



# AN OVERVIEW OF BIOPLASTICS, A GREEN ALTERNATIVE FOR FOOD PACKAGING- FACTS AND FIGURE.

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## **ABSTRACT**

Modern life introduced plastic in our world and now it's an integral part, though it has significant role in packaging, protecting, carrying quality products etc, but the bane was bigger than boon in context of plastic, the non-biodegradable characteristics and toxic effect of plastic result in increased carbon, soil, air, water pollution and large amount of plastic waste in environment, moreover it has limited fossil resources to manufacture. These drawbacks induced to find an alternative of plastic, then as green-approach toward the world "bioplastics" came into existence. Bioplastics are bio-based plastic which holds similar applications as conventional plastic but has additional key properties and functions as-biodegradable- instead of generating solid waste it switches organic recycling, reduced carbon in environment, biological resources- it is bio-based so has sufficient biological resources, it has potential to accelerate economic growth and sustainable development bioplastic market India had revenue of \$0.2 billion in 2022, representing a compound annual growth of 12.9% between 2017 and 2022. Even every ton of plastic waste recycled result in saving of 3.8 barrels of petroleum. Though bioplastic in the form of polylactic acid is largest in volume approx. 45.1% of total biodegradable plastic market. European bioplastics estimated top five bioplastic- bio-PE, PLA, PHA, biodegradable polyester and starch (which is currently replaced by polyethylene terephthalate PET). According to recent data more than 10 billion plastic produced so far since 1950 and only 35- 40% of portion is well utilized and majority has thrown as waste. Therefore, awareness toward bioplastic has risen day by day.

**Key words:** Bioplastic, Biodegradable, Packaging, Toxic effect.

## **INTRODUCTION-**

We all are aware plastic in the form of polyethylene (PE) polystyrene (PS) and polypropylene (PP) has a crucial role in maintaining preservation and packaging of stored food, other application too such as plastic bags, containers, bottle etc. so major population rely on it. On the other-hand the concern of plastic manufacturing from non-renewable sources and increasing non degradable plastic waste is threat for environment and upcoming generation. World plastic production was estimated at 390.7 million metric tons in 2021, an annual increase of four percent. As per Terri's report annual per capita consumption in India would be 20 kg in recent

year which is 16kg now. Plastic contributes of 8% of total solid-waste, Delhi producing maximum followed by Kolkata and Ahmedabad, moreover Bangaluru, Mumbai, Hyderabad are top generators of plastic waste. Even daily-basis stuffs as-food packets, single-time use plastic, carrying stuffs and households produce major portion of plastic waste in the form of wrapper of snacks, plastic bottles of water, beverage as soft drinks etc. Plastic consumption in world-wide growing exponentially. Around 45% of manufactured plastic utilizing in form of packaging purpose and single use plastics, and rising concern is only available or reachable plastic approx. 60% of total can be recycled in appropriate way.

It is practically not conceivable to avoid all plastic product in the human world, so must to have a substitute for plastic. As a green approach initiated to formation of plastic from natural substances. Bioplastics are material originates biologically not fossil based. Bioplastic packaging of food has way better impact on health criteria too, it is safe to adopt and degradable. Meanwhile fossil based plastics as- polyethylene, plastic bags etc take years to decompose and also discharge high amount of  $\text{CO}_2$ , which leads chemical pollution in environment with toxic effect on aquatic and land animals, moreover also creates microplastics. Scientifically proven health effects by microplastics are cognitive impairment and reproductivity. Microplastic also carry other toxic chemicals some organic pollutants or heavy metals they are small plastic less than five millimetre long, that can harm ocean and aquatic life.

Bioplastic can be referred to a better plastic. Plastic has been essential to human life, but improper disposal of it can cause millions of deaths of animals annually. It reduces fertility of soil and other rising environmental issues of blockage of drain and sewage are inviting uncountable disease in local area.

