Biodegradable Plastics

A De-cluttering Narrative

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Gripping visuals of plastic pollution has shaken up the collective consciousness of people across the globe. The waste has adversely affected flora and fauna bringing in a sense of urgency amongst policy makers and regulators to control it, as businesses and consumers are groping for solutions. All efforts so far, however, have not delivered any tangible results on the ground. While plastics waste keeps mounting, clamour for solutions becomes louder. The issue is complex and defies a simple solution. One of the prognoses is promoting biodegradable plastics. This could, in theory, prevent further accumulation of waste in the environment. Products made from biodegradable plastics would presumably degrade and assimilate in nature. Sounds good, but it deserves a closer look.

Traditional plastics have many advantages. One of them is durability. Scientists have toiled to make plastics withstand oxidative, thermal, hydrolytic and photonic stresses encountered during processing and use. The polymer structure and additives have made plastics withstand these stresses. Durability, which made plastics popular, has now come to haunt it.

Notwithstanding the majoritarian perception that traditional plastics are virtually indestructible, evidence suggests otherwise. In marine environment, a typical nylon rope was found to degrade at the rate of 1% per month. This makes the lifetime of nylon fishing rope between 8 - 9 years. Similarly, the life of many traditional plastics in marine environment was found to be, on an average, 50 years. High, but nowhere near thousands of years as reported in media reports and articles. Do these later become micro or nano plastics? No clear evidence of this either. Even if it does, would these be harmful to human life? The jury is still out on this last question. Incidentally, the history of largescale use of plastics goes back only 50 - 70 years in the past.

Comprehending Degradation

Degradation of plastics typically follows a pathway of initial photodegradation resulting in fragmentation and loss of properties. It may then undergo thermo-oxidative degradation, hydrolytic degradation and finally biodegradation. The rate of degradation varies with polymer types, structure and level of additives. Research points to faster rate of degradation for plastics belonging to polyester and polyamide families compared to polyolefins. Similarly, amorphous regions show faster rate of degradation as compared to crystalline zones. These variabilities may open-up opportunities to optimise functionality and durability in traditional plastics.

Common perception is that anything derived from nature is degradable and benign. Our current understanding, based on science, does not support this. For any organic matter to degrade, the surrounding environment should be conducive with a mix of the right temperature, level of moisture and presence of micro-organism that can break down the product. Landfill sites or open dumps are not fully facilitative of this process. If we toss out a product made even from biodegradable plastics, it will only add to litter and not solve our problem. There is also considerable haziness surrounding biopolymers, bioplastics, biodegradable plastics and compostable plastics. Most commercially available biodegradable plastics are in true sense compostable plastics since these need industrial composting facilities to degrade. This applies to polylactic acid (PLA), the largest bio derived compostable plastics. Biodegradability of PLA was observed to be marginally higher than polyethylene (PE) with starch being at the highest end.

Plastics derived from renewable sources are categorised as bioplastics and those that are supposed to degrade in natural surrounding are termed as biodegradable and those requiring industrial composting facilities as compostable plastics. It is not necessary that bioplastics would also be biodegradable under normal circumstances. We have both national and international standards to define biodegradable and compostable plastics. Biopolymer has a much wider connotation which includes bioplastics but not necessarily confined to these. Most traditional plastics are non-biodegradable in stricter sense of the term. We also have bioplastics (derived from renewable sources) that are non-biodegradable. A classic example is polyethylene (PE) produced through bio-ethanol route. We also have non-renewable fossil-fuel based plastics that are compostable. An illustrative example of non-biodegradable plastic, polyethylene (PE) and polyethylene terephthalate (PET), from bio sources and compostable plastic polybutylene adipate terephthalate (PABT) from traditional sources is presented in Figure 1.

Renewable feedstocks have potential environmental benefits. We move away from non-renewables to renewables. However, it needs to avoid conflict with our food system.

An Eye Opener

Traditionally, nearly all plastics can theoretically be made from naturally occurring feedstock. That is how some of the plastics, we are familiar today, were initially produced. The first PE plant in India was based on bio ethanol, derived from a waste product of sugar production. There is a commercially operating mono ethylene glycol (MEG) plant in India based on bio ethanol. Brazil has large production capacities of PE based on the bio ethanol. However, at prevailing levels of technologies, production cost of most of these are too prohibitive to be commercially viable.

