Bioplastic- Futuristic Approach

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ABSTRACT: The ever-growing production of non-recyclable plastic products causes plastic pollution to be the one of most pressing environmental issues. The transition of petrochemical-based plastic with eco-friendly biodegradable plastic has become the promising solution to overcome the plastic pollution crisis. Recycling technology is an effective but incomplete measure to address these environmental issues. Bioplastic is a type of plastic made from biomass materials. Biomass normally refers to a union of microorganisms, which mainly contains macromolecules including starch, cellulose, protein, etc. Biodegradable bioplastic is a natural polymer modified class (PSM). Bioplastics are considered highly significant to increase sustainability where sustainability defines a balance between economic, environmental and social aspects of business and can be applied to different domains. In this research, the development of bioplastics is introduced in the context of circular economy. The choice of proper raw material for biopolymer production is very important as it can have an additional impact on the ecological pressure caused by the process. Here, waste water from rice mill is taken as raw material and natural coagulant like oil, starch, gelatine (commercial) etc are added for its flexibility. The thought of "Zero Emission" and "Recycling" the waste water in the production process can be highly beneficial in moving a step closer towards sustainability.

***Key words**: bioplastic, waste water, circular economy and zero emission*

INTROCUCTION

TWO THREATS

Two great threats in current situation are reduction in water level and increase in plastic usage. Reduction in water level indirectly indicates the increase of waste water level. Wastewater production is expected to increase by 24% by 2030 and 51% by 2050. The amount of wastewater generated globally is increasing due to population growth, urbanization, and economic development. Increase in water waste contributes to the depletion of freshwater resources, leading to water scarcity in many regions. This can severely affect ecosystems, agriculture, and human communities. Increase in plastic usage indirectly indicates the contamination of soil, water and environment. When the term "plastic pollution" is indicated it mainly denotes the "microplastic". These microplastics are main contaminants of ground water. Microplastics in ground water, when consumed by humans or used for agriculture causes severe health hazards to all living beings. The main cause of this plastic pollution is the use of Single-use plastics (SUPs). These are the plastics that are used only once before disposing like plastic bags, straws, coffee stirrers, soda and water bottles and most food packaging. These SUPs are not biodegradable and when thrown away or disposed of on the land, they release toxic substances and cause harm to the environment and human health (Infertility, Diabetes, neurodevelopment disorders) (Ben adler.2023). Global plastic production and the consequent waste generation have increased bifold when compared to the past decades. This in turn accounts for nearly 4.5% of greenhouse gas emissions (TIMES OF INDIA ,2021). Due to this huge disposal of plastics, around 70,000 microplastics are consumed by an average person each year and 1 million marine animals die due to plastic pollution. To overcome these two threatening issues the development of bioplastics is introduced in the context of circular economy.

REVIEW OF LITERATURE

PLASTIC AND ITS REPLACEMENT

Plastics are also essential to many aspects of sustainability: lightweight plastic materials improve the fuel efficiency of cars and aeroplanes, plastic insulators can increase energy savings and plastic food packaging increases shelf life, which can reduce food waste. The transition of petrochemical-based plastic with eco-friendly biodegradable plastic has become the promising solution to overcome the plastic pollution crisis. Recycling technology is an effective but incomplete measure to address these environmental issues. Bioplastic is a type of plastic made from biomass materials. Bioplastics typically plastics manufactured from bio-based polymers stand to contribute to more sustainable commercial plastic life cycles as part of a circular economy.

WASTE WATER RECYCLING

Water reuse (also commonly known as water recycling or water reclamation) reclaims water from a variety of sources then treats and reuses it for beneficial purposes such as agriculture and irrigation, potable water supplies, groundwater replenishment, industrial processes, and environmental restoration. Apart from these beneficial purposes, we came with idea of producing bioplastic from waste water.

SUSTAINABILITY AND CIRCULAR ECONOMY

Bioplastics are considered highly significant to increase sustainability where sustainability defines a balance between economic, environmental and social aspects of business. Increasing concern regarding the environmental impact of plastic waste and the plastic-related emission motivates the transition towards a ‘circular plastic economy’. In a circular economy, the use of non-renewable resources and waste production is minimized, while reuse and recycling dominate the life cycles of materials. Although most commercial plastics are made from fossil resources, these materials can also be made from renewable resources and are commonly referred to as bioplastics. In this case, the monomers are extracted or synthesized from biomass compounds (such as sugars in plants) and then polymerized to either make a direct replacement for an existing plastic, such as polyethylene (PE), or novel polymers, such as polyhydroxyalkanoates (PHAs). Biomass extraction can also yield non-synthetic natural polymers, such as starch, natural rubber and proteins. Bioplastics are plastics that are either made from renewable resources.