#### Definition-

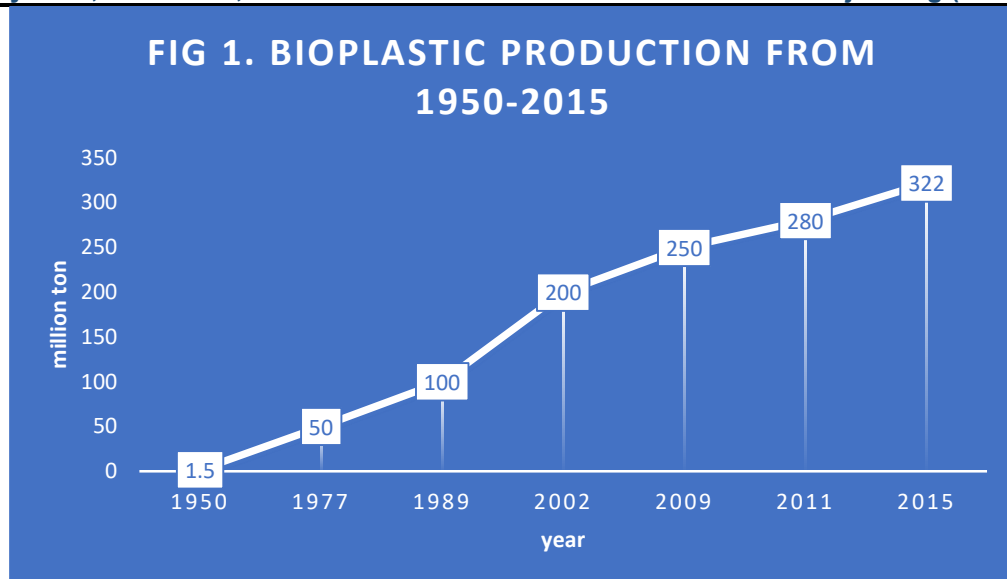
“Bioplastics in general terms are bio-based plastic product or an unorthodox plant-based plastic as a green alternative of plastic. They are plasticizer starch obtained from recycled food waste or plant containing sugar molecule or vegetable fats and oil.”

“Bioplastic is defined as bio- based polymers for plastic production and also refers to biodegradable in nature (Sudhakar et al. 2023, Vert et al. 2012)

#### HISTORY OF BIOPLASTIC-

There is multiple theories of bioplastic origin and progressive development –

- 1- It was a convinced theory bioplastics were originated from biological substances even before the fossil-fuel based plastics discovered. Back in 16<sup>th</sup> century latex and rubber were used as 1<sup>st</sup> plasticizer.
- 2- In 1855 Alexander Parks develop bioplastics from cellulose and named it parkesine, which is current celluloid.
- 3- In1907 after many years of research and experiments resulted in 1<sup>st</sup> synthetic plastic's existence.
- 4- In1926 Maurice lemoigne discovered 1<sup>st</sup> known bioplastic- polyhydroxy butyrate (PHB) by working on bacteria -bacillus-megaterium.1<sup>st</sup> bioplastic was derived from bacteria according to his principle – human consumption of sugar assimilates in fat, when bacteria consume/ absorb sugar, they synthesize polymers.
- 5- In 1930 petroleum-based plastics discovered
- 6- In 1975 a Japanese scientist discovered a bacterium(flavobacterium) that was able to breakdown nylon ,1<sup>st</sup> authentic bioplastic(biodegradable) came into existence.
- 7- In 1990 novament 1<sup>st</sup> bioplastic industry and even after all these years it is still only.
- 8- In 2010 bio-plastic from seaweed.
- 9- In 2018 first packaging made from a fruit.

**FIG 1. BIOPLASTIC PRODUCTION FROM 1950-2015**

### CAUSES BEHIND BIOPLASTIC ORIGIN-

Bioplastic came into existence to reduce issue of increasing plastic waste day to day. Bioplastics has been perfect substitute of plastic, it is light weight, non-permeable stable and most imp. degradable. It has been a magic material in food packaging and appropriate solution for plastic waste. They just need to make it affordable to human population, so it can be biggest competition against petrochemical.

There's following some major causes to lead us to bioplastics-

#### 1-Rising issues of fossil fuel-based plastic –

Fossil based plastic has oil as base which result in discharge high amount of  $CO_2$  to atmosphere. So on back days plastic manufacturing completely depended on oil wells. Though even in medical science, formation of syringe, capsules etc involve plastic. Instead of replacing it and things keeps going on.

#### 2- Pollution and degradable bioplastic-

plastic has been most durable material on earth, that even after 10,000 years barely had a chance it will degrade, plastic waste is rising and contaminating land and water bodies. There can be slow breakdown but it leads toxin and other harmful greenhouse gases, chemicals to human world. As a solution bioplastic originates in the form of natural monomer or hydrocarbon leading as biodegradable plastics.

