90
3.5	Recycling of packaging plastics	91
Conclusions		91
Challenges and future perspective		92
References		92

1. Introduction to degradable & biodegradable plastics

Twentieth century is marked with one of the greatest invention of plastics, consisting of large number of synthetic or semi synthetic organic materials. Plastics are high molecular weight polymers conventionally derived from petrochemical resources but not limited to such materials only. A large number of products are derived from renewable resources preferably termed as “bioplastics” extracted from biobased, refined materials which are biodegradable in nature. Undoubtedly, plastics are very convenient to use in food, packaging and all sort of consumables. The clean and lightweight material can not only be used conveniently, but it can also be thrown away easily along with other debris [1]. As the concerns towards a clean and safe planet grew, society became more vigilant towards disposal modes of plastics. Soon it was realized, that life without plastic is unimaginable but what sort of safety measures can be adopted? This was a very important question which lead scientists to make a clear distinction among the sources and products of the plastic materials. With the enormous efforts of chemists, biochemists, environmentalists, scientists were able to figure out that all the plastics can ultimately be disposed of but at the cost of our health and environment. Plastics and their toxicity have endangered the planet making its proper disposal indispensable. In order to develop a safe method of disposal, the plastics have been categorized into degradable and biodegradable plastics, it is mere effort to evade the severe misperception amongst the community surrounding the difference between degradable and biodegradable plastics (Fig. 1). The word degrades refers to “break down” and essentially, all plastics are degradable. The degradable plastics are also known as “oxo degradable plastics”. Polyethene bags or commonly known as traditional shopping bags are the product of a non-renewable resource; these bags are exceptionally injurious to the environment as by no means they are biodegraded. Instead, they can only disintegrate into tiny pieces over hundreds of years, inflicting indescribable damage to the natural ecosystem. Conspicuously, degradable plastics do not possess living organisms as a vital part of the degradation process. Instead, chemical constituents used in the plastic allow it to disintegrate faster

than a standard plastic usually would. Principally, the plastics advertised as “degradable” are undeniably not advantageous, they can even be “*worst*” for the environment! The degradable plastics can adopt various modes of degradation including, aerobic, aquatic, thermal and chemical (Fig. 2a). Hence, degradable plastic will find multiple environments to degrade, however it is not as simple. As a matter of fact it takes time if just dumped on land. The process is usually speedup when burned. However, it hazariously affects the environment in all its disposal modes. In every mode of its disposal, degradation of plastics converts them into smaller fragments and then poses serious threats to ecosystem. Alarmingly, even the microplastics enter the food chain, get eaten by smaller species and then continue to make their way through the food chain when these smaller species are consumed in the ecosystem [2]

On the other hand, biodegradables are differently identified as compared to degradable plastics. These materials can be “biobased plastics” or “petroleum based plastics”. Biodegradable biobased plastics are the product of plant-based materials like corn, soy, sugarcane, potato, or other renewable material source. However, the biodegradable petroleum plastics can be the product of synthetic polymers as well. It is convenient to acclimate the composition of biodegradable plastic to degrade it at a faster rate. The resultant fragments are generally less toxic to the environment based on its composition. The life cycle of biodegradable plastic is quite simple as shown in (Fig. 2b). Biodegradable plastics are considered superior over petrochemical-based plastic due to their higher proportion of natural sources which greatly diminishes their probability of eventually converting into a horrid plastic pollutant. Specific environmental factors including temperature, pressure, humidity, natural gases are required for the process of biodegradation. Biodegradable plastics are transformed to biomass, CH₄, CO₂, and H₂O and other organic residues by a thermochemical protocol in a certain time and environment. Numerous biodegradable plastics provides the solution to many environmental problems and it is the need of the hour to develop products and techniques to enhance the functionality of biodegradable plastics so that they can replace the traditional plastics [3].

Fig. 1 Degradable and non degradable plastics.

Fig. 2 (a): Degradation modes of plastics: (A) Aerobic degradation ;(B);Aquatic degradation(C)Thermal degradation(D);Chemical degradation.

2. Petroleum based plastics

2.1 Biobased Polypropylene

85

organic plant-based materials as well. The biobased polypropylene has the same composition as conventional petroleum based polypropylene. Biobased polypropylene is produced from ethanol by the process of fermentation which converts the sugar of sugar cane, corn or potato to ethanol. The ethanol is converted into polypropylene via formation of butylene and ethylene as an intermediate step, known as metathesis reaction of butylene and ethylene [5].

2.2 Biobased polyethylene terephthalate (PET)

Another important form of bio based polyethylene is PET (Fig. 3), which is made from plant sources of monoethylene glycol (MEG) and terephthalic acid. There is usually no difference in the properties of petroleum based PET or biobased. Only 30% biobased PET is currently synthesized which can be extended to 100% in near future [6].

Fig. 3 Chemical structures of polypropylene (PP) and polyethelene terephthalate (PET).