Many researches have been conducted for finding an alternate solution for both plastic and reduction in waste water level. Reviews on bioplastic production from wastewater have covered topics such as:

BIOPLASTICS FROM WASTE WATER

The treatment of wastewater to protect human health and water bodies remains the primary task of wastewater treatment plants. In addition, the recovery of resources is becoming increasingly important on the path to circular economy. Wastewater, for example, contains a lot of organic carbon that is often converted into methane for further energy production. working with bacteria that are able to store organic carbon as polyhydroxyalkanoates (PHA). These biopolymers serve as energy and carbon source for the bacteria. They can be extracted from the bacterial cells and further processed to biodegradable plastic. Production of bioplastic from wastewater, would offer several advantages over current production methods. PHAs are at present produced from primary feedstock such as sugar or vegetable oils under sterile conditions. This results in high production costs, which is why PHA bioplastics, despite their attractive properties, cannot compete with petroleum-based plastics so far and therefore remain a niche product. The use of organic carbon from wastewater, which is available for free, and the use of mixed microbial cultures, which do not require energy-intensive, sterile conditions, are therefore a promising approach. It takes three steps to produce these bioplastics from wastewater. First, as much of the organic carbon as possible must be extracted from the wastewater. Subsequently, this carbon must be fermented into volatile fatty acids, the precursors of PHA. (Brison, 2022)

WASTE WATER AS A RESOURCE

Globally, about 380 billion cubic meters of wastewater is generated each year. In 2020-21, India's urban areas generated an estimated 72,368 million liters per day (MLD) of wastewater, while rural areas generated 39,604 MLD. However, only 28% of the total wastewater is treated, and the remaining 72% is disposed of in rivers, lakes, and aquifers. Only about 52% of wastewater is treated globally, with treatment rates varying by income level. High-income countries have a treatment rate of 74%, while low-income countries have a treatment rate of 4.3%. The common perception remains that wastewater is a source of pollution that needs to be treated and disposed of, wastewater is perceived as a growing problem rather than a valuable and sustainable source of water, energy and nutrients.

A paradigm shift is currently underway, with developed countries taking a proactive interest in improved wastewater management. The goal is to go beyond pollution abatement and to seek to obtain value from wastewater. As a result, the wastewater sector in developed countries has started moving away from simply treating wastewater in wastewater treatment plants and has instead started seeing the potential of these plants as water resource recovery facilities. One among them is usage of waste water for production of bioplastic. Many developing countries are interested in production of bioplastic for the term circular economy and zero emission. Therefore, many research studies have been done throughout the world focusing on cost-effective eco-technologies and alternative solutions to manage wastewater. (Bhanu et.al 2023)

ENVIRONMENTAL IMPACT OF WASTEWATER

Bioplastics can reduce environmental impact and dependency on fossil fuels. However, there are challenges to bioplastic production, such as competition with food production for feedstock, high production costs, and uncertainty in end-of-life management. The organic carbon and nitrogen in wastewater can be used to produce bioplastic, but there are challenges such as low productivity and scalability issues. Bioplastics have better mechanical properties than synthetic plastics, making them more sustainable and reliable.

Life cycle assessments (LCAs) can help understand the environmental impact of bioplastics. Biodegradability is an important feature for bioplastic applications, especially in controlled or predictable environments. Used water from homes, industries, and other sources, can have significant negative impacts on the environment if not treated properly. Contamination of water bodies, eutrophication, groundwater contamination, ecosystem disruption, public health risks, climate change etc. To mitigate these environmental impacts, it is essential to implement effective wastewater treatment management technique. Additionally, reducing water consumption and adopting sustainable water management practices can help minimize the amount of wastewater generated.

BENEFITS OF BIOPLASTIC FROM WASTEWATER:

Circular Economy, by Reducing waste and pollution by turning a byproduct into a valuable resource. Sustainability, by providing a renewable and biodegradable alternative to traditional plastics. Resource Recovery, helps in Recovering valuable materials from wastewater, reducing the demand for raw materials. Bioplastics derived from wastewater can have a lower carbon footprint compared to petroleum-based plastics.

Mitchell Waldrop et al. (2023) concluded that bioplastics are advantageous when compared to non-conventional plastics, but they also have their effect in terms of cost, time and resource. This article explains that not all bioplastics are biodegradable and not all bio-based plastics are not biodegradable. These bioplastics are carbon-cutting, but the resources required to produce are enormous and expensive when bioplastics are replacing 3.8 million metric tons per year. So, whether resources will be enough to make bioplastics viable in the coming years is to be seen.

George et al. (2021) focused on the types of bio-based plastics and gave an insight into biological wastes that can be utilised to produce bioplastics. The future trends emerged in the fields of bioplastic and challenges regarding bioplastics were explained.

Bioplastics Production from Various Sources

El-Kady, M. F. et al. (2022) investigated the production of bioplastics from agricultural waste, particularly banana peels and potato peels. The researchers explored the feasibility of converting these waste materials into biodegradable plastics, highlighting their potential as sustainable alternatives to conventional plastics.

Saba, N. et al. (2022) reviewed the current state of biodegradable and sustainable bioplastics made from natural fibres. The authors explored the mechanical properties and potential applications of these composites, highlighting their eco-friendly nature and potential to replace traditional petroleum-based plastics.