Renewable feedstocks have potential environmental benefits. We move away from non-renewables to renewables. However, it needs to avoid conflict with our food system. This makes agricultural waste a preferred alternative. Although at its infancy, cellulosic ethanol can be an economically viable source for ethylene, the largest building-block for plastics. The limiting factor today is high cost arising out of

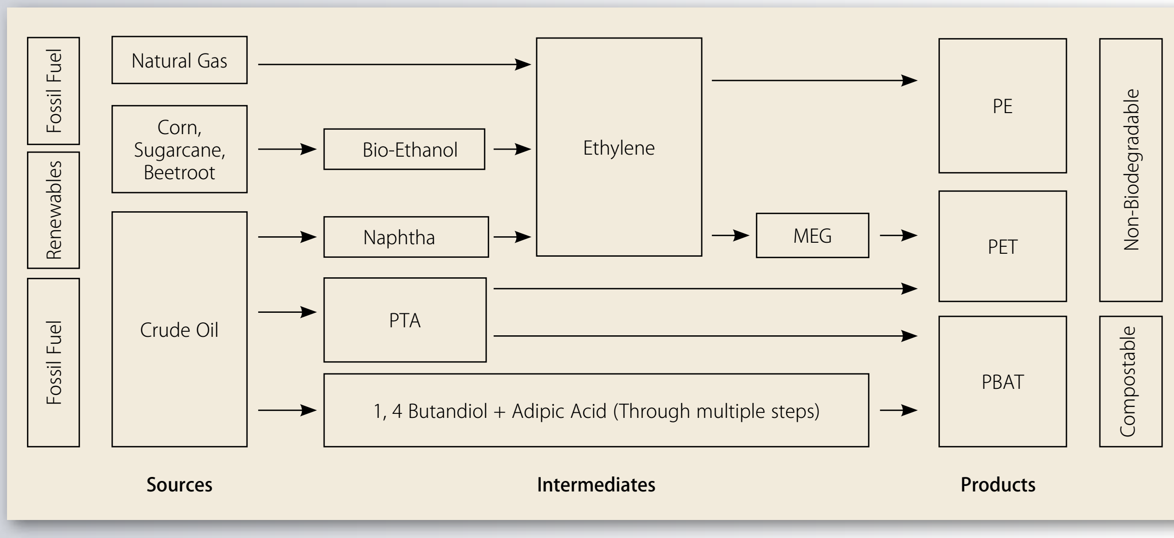

Figure 1: Illustrative examples of polyethylene (PE), polyethylene terephthalate (PET) and polybutylene adipate terephthalate (PBAT).

low yield. This is due to limitations of currently available catalyst systems - a parting comment on biopolymers. All intermediates shown in Figure 1 can be obtained from bio sources. The challenges are cost and scale. This is unlikely to change in the near future and could be a major thrust area for research and development.

All biodegradable and compostable plastics, commercially available today, face three major challenges - functionality, scale and cost. Products made from truly biodegradable plastics (mostly starch derivatives) are way off in their performance as compared to traditional plastics. This not only limits their uses, but also magnifies the cost disadvantage. An additional downside is the concern of contamination. Biodegradable or compostable plastics waste has the potential to destroy the value of traditional plastics waste meant for recycling when it inadvertently gets mixed. And, in the waste streams, it is hard to keep them apart.

Does this close the door for biodegradable plastics in future? Not really. Science will come up with solutions to improve the performance of biodegradable plastics. Improved production technology and higher economy of scale would also beat down cost disadvantages. Toughest part of the challenge would be changes necessary in the human behaviour to reduce, if not eliminate, littering. This would need to be complimented with building infrastructure to manage waste separately. Does this sound familiar? Yes, it is the same solution for management of traditional plastics waste.

A Valid Approach

Biodegradable and compostable plastics have a role to play where economic and environmental cost of collection, segregation and recycling of traditional plastics is prohibitive. Few obvious examples are mulch films in highly mechanised agricultural set-up or colour-coded trash bags which are meant to move through separate waste management stream. Indiscriminate promotion and use of biodegradable and compostable plastics could cause more harm than good to our environment.

Thought Provoking

In our debate on traditional versus biodegradable plastics, few critical parameters are yet to be fixed - environmental cost of littering, investments necessary to make changes in human behaviour and creating a robust waste management infrastructure. The positive fall out of the prevailing discourse may be the convergence of research and development efforts both in traditional and in biodegradable plastics fields. While the focus of future research on biodegradable plastics would be to enhance performance and reduce cost, there could be opportunities in conventional plastics to improve yield based on renewable feedstocks. Introducing a degree of biodegradability through incorporation of functional groups or changes in the additive technology to achieve this might get some traction. Eventually human ingenuity would prevail over the mounting plastics waste management challenges.