3. Recycling

Recycling is the process of conversion of a waste material into a new product. It is usually performed with the intention to attain the original properties of the material. The concept gained popularity as an alternative to the conventional attempt to reduce the greenhouse gas emission from waste materials. However, currently recycling is more useful than the previous practices. Now a days it is the prevention of disposal of useful materials and also an attempt to diminish the consumption of new raw materials, thus reducing not only the energy usage but also the pollution. The two important categories of recycling are the closed-loop recycling and cradle to cradle recycling; the former

describe a process where the recycled material is converted to original material without giving it a new form. Hence polypropylene will essentially remain polypropylene even after recycling. Whereas, the later term promotes the concept in which the industrial practices imitate nature in a closed loop by recycling feedstock materials in an endless loop, the waste produced during this process is converted into feedstock for a succeeding process. The recycling is based on a very systematic approach of “Life cycle assessment” popularly known as (LCA), it is based on the principle of product’s life from “cradle to grave,” It describes how a material is produced, how its raw materials are extracted, which kind of process are involved in its manufacturing, how the product is manufactured, where it was distributed, how it was used, when it was expired, disposed of or recycle. So LCA is a complete guide of any product. Internationally the recycling is represented with a “chasing arrow triangle” of arrows as shown in (Fig. 4).

Fig. 4 Conventional symbol of Recycling.

The process of recycling is not complicated as shown in Fig. 5. The recycling of a plastic bottle can be carried out in either chemical or biochemical way ending up in the useful intermediates and final products. However, the cross-contamination during the recycling can make it a real burden on the recycling industry. Prolific recycling typically requires separation and cleaning of materials before they are transported to manufacturers to launch it as a new brand, nevertheless inducing discordant materials makes it challenging to process occasionally unsuccessful recycling trials, resulting in yield loss and end up disposing of the material. Recycling process varies for each materials and different protocols are developed for better recycling yield. Recycling is also dependent on the

design of new product and the techniques of assembling various parts. The recycling automobile industry is considered difficult and for the reproduction of various vehicles mostly biodegradable materials is preferred in various parts [7-9].

Fig. 5 Biobased plastic recycling Process.

Recycling is not devoid of issues. There are many concerns related to recycling such as which items can be recycled? How many times an item can be recycled? In order to answer the first question for example we assume that plastic and paper can be recycled. Paper can be recycled easily whereas the situation for plastic is very complexed. The one thing which is most important in this regard is the lack of public awareness. Many of us do not know that either a useable item can be recycled or not. Primarily, it is the duty of production agencies and manufacturing companies to write the information guidelines regarding the recycling on packaging. One another way to promote recycling is the promotion of reusable material. It will keep the product in circulation for a longer time for example; packaging bags, boxes, envelops can be reused several times by the proper awareness campaign [10-12]. Another important issue related with recycling is to discard

the materials right in the litter, but lots of our recyclable materials actually end up in landfills or oceans, it makes a real mess to the ecosystems. As a matter of fact recycling forces customers to take the responsibility to manage the waste, as a result the customer sometimes look for the alternate available resources instead of using such materials. Consequently the, recycling industry is working effectively but the piles of waste are increasing as well. It has resulted in the proper legislation of the recycling material and to dispose of the solid waste material.

Plastic waste management prohibits the dumping of plastic into the sea which was used as a major dumping area due to lack of awareness regarding marine life and without considering a major part of the ecosystem. The plastic waste is one of the major causes of marine pollution. A movement aroused throughout the USA to question the ability of plastic to degrade which finally resulted into the spread of more public awareness regarding the use of plastic bag. On the other continents, European union made it requirements that all automobiles companies must use 85 % of material which can be reused [9].

3.1 Recyclable bioplastics

Bioplastics made from renewable resources possess the natural tendency to be recycled by biological methods using limited resources and reduced greenhouse gas emission. However, the third generation bioplastics are bio-based which has dominated the plastic market of – polyethylene (PE), polypropylene (PP) and polyethylene terephthalate (PET). It is expected that in near future all this market will be replaced by bioplastics.

3.2 Reusable plastic bag

Plastic bags are best example of reusable materials; these are available in both biodegradable and non-biodegradable materials. The biodegradable plastic bags are major contributors to reduce the environmental pollution. The reuse of plastic bags overcome number of problems such as; cost, greenhouse gas emission, multiple type of pollution including land and water pollution. Plastic bags can usually be washed which reduces the chances of infection of bacteria [13].

3.3 Recycling issues related to biodegradable plastic

The recycling of biodegradable plastics is very challenging due to removal of macro and micro contaminations. The biodegradable plastic displays a very unique affinity with the microbes and becomes polluted instantly. Hence the convenience in the biodegradation is actually a great hurdle in recycling. However, all the impurities cannot be identified during this process. For example polylactic acid (PLA) and polyethylene terephthalate

(PET) has the same density, but after the recycling process PLA exhibits lower quantity of impurities as compared to PET which not only seriously impact the quality of recycling process but also the quality of the product as well. The situation is the same for some other materials where contamination cannot be avoided despite taking all the necessary measures. The problem becomes sever in case of multilayers due to greater chances of contaminants to be entrapped in between layers. Research show that 10 % contamination of biodegradable plastics does not show any negative impact and the quality of recycled material can be ensured below this range. For optimal recycling ability the mechanical system of recycling should be adopted which is useful for both biodegradable and non-biodegradable plastics [14,15].

