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RESEARCH ARTICLE

A REVIEW ON PREVALENCEOF BIODEGRADABLE PLASTIC IN CURRENT LIFE

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Abstract

Plastics have become an integral part of our lives. The problem of conventional plastics istaking decades to degrade in nature. Plastic waste is increasing every year and the precise time needed for biodegradation is unknown. Environmental awareness has driven the development of new biodegradable materials, especially for single use plastic items. Synthetic plastics provide a range of utilities in the civilization of mankind, at the same time the accumulation of these nonbiodegradable plastic in the environment is a menacing drawback increasing day by day. So thatthe management of plastic waste is a worldwide concern and also a substitute for plastic has become essential to us.

Introduction:-

Plastics are advantageous as they are strong, lightweight, and durable (1). The diverse group of chemicals used in the making of plastic is known to be highly toxic and poses a serious threat to the biosphere. These substances besides hitting hard on the ecosystem can also cause an array of problems like birth defects, cancer, and damage to the nervous and immune systems (2). Because of economic growth and changing consumption and production pattern plastic waste generate highly in the world. This implies that on one hand, more sources are being used to meet the increased demand for plastic, and on the other hand, more plastic waste is being generated. Due to the increase in generation, waste plastics are becoming a major stream of solid waste.This rise has posed a significant problem for local
authorities in charge of solid waste management and sanitation. The production and use of bioplastics are generally regarded as a more sustainable activity when compared with plastic production from petroleum (petro plastic), because it relies less on fossil fuel as a carbon source and also introduces fewer, net-new greenhouse emissions if it biodegrades. They significantly reduce hazardous waste caused by oil-derived plastics, which remain solid for hundreds of years, and open a new era in packing technology and industry (3).

Bioplastic or organic plastics are a form of plastics derived from renewable biomass sources such as vegetable oil, corn starch, and pea starch unlike fossil-fuel plastics derived from petroleum. Bioplastics provide the twin advantages of the conservation of fossil resources and reduction in carbon dioxide emissions, which make them an important innovation for sustainable development. Bacteria serve as an excellent feedstock for plastic production owing to its many advantages such as high yield and the ability to grow in a range of environments(4).Bioplastic is not just a single substance, they comprise a whole family of materials with different properties and applications (5).

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Review Of Literature:-

Plastics

The word 'plastic' is derived from the Greek word “plastikos”, which means ‘able to be molded into various shapes and sizes(6). Plastics are man-made long-chain polymeric units. Plastics play a vital role in modern society, from the vinyl siding on a house to the disposable beverage bottles sold in vending machines plastics are present. Nearly every modern product contains at least a few plastic components, yet synthetic plastics have only existed since the introduction of Bakelite in 1907(7). Plastics are advantageous as they are strong, lightweight, and durable (1). Kaliaet al., 2000 observed that during the past 3-decades, plastic materials have been increasingly used in food clothing, shelter, transportation, construction, and medicinal and recreation industries (8). Momani2009 reported that all plastics are polymers but not all polymers are plastics and are ubiquitous. Plastics have proliferated so readily throughout the modern world because of their versatility. Plastics can be flexible or rigid, brittle or resilient, clear or colored, and have manyother useful properties.
Some plastics conduct electricity, while others serve as great insulators. Its widely divergent properties allow the plastic to perform almost any role(9).

Today plastics have become a necessary part of contemporary life due to their durability and resistance to degradation. Plastics are the most extensively used material. These are truly significant in our daily life and in modern society and are used in manufacturing industries (10). Plastics have been an integral part of our lives. From automobiles to medicine, plastics are utilized in almost every manufacturing industry in the world. Approximately 25 million tons of plastics are produced by the plastics industry every year (11). Reddy et al., 2013 also said that plastics have become an integral part of our lives. The problem with conventional plastics is taking decades to degrade in nature (12). The diverse group of chemicals used in making plastic is highly known to be highly toxic and poses a serious threat to the biosphere. These substances besides hitting hard on the ecosystem can also cause an array of problems like birth defects, cancer, and damage to thenervous and immune systems (2).

