Methods of Assessment of Biodegradability and Chemical Degradability of Petroleum based and Fermentation based Plastic films to Estimate the Ways to make Plastics Eco-Friendly

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Abstract— Plastic is one of the most consumable and useful material of modern times and its growing demand and consumption is not easy to check. But, the only hurdle in its prolonged use is its low rate of degradation in environment after being disposed of. This is because such products tend to accumulate in nature due to their excellent mechanical properties [2]. Thus, the present work highlights on the biodegradation rate of various synthetic polymers by calculating its elongation at break, the rupture load and loss in weight in various conditions in which these plastics are generally exposed of after use [1,2]. A comparative analysis was made by studying the degradation rate of Poly Lactic acid, a fermentation based biopolymer. Considering the fact that the plastics are generally associated with slightly acidic or slightly alkaline condition the degradation study was extended by immersing the samples in 0.1N HCl and 0.1N NaOH solution. Synthesization of a Thermoplastic starch was done by adding propane-1, 2, 3-triol as a plasticizer into potato starch (Figure 1).The TPS obtained was translucent and flexible, same as the conventional plastics and in order to test its degradation rate it was kept in landfill condition for 45 days and the loss in weight with increase of degradation period was observed. The above study also elaborates on the various other alternative methods like proper disposal systems, recycling, and production of useful substances from plastic waste which can be put into application to make plastics eco-friendly. Thus, with the accomplishment of above objective it is believed that the beneficiary and useful aspect of plastic will be maintained for the humanity by overcoming the threat posed by it to the environment.

Key words: Degradation, Synthetic Polymer, Biopolymer, Elongation At Break, Loss In Weight, Thermoplastic Starch

I. INTRODUCTION

Right from drinking cups to automobile parts, plastics has become a universal material. Its low cost, light weight, high strength and attractiveness, makes it possible to be synthesized with the wide range of properties. Due to their relatively low weight, the ability to be coloured while manufacturing and to mould complex shapes relatively easily, plastics are extensively used for product casing and other applications, where mechanical strength is not at a premium.

Plastics have a growing demand and it is believed that plastics play a vital consumable material in current generation. But, the problem lies with its low rate of degradation after getting disposed to the environment. Thus, the solution of the problem is to first study the degradation behavior of plastic and then provides the best possible way to make it eco- friendly.

II. EXPERIMENT

1) Sample Preparation and Degradation Study of Synthetic Polymers: Conditions: The samples (HMHDPE, LLDPE, LDPE, and PLA) were collected from commercially available plastics finding use in everyday life and the samples were made from plastics which are generally used for packing purposes, such as milk packets, carry bags and departmental stores bags. (Figure 1, Figure 2, Figure 3 and Figure 4) The experiment has been conducted under different conditions to understand which polymer degrades most under which condition.
   - Samples were placed in pits dug out in the ground in dimensions of 0.5m X 0.5m X 0.5m and covered with soil.
   - Under vegetable waste: In this condition, the samples were placed in pits dug out in the ground in dimensions of 0.5m X 0.5m X 0.5m and covered with vegetable waste or organic matter.
   - Underwater: The samples were also placed in water bottles to observe their degradability in water.
   - In open air: Also, the samples were kept in open air to see the effects of exposure to natural environment on the plastic's degradability.
   - In acidic conditions: As the environment to which plastic waste is exposed on a daily basis could also be acidic, we tested the degradability impact of an acidic condition on the plastics by keeping them in a 0.1N solution of HCl for a duration of 15 day.

   In basic conditions: As the environment to which plastic waste is exposed on a daily basis could also be basic, we tested the degradability impact of a basic condition on the plastics by keeping them in a 0.1N solution of NaOH for duration of 15 days.

Fig. 1: Sample under soil

Fig. 2: Vegetable e

Fig. 3: Samples in water

Fig. 4: Samples in HCl NaOHy

2) Samples Collected After Degradation: All the samples, after exposure to the respective conditions were taken out and tested after duration of 20, 45 and 80 days. Their tensile strength, weight loss and thickness were measured. (Figure 5).