#### 3-Chemical based product-

Fossil based plastic involve chemical substances to manufacture, they may cause health issues like- allergies, toxicity and more, bioplastics are completely naturally synthesized so less negative impact.

#### 4- Limited Resources-

Conventionally plastic manufactured from fossil-fuel a non-renewable resource, there's limited amount of fossil fuel is left on earth. May be in upcoming 50 years there will be no fossil /petroleum oil left.so must have to find an alternative in the form of biomass that can be easily available.

#### 5- Economically Beneficial-

We know conventional sources of plastic are fossil fuel, which are non-renewable and more expensive.so technologies and modern science's work over it find a solution of it in the form of bioplastic. bioplastic is relatively not as difficult to produce packaging as they're easy to adopt and operate.

#### 6-Future prospective-

it has been an ecofriendly and sustainable approach toward environment. Bioplastic maintain carbon cycle in natural way, no addition of extra CO<sub>2</sub> through mining oil wells. As further development cost will drop and it would be cheaper.

## FACTS AND FIGURE-

According to UNEP's current report- plastic production has been rising since 1950s,

Annual production of plastic in 2000- 234million metric tons

Annual Plastic production in 2019- 460 million metric tons

Forecast plastic production in 2060- 1,231 million metric tons

Whereas an estimation by plastic Europe (association of plastic manufacture)- plastic industry growing for more than 50 years.

Plastic production in 1950 was 1.5 million ton. Plastic production in 2015 was 322 million ton. Compound annual growth rate from 1950-2015 is about 8.6%. As production is increasing so as waste.

According to central pollution board's report on plastic waste in major city of India (Mumbai, Bengaluru, Delhi, Kolkata, Ahmadabad)-

Total waste was approx.25,940 tonnes per day plastic waste.

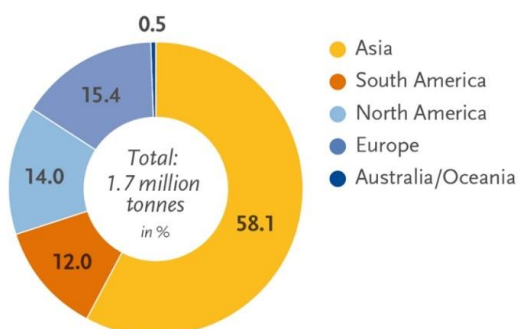
Recycled around 15,600 tonnes per day.

Remained waste was nearly 10,000 tonnes per day.

Plastic pollution is now on alarming level, out of 369 million tons of plastic -waste generated every year about 11 million metric tons enter in ocean (UNCTAD,2022d and UNEP,2022).

As per demand of Eco life, bioplastic production accelerate, now Asia is leading in bioplastic production in world-wide bioplastic production, whereas China approx. 29% of total production capacity.

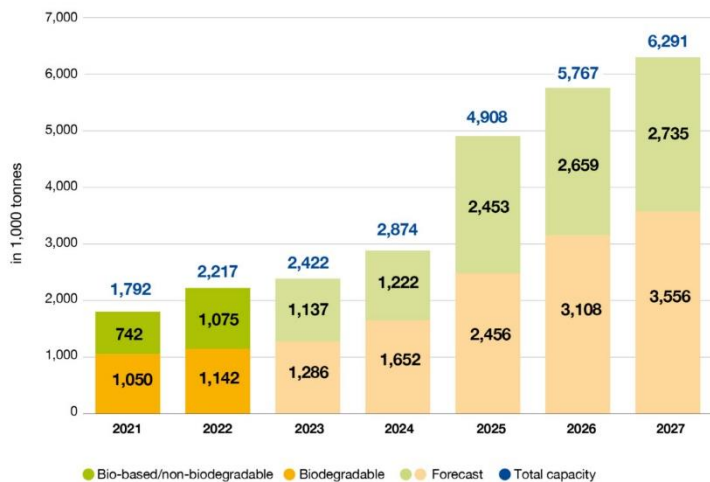
*Global production capacities  
of bioplastics in 2014 (by region)*



Source: European Bioplastics, Institute for Bioplastics and Biocomposites, nova-Institute (2015). More information: [www.bio-based.eu/markets](http://www.bio-based.eu/markets) and [www.downloads.ifbb-hannover.de](http://www.downloads.ifbb-hannover.de)

Bioplastic in recent scenarios represent approx. 2% of about 300 million tonnes of annual plastic production. According to latest market data by European bioplastics, it is expected to 7.8 million rises in upcoming years.