Seymour et al., 1993 suggested that plastics are made from inorganic and organic raw materials such as carbon, silicon, hydrogen, nitrogen, and oxygen. The basic materials are extracted from oil, coaland natural gas are used for making plastics. Plastics are recalcitrant to microbial degradation(13). These non-degradable plastics accumulate in the environment at a rate of 25 million tons per year (14).Plastics are strongly recalcitrant, as they have long polymeric chains and specialized groups associated with them (15). Plastics, especially thermoplastics, are readily recycled. Relatively small amount of plastic was recycled is that it is cheaper to make new plastic than to recycle old plastic in most cases (16). The economic growth and changing consumption and production pattern, plastic waste generate highly in the world. This implies that on one hand, more sources are being used to meet the increased demand of plastic, and on the other hand, more plastic waste is being generated. Due to the increase in generation, waste plastics are becoming a major stream in solid waste (3).

Plastic pollution

Petroleum-based plastics constitute a major environmental problem due to their low biodegradability and accumulation in various environments. Plastic is one of the major pollutants at present time around the world, which is used for daily use like packaging materials, carry bags, manufacturing of different types of materials etc. So, to replace the use of synthetic plastic as well as to reduce the increasing environmental pollution an alternative must be needed (17). Low-density polyethylene is one of the major sources of environmental pollution. Polyethylene is a polymer made of long chains of ethylene monomers. The use of polyethylene growing worldwide at a rate of 12% per year and about 140 million tons of synthetic polymers are produced worldwide each year. With such a large amount of polyethylene gets accumulated in the environment, generating plastic waste ecological problems are needed for thousands of years to efficiently degradation

Plastic materials have been universally used in our daily lives and are now causing serious environmental problems. Millions of tons of these non-degradable plastics accumulate in the environment per year. For efficient management of used plastic materials, recycling is one solution. Another solution to reduce plastic residue is the use of biodegradable plastics (10).As conventional plastics are persistent in the environment, improperly disposed of plastic materials are a significant source of environmental pollution, and potentially-harming life (15). Dependence on conventional plastics and their boundless usage have resulted in waste accumulation and greenhouse gas emissions. Recent technologies are directed towards the development of bio-green materials that exert negligible side- effects on the environment (18).

Biodegradable plastics

Biodegradable plastic or organic plastics are a form of plastics derived from renewable biomass sources such as vegetable oil, corn starch and pea starch unlike fossil-fuel plastics derived from petroleum. Bioplastics provide the twin advantages of conservation of fossil resources and reduction in carbon dioxide emissions, which make them an important innovation of sustainable development. Bacteria serve as an excellent feedstock for plastic production owing to its many advantages such as high yield and the ability to grow in a range of environments (4). Biopolymers are a subset of polymers. The difference between biopolymers and petro-polymers is that the monomers of a biopolymer are derived from a living source. Two main types of biopolymers exist. The first type is synthesized directly by an organism. The second type is produced by a synthetic chemical reaction from biological reactants. Examples of the first type include DNA, RNA, proteins, and polysaccharides. The second type includes most of the biopolymers used to make bioplastics (9).Bioplastic is not just a single substance, they comprise a whole family of materials with differing properties and applications (5). Brian and Modney 2009 gave an insight about bio-plastics, their composition, preparation, properties, advantages and disadvantages(19). The disadvantages of PHB are, it is still much more expensive and lacks mechanical strength compared with conventional plastics, high crystallinity, stiff and brittle, thereby resulting in poor mechanical properties with a low extension at break (20).

Microbial polyesters known as polyhydroxyalkanoates (PHAs) are biodegradable plastics. Life cycle assessment indicates that PHB is more beneficial than petroleum-based plastics (21).Polyhydroxybutyrate (PHB) is a biodegradable material, which has physical properties similar to synthetic plastic (22). PHB was first identified by Lemoigne in 1926 as a reserve material of *Bacillus megaterium*. PHB is insoluble in water, resistant to ultraviolet radiation and is impermeable to oxygen, and is very much suitable for use as food packaging material. This polymer is readily degraded in the soil and sewage (23). Now a day there has been considerable interest in the development and production of biodegradable plastics in response to problems associated with plastic waste and its effect on the environment (24).