Fig. 5: Samples collected after degradation

3) Synthesis of Biopolymer- Eco friendly or Biodegradable plastics are plastics that decompose in natural aerobic (composting) and anaerobic (landfill) environments at fast rate. Biodegradation of plastics can be achieved by enabling micro-organisms in the environment to produce inert humus like material that is less harmful to the environment.
4) Making the Plastic Film- Materials used: Beakers, conical flasks, pipette, stirrer, 0.1N NaOH, 0.1N HCl, glycerol, Z-Zero gluten free potato starch (purchased from online store Snapdeal).
   - To prepare the plastic film 100 cm3 of water was put into the beaker and 9 g of the potato starch, 13 cm3 of hydrochloric acid and 7 cm3 of propane-1, 2, 3-triol were added to it. To observe the effect of the amount of glycerol on the biopolymer synthesized, the quantity of glycerol added to the mixture was varied. 7 cm3, 8 cm3 and 9 cm3 of glycerol were added to each of the three respective compositions. (Figure 6)
   - The watch glass was put on the beaker and the mixture was heated using the Bunsen burner for 15 minutes with continuous stirring.
   - In the end the pH of the solution was measured and sodium hydroxide solution was added to neutralize the mixture.
   - The mixture was then poured onto a labeled Petri dish for moldings. Here, it was noted that the sample obtained from the composition with 7 cm3 of glycerol had a good consistency, while the samples obtained from the compositions with 8 cm3 and 9 cm3 of glycerol were less viscous and runny.
   - The mixture was then left to dry out in a drying cabinet for about 90 minutes at 100 ^{0}C.

III. RESULTS

Plastic Reduce, Reuse and Recycle:

Based on Pyramidal Rule for Plastic Recycling, we tried to synthesize Eco-Friendly Bio-plastic in concern to the most favored option of prevention of threat posed by the conventional plastics. But, it is also a fact that our dependence on conventional plastics is so large that we cannot completely prevent their use in current scenario. Moreover, even if we replace existing Conventional Plastics with Bio plastics in appreciable amount, we also need to provide a solution for existing dump of plastic waste so that environmental threat due to plastic waste can be addressed properly. So, keeping this view into consideration we have the following options:-

- Reduce: or Waste minimization is the process and the policy of reducing the amount of waste produced by a person or a society.
- Reuse: It is the method of using the plastic material in its current form again but in new use.
- Recycle: It is processing used materials (waste) into new products to prevent waste of potentially useful components, reduce energy usage, reduce air pollution (from incineration) and water pollution and lower greenhouse gas emissions as compared to virgin production.[3]
- Reuse of plastics: To reuse is to use an item more than once.

A. Advantages of Reuse:

1) Energy and raw materials savings.
2) Reduced disposal needs and costs.
3) Refurbishment can bring well-paid jobs to underdeveloped economies.
4) Cost savings for corporate business as a recycled product is often cheaper than the many single use products it replaces.

B. Examples of reuse:

There are several innovative ways by which plastics can be reused. These include reusing plastics
i.e. weaving & knitting plastics into various commodities like making accessories like coasters, bookmarks etc.

C. Plastic Recycling:

Plastic recycling is the process of recovering scrap or waste plastics and reprocess the material into more useful products, sometimes completely different in form from their original state. Typically a plastic is not converted into the same kind of plastic, and products made from recycled plastics are often not recyclable. [1]

5.42 million tons of plastic wastes were effectively reutilized in the year 2002, an increase of 60,000 tons from the previous year. The effective reutilization rate is also increasingly rising 2 points from the previous year to 55% in 2002. This is due to the increased use of mechanical recycling & feedstock recycling of plastic wastes as blast furnace feedstock. [2]

D. Advantages of Recycling Plastic:

- Conservation of non-renewable fossil fuels
- Reduced consumption of energy.
- Reduced amounts of solid waste disposed to the environment.

– Reduced emissions of CO_2, nitrogen-oxide (NO) and sulphur-dioxide (SO_2).

E. Applications of Recycled Plastics:

Road engineers have been experimenting with use of certain synthetic polymers to improve the binding property of asphalt roads. Polymer blended bitumen shows higher softening point, lower penetration value, and better ductility. Polymer coated aggregates blended with bitumen gives higher Marshall Stability value. All these aspects improve the performance criteria of asphalt road.

It was while looking for a cheaper and viable alternative to virgin synthetic polymers that Indian scientists stumbled across plastics waste as an effective substance. Later it also proved to be a scientific and environment friendly method of disposing low-end plastics waste, especially the thrown away carry bags and some varieties of one-time used plastics materials. On the other hand, these low-end plastics waste can be used for road construction without elaborate cleaning and segregation. By simple techniques, these are shredded into powdery form and mixed with hot bitumen and hot aggregate. [1]

The aggregates are heated to a range of 170-180 ^{0}C in a hot mix plant and the shredded plastics waste is added to it. The plastics become softened and get coated over the aggregate. The hot bitumen with or without plastic waste is then added to it and mixed well. This mix is then transferred on to the road for laying. In the continuous plant, the shredded plastics waste is spread over the aggregate with the help of automatic dosing machine. The aggregate with shredded plastic enters the hot rotor, where the plastics get molten and is deposited on the surface of the aggregate in the first half of the rotor. Molten bitumen is then sprayed on the plastics coated aggregate, which is still under rotation. Such mix is then taken out and used for laying the road. [1, 2, 3]

Experiments have proved that use of waste plastics increases the life of roads and at the same time the cost of construction of such roads also comes down due to the fact that cost of plastics waste is less than that of bitumen. 10 to 15% replacement of bitumen by plastics waste reduces the overall cost substantially. [3]

India is considered a pioneer in using plastics waste for the construction of asphalt roads. Hundreds of miles of roads have already been constructed in the States of Tamil Nadu, Karnataka and Kerala, using plastics waste. Road Department of Gujarat Government has approved construction of trial roads in Vadodara and Surat.

