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Role of Sustainable Alternatives to Petrochemical Based Plastics in Achieving the SDGS

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ABSTRACT: A significant transition from fossil fuel-based economy to one based on biomass is occurring as a result of global warming, socioeconomic challenges, and new policies, which are propelling decarbonisation process across industries. The usage of bioplastics is the most effective way to address the issue of plastic trash. Bioplastics are a safe and sustainable substitute for petrochemical or traditional plastics that lessen our reliance on fossil fuels. The strategic substitution of sustainable products for those derived from petrochemicals not only promotes environmental conservation but also advances the achievement of several sustainable development goals (SDGs). Post-treatment methods, such as photolysis, thermochemical treatment, and biodegradation were used in this study. These alternatives support in lowering greenhouse gas emissions and increasing resource efficiency, which greatly supports SDGs 12 and 15, Responsible Consumption and Production and Life on Land, respectively. This study explores how the (SDGs) could be implemented effectively and makes it clear that sustainable consumption and production (SCP) should be given significant consideration in their production.

Keywords*:* Petrochemicals**, S**ustainable Alternatives, SDGS, Renewable Energy, Circular Economy

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INTRODUCTION

Sustainable development and the circular economy are significant issues in recent years because of the increasing pollution of the environment caused by solid waste, including plastics and petrochemical based products (Bernal-Carrillo et al., 2024). The transportation revolution is among the biggest of the 20th century. A world increasingly reliant on the burning of hydrocarbon fuels like gasoline, diesel, and jet fuel has been brought about by the invention of automobiles, trucks, and airplanes as well as engine-powered trains and ships. The globe has been more electrified with the development of electricity-producing plants, electric appliances for home use, desktop computers, and mobile phones. As a result, the world is becoming more reliant on energy produced mostly from carbon-based resources like coal and natural gas (Song, 2006). In many regions of the world, there is growing concern about the shortage of natural resources.

Petroleum-based materials find application in several industries and products. Plastic is the most widely used material when it involves end-of-life recovery, reuse and recycling. High energy and carbon content materials either burn in combustible releasing a lot of greenhouse gases when they burn, or they slowly break down into microplastics in landfills and oceans (Hackler & Kennedy, 2024). According to estimates, by the end of 2016, there were between 9 and 23 million metric tons of plastic garbage released annually into rivers, lakes, and the ocean worldwide. A comparable amount was released into the terrestrial environment, estimated to be between 13 and 25 million metric tons monthly.

In order to achieve sustainable development, both developed and developi ng economies have been challenged by the United Nations (UN) 2030 Agenda f or Sustainable Development resolution. As a result, 17 SDGs with 169 targets and 213 quantifiable indicators have been established with the intention of increasing well-being in the areas of the economy, society, and environment. According to estimates, PM air pollution is responsible for hundreds of thousands of lung cancer deaths globally each year. Additionally, air pollution can affect the quality of soil and water bodies by polluting the process of precipitation which then finds its way into soil and water ecosystems and affects the ecosystem as a whole. Reducing air pollution could help to improve the current situation and the SDGs' implementation. SDG1, SDG7, and SDG11 are directly correlated with air pollution, and there may be indirect connections between air pollution and other SDGs' objectives, such SDG12.

Plastics are not harmless substances; rather, they are made of a number of hazardous compounds that can leak out into the environment as microplastics pollutants. They contain substances that can lead to long-term respiratory conditions as well as other health issues. Micro- and nano-plastics in food can also result from extensive plastic pollution in the environment (Ullah et al., 2024). A significant proportion of the available data on microplastic pollution in the environment is on the marine environment, but freshwater and terrestrial ecosystems and the atmosphere are also contaminated. Dioxins are deadly organic pollutants that are emitted from plastic polymers and cause cancer, neurological impairment, and impaired reproductive system development. We can increase public awareness of the consequences of plastic pollution by showcasing an abundance of data that shows the harm that plastic trash brings to the ecosystem (Fatima et al., 2024).