Table 1:- Different types of Plastics.

Sl.No	Types	Properties
1	Starch based plastics	The thermoplastic starch, such as plant material, currently represents the most important and widely used bio plastic.
2	Aliphatic polyesters	The aliphatic biopolyesters are mainly polyhydroxyalkanoates (P HAs) like the poly 3-hydroxybutyrate (PHB), polyhydroxyvalerate (PHV) and polyhydroxyhexanoate (PHH).
3	Polylactic acid (PLA) plastics	PLA is a transparent plastic produced from cane sugar or glucose.
4	Poly3hydroxybutyrate (PHB)	The biopolymer poly3-hydroxybutyrate (PHB) is a polyester produced by certain bacteria processing glucose or starch.
5	Polyamide 11/ PA 11	Biopolymers are derived from natural oil. PA 11 belongs to the technical polymers family and is not biodegradable. It is used in high-performanceapplications like automotive fuel lines pneumatic air brake tubing, electrical cable etc.
6	Bioderived polyethylene	The monomer of polyethylene is ethylene. This is produced by fermentation of agricultural feedstock such as sugar cane or corn.

PHB is equivalent to a very basic polymer, PHA (Poly hydroxyl alkanoates). PHB is produced by microorganisms in the form of reserved food granules under stress conditionslike excess availability of carbon source but a limited provision of other nutrients such as nitrogen, phosphate, oxygen and sulphur. The main limitation of PHB as biodegradable plastic is its high production cost as compared to that of production of synthetic plastics based on petrochemicals (22).

Poly-β-hydroxybutyrate (PHB) is a biodegradable and biocompatible thermoplastic produced by various microorganisms. It can be made into films, fibers, sheets, even molded to shape of bag and bottle (24). Polyhydroxybutyrate (PHB) is the best known polyhydroxyalkanoate (PHA) which is now well recognized that this lipid inclusion is accumulated by many bacteria as they enter the stationary phase of growth to be used later as an internal reserve of carbon and energy (25). Biosynthesis of PHB is simpler than the formation of most

polysaccharides, as only 3 enzymes are normally involved- β- thioketolase, acetoacetylCoAreductase and PHB synthase (26).

Substrate
↓
Acetyl CoA
↓ Acetyl CoA acyltransferase
Acetoacetyl CoA
↓Acetoacetyl CoA reductase
3- Hydroxybutyryl CoA
↓PHB synthase
Poly- β-hydoxybutyrate

Figure 1:- The synthesis of PHB. PHB produced with the help of three enzymes such as Acetyl CoA acyltransferase, Acetoacetyl CoA reductase and PHB synthase

Microorganisms are capable of producing a wide range of polymers and copolymers based on 3-hydroxypropionic acid substituted with various alkyl groups in the 3-position. The most common homo polymer is poly (3-hydroxybutyrate), PHB, which has a 3-methyl substituent, but monomers having C_2-C_5 alkyl side groups are found in natural co polyesters (27). The monomers are all optically active in the absolute configuration. PHB can be produced from carbon substrates as diverse as glucose, ethanol, acetate, methane and even gaseous mixtures of carbon dioxide and hydrogen. Polyhydroxybutyrate (PHB) is a biopolymer that can be used as a biodegradable thermoplastic material for waste management strategies and biocompatibility in medical devices (28). The various bacterial strains among archaebacteria, Gram positive and Gram negative bacteria and photosynthetic bacteria including cyanobacteria have been identified to accumulate Poly-3Hydroxybutyrateboth aerobically and anaerobically (18). For industrial production of PHB, some bacterial species like *Bacillus spp*., *Pseudomonas spp.Aeromonas spp*. and *Cupriavidusspp*. have been extensively used (17). Since the production of bio-plastic is expensive many techniques have been adopted for large scale production. Therefore they compare the production of PHB (Bio- Plastic) in marine and soil bacteriato find out which one has the potency to accumulate more PHB.