## Global production capacities of bioplastics



Source: European Bioplastics, nova-Institute (2022). More information: [www.european-bioplastics.org/market](http://www.european-bioplastics.org/market) and [www.bio-based.eu/markets](http://www.bio-based.eu/markets)

## CATEGORIZATION-

Bioplastics are categorized into three major parts on the basis of their origin-

- 1-Origin from biomass- natural polymer
- 2-Origin from chemicals renewable sources-synthetic polymer
- 3-Origin from microorganism- microbial polymer

## 1- Natural polymer-

Natural polymer is obtained from naturally originated sources as- plant- seeds, grains from rice, wheat, whey, pulses etc. that include-starch, cellulose, gum, gluten. Some of polymers derived from animals too as- collagen, gelatine, lipid etc. they're non-permeable, light weight, solid or crystalline and hydrophobic in nature.

## (A) Plant based-

Starch- starch a polysaccharide carbohydrate is a liberal source of bioplastic, most of agricultural plants ex- sweet potato, potato, rice etc as alternative of polystyrene in manufacture of thermoplastic as packaging and filler. Also use in medical sectors in production of drug capsule. Starch can be converted in bioplastics through plasticizer material as modification of starch in reaction with cheapest plasticizer glycerol at optimum heat and after multiple addition of biopolymer that result in thermoplastic starch availability at low cost. glycerol basically enhances plasticizer effect in starch.

## (B) Animal based-

Protein- protein a complex long chain of amino-acids, fibrous and globular in structure. They're derived from animal in the form of keratin from hair, casein from milk etc.so as well from plants too as- gluten from wheat, soy protein etc. they have numerous industrial application due to complexity of peptide chain in their structure. It has specific barrier to gas and aroma, more than lipid and starch.

Casein-obtained from milk, casein layer basically flexible, transparent in nature and can be pigmented. it is expensive in compare to another bioplastic. Casein has adhesive properties so often used in labelling of containers and bottle too.

Keratin- bioplastic manufacture from keratin has been tested with glycerol has the best mechanical and thermal properties.

## 2-Synthetic polymer-

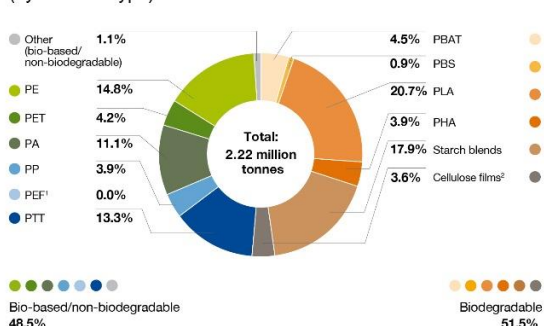
These polymers produced through chemical synthesis from renewable sources.

For example- Polylactic acid (PLA)- polylactic acid derived from dehydration of lactic acid at optimum temp. around 70% of total polylactic acid is used in packaging industry, so an ideal substitute of fossil-fuel based polymer. lactic acid obtained from lactobacillus genera then it is polymerized into PLA. It is extensively utilized in food packets industry for keeping them safe from moist and fungal or bacterial infection. Moreover, it is used for short and long self-life products.

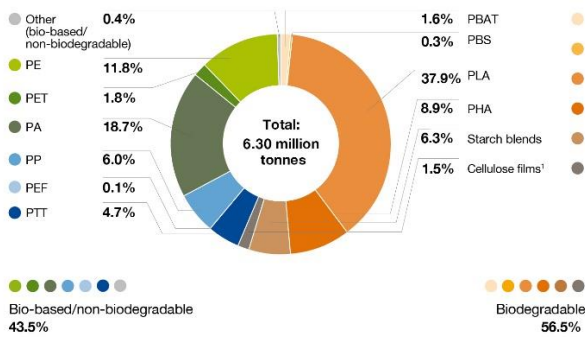
## 2- Microbial polymer-

These bioplastics are generated by microorganism as- genetically modified plants, fungi and bacteria as- pseudomonas, E. coli. Halo monas Bolivian, hydrophiles, They ferment polysaccharide at low oxygen level in microbial cells and produce polymer like PHA (polyhydroxyalkanoates), and PHB by enzymatic reactions. They're extensively use in pharmaceutical sectors, genetic engineering as- blood vessel replacement, drug dose, herbicide etc. PHA has a beneficiary role in food packaging, composting bags etc. companies like biocycle, tephra etc producing PHA at industrial level