Petrogenic and pyrogenic processes produce polycyclic aromatic hydrocarbons, which are hazardous and carcinogenic substances found in the environment. The pyrogenic portion comes from fires, forest fires, volcanic eruptions, and incineration, whereas the petrogenic proportion comes from oil and drilling-related activities, including oil mishaps, spills, and pollution from industrial sites, refineries, and most importantly traffic exhaust emissions (Haidri, Fatima, et al., 2024). Recent investigations have revealed significant cumulative quantities of PAHs in soil, aquatic, and atmospheric environments. PAHs also have lengthy degradation periods. The atmospheric effects on smog clouds, from air to soil, from air to water reserves, and from air to humans, cause pollution and pollutant migration to increase, especially with the arrival of winter (Haidri, Qasim, et al., 2024).

In order to achieve the SDGs, sustainable alternatives to platics based on petrochemicals are crucial. This review article seeks to examine this. Through an examination of the harmful effects of plastics derived from petrochemicals, on the environment and human health, this paper aims to emphasize the pressing necessity of shifting towards more ecologically friendly alternatives. This review aims to analyze the current status of petrochemical usage, clarify their harmful effects on air and water quality, evaluate the potential of sustainable alternatives to reduce pollution, and suggest implementation strategies that will meet SDG targets. This assessment is organized as follows: first, it looks closely at how petrochemical-based plastics affect the environment and human health; then, it explores sustainable alternatives and how they might help achieve the SDGs. This study aims to add to the global conversation on sustainable development and inform decision-making towards a healthier and more environmentally friendly future by synthesizing the collection of existing material and providing suggestions for future research topics.

THEORETICAL REVIEW

Innovative approaches to combat plastic pollution

Small-scale and Nano plastic pollution is a major worldwide concern because of the negative ecological impacts of plastic waste and litter and their environmental persistence. SDGs can only be achieved by searching for environmentally appropriate substitutes for products made from petroleum. Technology, research, and environmental awareness coming together to create sustainable alternatives that reduce ecological footprints and bring us closer to peaceful coexistence with our planet is what's driving us forward (Shinkevich et al., 2021). With the goal of achieving the SDGs and promoting a more sustainable future for future generations, this review brings readers on an investigation through the globe's array of sustainable alternatives.

Analyzing the evolution of Plastic Production

The application of personal protective equipment (PPE) and single-use plastics (SUPs) has increased at a rate that is unparalleled. According to the literature, 400.3 million tons of plastics were produced worldwide in 2022, compared to 58.7 million tons produced in Europe. The production of petrochemical plastics was slowed down globally during the pandemic. Still, there was a rise in 2021 (Bhan, Verma, & Singh, 2020). Maintaining the production and delivery chain was a challenge. Simultaneously, the global market has acknowledged the interest in recycling petrochemical plastics and biopolymer substitutes. The output from these groups has been rising yearly since 2018. Most plastic garbage is exported, ends up in landfills, gets burned in incinerators, and is poorly managed. The global transfer of plastic garbage from affluent to low-income nations has gained popularity in the 21st century because to the associated environmental dangers and economic benefits (Ummer et al., 2023).

Since 2018, the COVID-19 epidemic has decreased the amount of plastic produced using fossil fuels. On the other side, the demand for bio-based plastic and recycled materials has grown, much like the worldwide market's substantial growth in biopolymer output in 2022. The EU's policies and growing environmental consciousness are to blame for this. For Europe to expand sustainably, the ideas of green growth and green economy are essential (Olabi et al., 2023). With an emphasis on social justice and environmental sustainability, these programs encourage a change to more environmentally friendly production and consumption practices. Since 2018, the manufacturing of plastics derived from fossil fuels has decreased because to the COVID-19 pandemic. However, as with the worldwide industry, there is now more interest in bio-based plastic and recycled materials biopolymer production will rise noticeably in 2022. Eco-friendly and sustainable substitutes for conventional plastics are products manufactured from biomass-derived biodegradable polymers (Faazal et al., 2023).