Bio-based materials such as polynucleotides, polyamides, polysaccharides, polyoxoesters, polythioesters,polyanhydrides, polyisoprenoids and polyphenols are potential candidates for substitution of synthetic plastics.Among these, polyhydroxyalkanoate (PHA), which belongs to the group of polyoxoesters has received intensive attention because it possesses biodegradable thermoplastic properties (18). Apart from general applications like the manufacture of polythene bag, trays, containers and bottles for soft drinks and dairy products, blister foils for fruit, vegetables and medicines are manufactured from bio-plastics (29).For the development of a biodegradable material, based on PHB with better mechanical properties and long-term stability, the following qualities are necessary:

1. To prevent the degradation of chains in processing, which can be reduced by the addition of lubricants and plasticizers.
2. To stop the secondary crystallization that occurs in the amorphous phase after aging time at room temperature, i.e., by suppression of the crystallization and shift of the glass temperature to lower values.
3. To investigate the effect of high temperatures, melt processing, the cooling rate and holding time on the crystallization rate, and crystal size.
4. To investigate the influence of the concentration of plasticizers on glass temperatures and other relaxation mechanisms.
5. To investigate the influence of additives on the biodegradation behavior of PHB (soil burial, river water, compost conditions and the aerobic test).
6. To optimize processing technology like, for instance, injection moulding and extrusion.

Bio-degradable polymer plays a predominant role as a biodegradable plastic due to their hydrolysable ester bonds. PHB is produced by a variety of microorganisms under appropriate conditions such as the presence of nitrogen, calcium, magnesium, iron or essential vitamins (30). Due to their biological origin it is an advantage of PHB is, they are degraded naturally and completely to carbon dioxide and water under natural environment by the enzymatic activities of microbes. In most cases, bacteria produce PHB. Also in many cases, short-chain-length (SCL) PHA

copolymers are synthesized consisting of C3 and C5, including poly[(R)- 3-hydroxypropionate-co-(R)-3-hydroxybutyrate] (31).
Harding et al., 2007 investigate that Polyhydroxybutyrates (PHB) require less energy, when the energy of production and feedstocks are combined than petroleum-based plastics with similar characteristics(32). Polyhydroxybutarates (PHB) have some benefits in terms of carbon emissions compared to petroleum-based plastics. The total life cycle energy requirements for PHB are 44.7 MJ per Kg plastic produced. Poly-β-hydroxybutyrate (PHB) is the best known polyhydroxyalkanoate (PHA).PHB was the first homopolymer PHA to be discovered (33). There have been very few studies related to other non-PHB homopolymers, including poly (4-hydroxybutyrate) (P4HB). Some Rhizobium species has ability to produce PHB in various culture conditions (34). Kin et al., 2003 investigated that the starch-based plastics can be prepared in a wide variety of ways. The source of the raw starch is usually corn but could be any plant high in starch like potatoes. Starch can be embedded in other polymers like polyethylene, polystyrene and PVC (35).

Poly-β-hydroxybutyrate is a polyester produced by bacterial fermentation.The importance of this polymer is twofold. First, it is unique in being both thermoplastic and hence melt processable, and in having a biological origin, that gives PHB potential to replace existing oilbased commodity polymers as and when, the price of oil rises. Second, is its purity and chemical regularity of PHB making it an ideal model substance for fundamental studies of polymer morphology, crystallization and nucleation (36). PHB has some properties, including tensile strength and flexibility, similar to polyethylene and polystyrene. Reddy 2005 studied five different types of alkylphenols, each of the two different types of mono and poly-aromatic hydrocarbons selected for degradation, and conversion into poly-3-hydroxybutyrate (PHB) using the **Bacillus** sp. CYR1.Their results denoted that the strain **Bacillus** sp. CYR1 can be used for conversion of different toxic compounds persistent in wastewater into useable biological polyesters.