**Global production capacities of bioplastics 2022**  
(by material type)



**Global production capacities of bioplastics 2027**  
(by material type)



## MECHANISM OF BIODEGRADATION-

Biodegradation term has been used for degrading or breaking down of substances through biological organism(microorganism) present in outdoor environment. on industrial scale biodegradation has optimum requirement to proceed as- optimum temp., specific amount of microorganism and other under control condition as duration, humid etc. bioplastic after chemical breakdown converted in co<sub>2</sub>, water and biomass or compost. Even in some cases they generate biogas. Some natural polymers are easily degradable due to their hydrophilic nature and some can't because they show resistance to hydrolysis and biodegradation.

There're two methods of biodegradation-

1-Aerobic approach

2-Anaerobic approach

The final outcome after degradation is  $\text{CO}_2$ , water, soil like substances humus, inorganic compound, and importantly no toxic chemicals.

#### 1- Aerobic approach-

Oxo-biodegradation- it is method of oxidation of plastic material to reduce their molecular weight, so that can be easily degraded or eaten by fungi, bacteria. Oxo-biodegradation of carboxylic acid results in alcohol, aldehyde, ketone, that will be accessible to microorganism to degrade it or recycle. mostly in complex plastic, which cannot be easily degraded. Presence of polymer stabilizer in plastic to make them long lasting product, these stabilizer needs to be destroyed by metal catalyst before degradation process initiates. Though plastic's complexity reduced naturally but it is slow to biodegrade. Biodegradation of plastic requires oxygen to proceed, if they're buried in depth of earth, it is most likely they will remain same years after years in lack of  $\text{O}_2$ .

#### 2- Anaerobic approach-

Anaerobic degradation takes place in 4 steps-

- A- Hydrolysis,
  - B- Acidogenesis,
  - C- Acetogenesis,
  - D- Methanogenesis.
- A- Hydrolysis-Specific bacteria hydrolyse the complex carbohydrate polymer into simple molecular / monomer protein into amino-acid.
- B- Acidogenesis- those monomers by acidogenic bacteria converted into  $\text{CO}_2$  and hydrogen, amino acids into ammonia and organic acid.
- C- Acetogenesis- organic acids into acetic acids  $\text{CO}_2$  and hydrogen.
- D- Methanogenesis- methanogens (unicellular organism) convert intermediate substances into biogas- methane and  $\text{CO}_2$ , still some solid waste remains.

#### Feasibility of Bioplastic (accessibility and expense)-

Additional development and various new raw resources of bioplastic on an upgraded level will provide economically feasibility of production at industry. To get better of plastic pollution issues and replacement of non-renewable plastics to bioplastic needs to be reconsider and explore for large scale extraction. There's numerous research on bioplastic sources is currently proceeding such as- corn- based bioplastic, tomato-based bioplastic and so more.

Algae can be emerging source to produce bioplastic (Sudhakar et. al.) they grow often in aquatic habitat and feeds on organic waste. Even it was considered algal plastics in future can replace and reduce production of fossil-based plastics (Cinar et al;2020; Mekonnen et, al'2013). Algae intake inorganic material (as- N, P, K) and produce organic substances as-carbohydrate, lipid etc. (Shi et al.2012, Zhang et al;2000) that has huge industrial value even at large scale. It is potential source to amplify biodegradable plastic's supply and demand.

Accessibility and expense- Though bioplastics has chemical free, organic based biodegradable packaging material, but still most of bioplastics are more costly than petrochemical based usual plastics. Packaging industry are getting going with techniques and looking forward for affordable manufacturing, even now for small scale business of bioplastic will cost 60 lakh rupees, so as usual it is expensive for consumer also, for

now market prize of biodegradable plastic raw material will be 210rs, a bioplastic disposal bag will cost 450rs. As higher cost it won't be fit to adopt by target consumers. As world is evolving so as packaging industry, awareness of sustainability and ecofriendly approaches, discarding fossil-fuel based plastic. At some sort of bioplastic, they're affordable too, for ex- polylactic acid (PLA)- it is cheapest bioplastic for now. Bioplastic market is rising as people are getting aware of it and toxic impact of usual plastic.