Biodegradation

The process of biodegradation involves the breakdown of organic materials by microbes into more basic, naturally occurring substances including biomass, carbon dioxide, and water. By gradually dissolving things like plastics into non-toxic components, this natural process helps to lessen the impact of these products on the environment. Antimicrobial growth of plastic surfaces and the use of plastic polymers as carbon sources are necessary for the biodegradation of plastics (Sayed et al., 2021). Due to its ability to reduce pollution, biodegradability is a widely valued characteristic in produced materials. Since many plastic items, disappointingly, do not break down naturally, they can linger for decades or even centuries in heaps or other environmental debris, adding to pollution in the environment. Still, there is a benefit to using biodegradable materials because they help save resources by lowering the need for fossil fuels. Its use can also help preserve ecosystems, particularly those that are aquatic.

a. *Impact of biodegradation on Environmental sustainability:*

Biodegradable plastics offer a significant advantage: they decompose naturally by microorganisms like bacteria and fungi into harmless components. This translates to a dramatic reduction in plastic accumulating in landfills, which not only occupy valuable space but can also leach harmful chemicals. More importantly, biodegradation lessens the threat to wildlife. Countless animals, from majestic sea turtles to curious seabirds, mistake plastic debris for food, leading to entanglement, gut blockages, and even death. By breaking down into smaller, non-toxic components, biodegradable plastics significantly reduce this risk.

b. *Mechanism of Biodegradation*

Plastics can biodegrade by two different mechanisms: enzymatic and non-enzymatic. Microorganisms like bacteria and fungus, which produce enzymes that can break down plastic polymer chains into smaller molecules, are involved in the process of enzymatic biodegradation. In contrast, physical or chemical processes including photo decay, the enzyme hydrolysis, and corrosion lead to nonenzymatic biodegradation (Ghosh, Mekhilef, Ahmad, & Ghosh, 2022). Numerous factors, including the kind of polymeric material, the presence of chemicals, and environmental circumstances, can affect the speed at which plastics biodegrade. For instance, some polymers including polyethylene (PE) and polypropylene (PP) are less susceptible to biological degradation than others, such polylactic acid (Pop, Săplăcan, Dabija, & Alt) and polyhydroxyalkanoates (PHA). Plastic biodegradation is an achievable path approach for addressing the issue of plastic waste worldwide (Sulaiman et al., 2023).

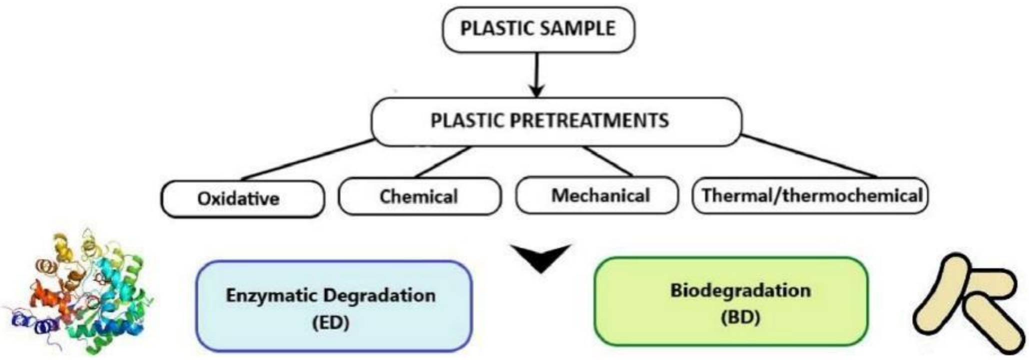

Figure 1. Different types of pretreatments of plastic material (Ciuffi, Fratini, & Rosi, 2024).