PHA has been produced by prokaryotic microorganisms, including bacteria and archaea, although transgenic plants were reported to produce PHA (37). PHA has rich properties depending on the structures. Homopolymers, random copolymers, and block copolymers of PHA can be produced depending on the bacterial species and growth conditions (38). With over 150 different PHA monomers being reported, PHA with flexible thermal and mechanical properties has been developed. PHA has a wide range of potential applications because of its desired features such as biocompatibility, biodegradability and negligible cytotoxicity to the cells (39). Hence, the potential application of PHA as replacement for petrochemical based polymers is gaining popularity in various fields involving packaging, medical and coating materials.

Polyhydroxyalkanoates (PHAs) are regarded as new environmental friendly biodegradable plastics. Some microorganisms which are moderately or extremely halo-tolerant may have the ability to produce PHAs. These PHA-producingmicroorganisms can be isolated and put to use in the treatment of effluents which have a similar salt concentration to the environment in which they flourish (40).These desirable properties in compounding and blending have broadened their performances as potential end-use applications.PHA has been manufactured for non-woven materials, polymer films, sutures and pharmaceutical products used in surgery, transplantology, tissue engineering and pharmacology (41).Koceret al., 2002 synthesized PHA-containing block copolymers in Cupriavidusnecator using periodic substrate addition. Byrom 2001 reported that despite the numerous advantages of using biodegradable plastics, the commercialization of PHA has been on-going since 1980s with limited success.The high production cost of PHA has been a major drawback to their replacement of petrochemical plastics (42).

Polylactic acid (PLA) currently consumes more energy in production than PHB.A kilogram of first generation PLA requires 54.1 MJ of energy input during its life cycle. In general, bio-plastics biodegrade more easily and at a greater rate than the average petro plastics. This is good for some applications and bad for others (43). Even for bioplastics, composting often has to be done at very specific conditions like high heat and oxygen levels or in the presence of certain microorganisms, for the desired degradation to take place.Galindo et al., 2007 reported that PHB can be produced from bacteria, algae and genetically modified plants. The polymer itself is synthesized directly by the organism requiring no extra polymerization step. The actual production of the polymer within the cell is a complex enzymatic process.PHB is the only polymer from the group of PHA's to be produced in large quantities. This polymer has poor mechanical properties (44).

Bio degradable plastics: True or False
Long 2010 was tested five types of bio-plastic bags to see how well they would compost. None of them broke down completely after 25 weeks in home compost conditions (77 degrees). A product from Italian bio-plastic

manufacturer Nova Mont came closest to what we would call truly compostable, with a product called Mater-bi. Mater-bi is "made of corn starch, vegetable oil derivatives, and biodegradable synthetic polyesters" In thier tests, only Mater-Bi was compostable at typical home compost pile conditions (45).

Biodegradable plastic: Good or Bad

The good

Biodegradable plastics are the best ways to reduce the harmful effect of plastics to environment. In order to save earth from dangerous plastic pollution, bio-plastics are the finest option. Bio-plastics are mainly manufactured from biomass substances such as potatoes or corn and many other starchy products. This plastic type requires three basic things, such as proper heat, airflow and water availability. The presence of all these factors automatically diminishes the decomposition time. Hence, such type of plastics is useful in compost heap(45).

The bad

Use of plastics in any form threatens all forms of life whether it's a human life, wildlife or the whole planet. The excessive usage of plastics automatically grows up the landfill areas to a very high extent. At the same time, water bodies are also getting polluted due to ultimate disposal center for plastics. Therefore, an advanced form of plastics called biodegradable plastics is brought in use. There are basically two kinds of bio-plastics available. One is oil-based and another one is starch-based bio-plastics. However, oil-based bio-plastics release carbon in the form of carbon dioxide during decomposition process. It may cause the greenhouse effect in the environment. Whereas, starchy-based bio-plastics may also harm in respect of excessive water usage during degradation. As starchy-based bio-plastics cannot get recycled, hence cause extreme wastage of food or raw materials(45).

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