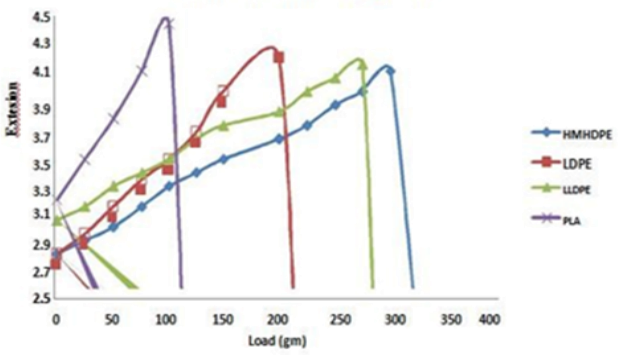
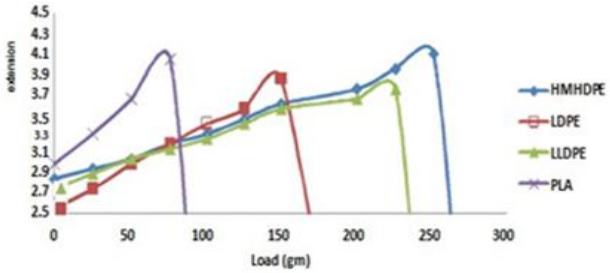


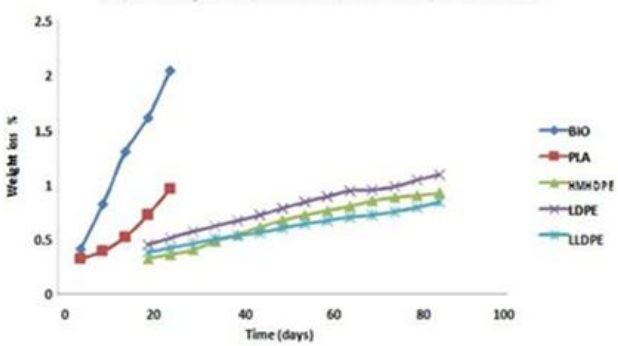
Fig. 1: tensile strength of different samples in HCl (15 days).

Above graph reflects information of tensile strength of different samples for fifteen days. Extension for HMHDPE is more per lower load and lower for PLA though load increases.

For LDPE,LLDPE tensile strength is moderate and drop off between 200 to 300 grams of load.



Graph 2: Tensile Strength of Different Samples in NaOH (15 days).



Graph 3: weight loss % of different samples under soil (80 days).

IV. CONCLUSIONS

1) The slow rate of degradation of plastic that makes it intensely useful also creates nuisance in its proper disposal and thus it remains as such in landfill condition for long time.
2) The experiment conducted for degradation rate of LDPE clearly shows that at its normal rate of degradation rate it will take 13.53 years to degrade and for LLDPE it will be 23.30 years to degrade and for HMHDPE it will be 28.19 years to degrade completely and thus demands for proper steps need to be taken.
3) In comparison with the conventional petroleum based waste plastics the bio degradable thermoplastic starch synthesized in the laboratory took a very small time of only a few days to degrade completely.
4) Thus, this synthesized bio plastics when blended with proper additives or conventional plastics can proved to be a better option for replacing conventional plastics.
5) These bio-plastics are also applicable in daily life, as plastic bags, cellophane films, disposable packaging films, medical capsules covers and food services items.
6) In addition to it keeping into consideration the present bulk of plastic waste, blending them with bio plastic synthesized from renewable resources seems only a viable option as it is economical,

environment friendly and also doesn't require major changes in the present infrastructure of the plastic industry.

As we use two different methods viz. samples kept under biological condition as well as under chemical conditions, we observed that degradation rate of the different samples under chemicals(using HCL and NaOH here) is slower in respect to the samples kept under biological condition.

A. Scope of Future Work

At present, there is extensive study and research being conducted on biopolymers –their commercial uses and application in today's world for large implementation. The use of biopolymer will be very vital and necessary for a cleaner, pollution free world. Synthetic polymer would soon be replaced by biopolymers as they are petroleum based and non-renewable, whereas the latter is renewable and mostly bio degradable. So in view of eco-friendly environment the following scope of future works are there from this project:

- As it is seen that biodegradable plastic are eco-friendly but at the same time compromise with the mechanical strength is done so future work can be enhanced with improvising the mechanical strength of the biopolymer by making a blend of starch and synthetic polymer.
- Further different additives can be incorporated into the fabrication of biopolymers so that applicability range of biopolymer can be increased.

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