c. *Limitations of Process of Biodegradation*

Numerous factors affect the biodegradation of plastic material. These factors include the chemical and physical qualities of the polymer itself, as well as those related to the environment, including temperature, pH, oxygen, UV light, and moisture (Chen et al., 2020). Plastic biodegradation has some disadvantages even though it seems promising. The duration required for conventional polymers to biodegrade is a notable disadvantage. Sometimes the process of biodegradation might be inefficient, particularly in places like landfills where the environment might not be ideal for an efficient breakdown. Furthermore, there is a chance that toxic chemicals will occasionally leak out of biodegradation byproducts, endangering wildlife and ecosystems. Furthermore, inconsistent policies and inadequate infrastructure for handling biodegradable plastics might cause misunderstandings and inefficient waste management techniques. In order to solve the issues surrounding biodegradable plastics and guarantee their sustainable use going forward, these disadvantages emphasize the significance of ongoing research and development (Safdar et al.).

METHODOLOGY

The post-treatment methods, such as photolysis, thermochemical treatment, and biodegradation, have been the subject of an increasing number of studies concurrently. Because it permits resource recovery from plastic wastes and drastically lowers carbon emissions as compared to incineration, chemical recycling of plastic wastes via a thermochemical pathway (i.e., pyrolysis) has drawn the most interest among them. Thermochemical conversion of plastic wastes, which are mostly composed of long-chain polymeric structures, yields short-chain hydrocarbons, oil, char, and synthetic gases (H_2 and CO), all of which can be processed further to produce further value-added goods or energy (Waseem et al., 2023).

RESULTS

Design for Recycling and Design for Reusing

Conventional plastics, despite their usefulness, have alternatives. Bioplastics, made from renewable materials, seem like a solution to plastic waste as shown in figure 2. But some bioplastics don't actually break down naturally. Plastic pollution comes from two main sources: large plastic debris we throw away and tiny plastic particles leaking from industry. Many everyday items, like clothes and car parts, also contribute to plastic pollution. Recycling efforts are limited, with only a small percentage of plastic actually getting reprocessed. Plastic pollution harms wildlife, both through entanglement and ingestion. The answer lies in designing products that can be easily reused or recycled, minimizing the amount of plastic waste we create in the first place.

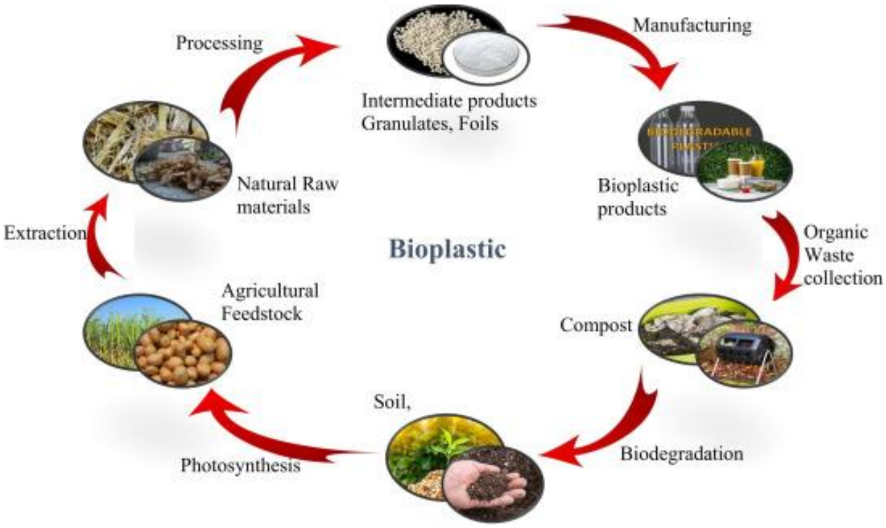

Figure 2. Manufacturing of Bioplastics (Bulla, Devi, Mishra, & Kumar, 2024).

Therefore, raising the rates of recycling and upcycling is the greatest strategy to solve the global plastic pollution issue. However, it is often less expensive to manufacture new plastic products from virgin resources than it is to recycle and reuse existing materials. Researchers are working on creating new methods, such as thermomechanical processing, chemical recycling (pyrolysis and glycolysis) and biological depolymerization with the use of microorganisms, enzymes, and catalysts, to increase the efficiency of recycling and upcycling. There are still difficulties with recycling technology, garbage sorting, economics, and social behavior in spite of these efforts. Recycling plastic garbage necessitates its separation, which can be challenging and intricate given that many goods have many plastic components (Mina, Kannan, Gholami-Zanjani, & Biuki, 2021).