Dutta, S. et al. (2022) explored the potential of lignocellulosic biomass as a feedstock for bioplastics. The study investigated the extraction of cellulose from agricultural residues and evaluated its properties for bioplastic production, emphasizing its eco-friendly nature and potential as a sustainable alternative to conventional plastics.

Jyoti Sharma et al. (2018) reviewed an article that highlights the potential of banana peel as a renewable source for bioplastic production. It discusses the composition of banana peel and the different methods used for the extraction of cellulose and other biopolymers. The authors also evaluate the properties of banana-peel-based bioplastics, such as mechanical strength, thermal stability and biodegradability.

SEAWEED AS A SOURCE OF BIOPLASTICS

Armeli et al. (2022) reviewed seaweed as a potential source for the production of bio-based products. They researched the Mediterranean Sea about seaweed and focused on the Italian situation which included companies and legislation on seaweed production and its contribution to the sustainable Blue Economy.

Vallikkannu et al. (2022) stated that seaweed is an alternative to conventional plastics and that bioplastics are effective live saviours. Their beneficial usage in food packages and disposal through food waste collection are discussed.

Ismael Santana et al. (2022) stated that the invasive seaweed Rugulopteryx okamurae can be used to produce bioplastics through injection moulding employing glycerol as the plasticizer. The results obtained in the present work are very promising, although further research should be performed to improve the mechanical properties of Rugulopteryx okamurae seaweed-based bioplastics.

ANALYSIS OF BIOPLASTICS FOR VARIOUS PROPERTIES

Dinesh Adhikari et al. (2016) analysed the degradation of three kinds of bioplastics and their effects on microbial biomass and microbial diversity in the soil environment. It showed that polybutylene succinate-starch was degraded by 1% to 7% after 28 days in soil with an initial bacterial biomass of 1.4×10^9 cells/g-soil, however poly lactic acid (PLA) was not degraded in the soil after 28 days. The rate of bioplastic degradation was enhanced accompanied by an increase of the bacterial biomass in the soil and 16S rDNA PCR-DGGE analysis indicated that the bacterial diversity in the soil was not affected by the degradation of bioplastics. Moreover, the degradation of bioplastic did not affect the nitrogen circulation activity in the soil.

Fakhry et al. (2018) stated that gelatin was used to produce a bioplastic film using a solvent-casting method. The researchers found that the optimal conditions for bioplastic production were a gelatin concentration of 5%, a glycerol concentration of 30%, and a casting temperature of 60°C. The resulting bioplastic film had good mechanical properties, including a tensile strength of 3.5 MPa and Young's modulus of 47 MPa. The bioplastic film was also found to be biodegradable, with a degradation rate of 80% after 60 days in soil.

Alshamrani et al. (2020) reported that gelatin was used to produce a bioplastic film with a tensile strength of 2.7 MPa and Young's modulus of 32.3 MPa. The bioplastic film was also found to be biodegradable, with a degradation rate of 45% after 28 days in soil.

Fang et al. (2021) reported the production of a bioplastic blend using gelatin and polyvinyl alcohol (PVA). The resulting bioplastic had improved mechanical properties, including a tensile strength of 14.6 MPa and Young's modulus of 213 MPa. The bioplastic blend was also found to be biodegradable, with a degradation rate of 65% after 28 days in soil.

CHALLENGES AND FUTURE TRENDS IN BIOPLASTICS

Swati Pathak et al. (2014) Carried out a comparative study that confers the likelihood of the conventional petro-plastics being substituted by new-age degradable and renewable bio-derived polymers. It presents the keynote issues that support findings of the benefits these materials have in relation to conventional, petrochemical-based counterparts and that biodegradable plastic materials are most apt for single-use disposable applications where the post-consumption waste can be locally composted.

Micaela et al. (2021) offered the latest development connected to the transition from the plastic sector which is achieved through the application of biotechnological routes for the preparation of completely new polymeric structures or drop-in substitutes derived from renewable resources (bio-based products) and it describes the specific role played by biotechnology in promoting and making this transition faster. It is the key enabling technology for the development of these innovative biomaterials and clearly supports their transition to full technological maturity and commercial accessibility. Valorisation of waste and forward-looking management of critical raw materials are the main drivers for the further development of the bioplastics discussed and biotechnological methods offer increasing opportunities for the whole plastic sector.

Mohammed Sabbah et al. (2017) stated that bioplastics replaced conventional plastics by only 1% of the 300 million tons of the total plastics produced annually and their limits were poor mechanical and barrier properties. But, as demand is rising and more sophisticated products and applications are emerging (As predicted to grow from around 4.2 million tons in 2016 to approximately 6.1 million tons in 2021), the market of bioplastics is changing rapidly.

FUTURE PERSPECTIVES

Numerous techniques, including biodegradation, bioenergy production, and by-product recovery, have been successful in increasing industrial productivity, enhancing pollution control, and promoting improved health outcomes through efficient industrial waste management. This process of production of bioplastic as a remedy in large scale will definitely be a futuristic approach and a remarkable solution for the waste water utilization and for replacement of plastics.

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