#### Application in food packaging and drawbacks-

Bioplastics as food packaging material are globally rising. bioplastics are referred more in food packaging, they often used in long self-life product as- packets of potato chips, corn puffed chips and various snacks or stored pasta etc, some beverage like coco-cola and short self-life as- fresh fruits, green vegetables and cutlery, carry bag etc. Bioplastic improve food safety plant-based oil in it amplify their potential, moreover, makes it durable and flexible, a sustainable packaging. Meanwhile in hot food and drink / beverages, bioplastic material keeps the moist resistant and reduce leaks. Its recycled management are more significant than Petro plastic.

Some companies already using bioplastics in food or liquor packaging for ex- one of well-known beverage brand coco-cola uses bioplastics. Even in upcoming years they will upgrade it to 100% bio-based bottle by using plant based terephthalic acid (from sugarcane), approx. 48% of total bioplastics utilized in food packaging.

#### Advantage of Bioplastic -

- 1- Food packaging industry – bioplastics are more favourable in food packaging industry because Petro-plastics contains some remain harmful chemical substances on surface that has poisonous effect or toxicity on health. On the other hand no toxic effect of bioplastic as they are synthesized through natural substances.
- 2- Improve food safety\_ PLA helps food to stay fresh longer.
- 3- Significant utilization of natural resources\_ there's limited resource of fossil fuel on earth so bioplastic manufacturing helps in conserving non-renewable and utilized renewable resources.
- 4- Recycling- bioplastics easily recycled back into environment such an ecofriendly alternative.
- 5- Medical industry- bioplastics used in formation of capsules, syringe etc.
- 6- Economically beneficial- now it is bit more expense but as research area and techniques develop it will be affordable.

#### Drawbacks –

- 1- There're numerous examples of biopolymers which are not biodegradable (polypropene).
- 2- Biodegradable components in food industry struggle to match the level of fossil fuel-based plastics.
- 3- The attractiveness and quality of usual plastic is little better than bioplastic.
- 4- Biodegradable material represents small fraction of total polymer production and limited activeness in commercial field. Though market for bioplastic isn't grown much, due to its expense in manufacturing and less competitive in compare to petrochemical based plastics.
- 5- Poor functionality- low melting capacity, oxygen permeability, high water vapour, thermal instability.
- 6- Limited industry of bioplastics exists, only one globally known "novament" exist, so as less production.

#### Role of Bioplastics in environment-

Bioplastics holding beneficial contribution in food industry without any destruction or damage to environment, they completely degraded into organic matter. Bioplastic has major role in dealing with environmental issue other than food-packaging, as- it has agricultural, horticultural and bioremediation application and so more. There're numerous environment issues are rising as- abiotic depletion, global warming due to emission of greenhouse gases, human toxicity due to chemical involved in usual plastic manufacturing, marine aquatic toxicity- disposal of plastic waste in water-bodies that remains even after 100 years. Terrestrial

toxicity, photochemical oxidation, acidification, microplastic formation etc. reliability on bioplastic will discard all above mentioned environment complications.

## CONCLUSION-

Now days technologies help to evolve develop bioplastics as a source of food packaging vegetable oil, corn based, algae-based, sugarcane-based plastic are leading the bioplastic production. though they're limited, not utilized on large scale there's still lot more to develop and work on execution, quality of product, awareness in human and industrial expenses on it. Now it is an emerging solution to deal with several problem by fossil - based plastic but it has to be in common citizen's reach, bioplastic is higher in cost, but further techniques and research can rift it in improved way as- cheaper manufacturing. PLA is often used in food packaging and it keeps food substances long lasting and fresh without any chemical leaching. Though annual world plastic production exponentially grows as **1.5 million tons in 1950 to 322 million ton now**, meanwhile according to an estimation by European plastic- bioplastic has minimal share in plastic industry as per reports annual bioplastic production for now approx. **2.2 million tons in previous year 2022 report to approx. 6.3 million tonnes expecting in 2027**. Meanwhile bioplastic production in **India market consumption** volume also increased with compound growth rate of **13% between 2017 and 2022** to reach a total of **144.3 thousand tonnes in 2022**. Though It is human responsibility to initiate progressive research and development in biodegradable plastics. As we are hopeful and can expect in upcoming decade a world full of bioplastic for the sake of environment.

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