3.4 Marine plastic debris recycling

Plastic pollution is a major threat to the oceans. The enormous usage of plastics poses a serious threat to the aquatic environments, the marine debris includes both degradable and nondegradable plastics however, the nondegradable severely affects the marine life. Plastics disintegrate into smaller and smaller pieces, unfortunately these smaller parts never settle down, nor are they absorbed in the aquatic system, resultantly they are always disguised until engulfed by some aquatic life. Marine debris acts as sponges absorbing toxins, hence any impurities entrapped in these materials becomes the part of the ocean, when any marine animal try to digest it as a food it becomes a part of food chain. Ocean gyre is very important part of marine system. It is a large system of ocean currents, these currents are usually generated by wind blowing. The mass of ocean gyre varies from 1000 miles to 5000 miles in the south pacific. These gyres are known for collecting marine waste, while in the north pacific region it is titled as “Garbage patch” because it is one of the major area of marine waste collection. This gyre absorbs excessive amount of plastic which is broken because of water current or due to wave movement, the floating plastic debris produce rings of gyre. A similar example is observed in south pacific region of Japan where the quantity of plastic debris has increased to a large extent during the last 20 years. According to Marine research foundation the plastic creates naval litter and contaminate the water of beach, surface and even in the depth of ocean. The large amount of suspended plastic ultimately settles down in the bottom. The seashores and beaches are the major sites of sea litter, it is harmful to human beings and marine creatures. Sea birds that swallow the plastic floating on sea surface often feed themselves and their children, the sea litter, plastic bottles, caps buttons party balloons are swallowed by the birds resultantly they often die of these remains in stomach [15, 16].

The most feasible solution to the marine debris is to treat it with plastic recycling technology which is employed for industrial and domestic plastic recycling. Plastic recycling technologies are classified into mechanical recycling, chemical recycling and thermal recycling. However, there are some factors which make the recycling difficult due to degradation of materials such as:

1. Decomposing via fungi, this leads to fiber swelling and deteriorates the plastic swiftly. 2. Availability of polar and non-polar groups, making the recycling difficult once the plastic is in water, 3. The inconsistency in the temperature in different zones of the ocean, especially the upper limit of temperature. In order to reduce the natural moisture ability of fibers hydrothermal method is applied. Similarly, chemical treatment leads to the disintegration of structural bonds in non cellulosic material such as; acrylates [17].

3.5 Recycling of packaging plastics

As a matter of fact the 7.8 billion population of the world is using the plastic material in any form, even the demand of developing plastic goods is increasing continuously. It only gives us a clue about how gigantic plastic is! Day by day, the concern over the problem of environmental waste is increasing and undoubtedly plastic industry is the major contributor. It produces 20 to 30% of whole waste. There is no solution of waste problem except recycling. Indeed, recycling rates remain small (approx. 14%) in the plastic packaging field on a global scale. Even in Europe, the recycling rate is approx. 32.5 wt%. However, these values only deal with the collected waste instead of total circulated plastic. Europe is dealing with the waste problem by introducing the circular economy policy. Indeed circular economy is badly affected by the principle of “take, make and dispose;”, it is now facing the consequences of decrease in natural resources [18-20].

Conclusions

Plastic is a giant industry producing a vast range of products for over 7 billion people of the world, majority of these plastic products are of daily use. The huge pile of waste given to the earth is indescribable. This waste is dumped on land, in the air and in water. The disposal of this plastic waste is expensive, tedious and an endless task, even the resources of advance countries never allow them to invest only to dispose of the material. In this situation we are left with no option but to recycle the degradable plastics. After a long time, the world has recognized the dire need and the potential challenges of recycling. People are more interested to use recyclable products to promote ecofriendly environment. However, prioritized reduction of plastic consumption and turning towards

recycling is the only safe route to meet the demands of the growing population worldwide.

Challenges and future perspective

The future of degradable plastic recycling industry is very challenging. Great efforts will be required to make people realize that use of plastic is associated with hidden hazards. Humans have already started to face the some consequences of the use of plastics but the future is more polluted by the heaps of unrecycled plastics. They are not going to dispose of easily, and now we cannot eliminate it from our lives as well. Hence, it will need a common legislation to be adopted by the world to conserve the natural resources and to control the pollution caused by plastic litter. It will not be easy to bring 195 countries of the world on a single page. However, by adopting the right strategies this industry has the potential to be emerged equally important as plastics are today. It will need multisector collaboration to be emerged and accepted.

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