Limitations of Reusability

The possibility of higher energy consumption and greenhouse gas emissions during the cleaning and reprocessing of plastics for reuse is one of the limitations of reusability in plastic design processes when it comes to the environment. In addition, the transportation and logistics associated in accumulating and dispersing reused plastics can have an adverse effect on the environment if improperly handled (Malla & Bandh, 2023). To overcome these constraints and create more environmentally friendly procedures, greater study in the area of plastics reusability design is essential. Research endeavors may concentrate on enhancing recycling technology, investigating novel materials for increased robustness, and refining collection and sorting procedures to reduce ecological footprints (Luengo, Leonforte, Greaves, Rubio, & Guzman, 2023). We can move closer to a circular economy and lessen the impact of plastic consumption on the environment by funding further research and development.

Table 1. Comparison table to showcase difference between petro-chemical based products and Sustainable Products

Aspects	Petro-chemical Based Products	Sustainable Products
Environmental Impacts	Detrimental impacts on ecosystem	Contribute to environmental conservation efforts
Renewability	Depend on finite Fossil fuels	Made up from recycled Materials
Biodegradation	Not able to biodegradable or contribute to air and land pollution	Biodegenerate to less toxic substances
Carbon Footprint	High level of Carbon footprints	Less or reduced Carbon footprints
Performance	Not Efficient	Highly Efficient

Sustainable Development Goals (SDGs):

The SDGs for 2030, which resulted in a set of 17 goals as indicated in figure 3, are the result of the United Nations' validation of its commitment to achieving a sustainable environment and the standard of living. The UN and individual nations are addressing the problems associated with plastics from the ocean on a global scale at the national, subnational, and supranational levels, as well as at the regional level. Goal 3 of SDGs ensure that everyone, regardless of age, leads a healthy life and encourages wellbeing. Goal 6: Guarantee that everyone has access to water and sanitation facilities and that they are administered sustainably. Goal 12: Determine environmentally friendly methods of consumption and production (Livingston et al., 2020). The UN SDGs, under Goal 14: Conserve and sustainably manage the oceans, seas, and marine ecosystems for sustainable development and recognize the problem of marine (micro) plastics on a worldwide scale.

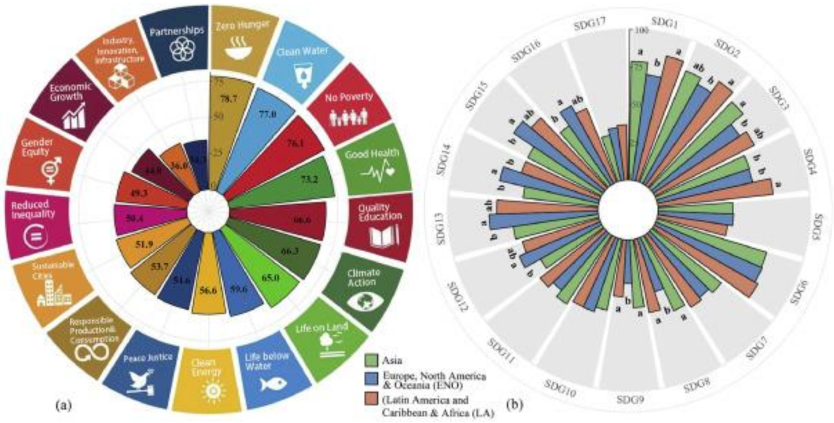

Figure 3. Prioritized scores of seventeen SDGs on global and their regional differences (Yang et al., 2020).

Green Initiatives: Transforming SDGs with Alternatives

That micro plastics have been discovered in the human body, including the placenta, is now evident. Due to the fact that food packaging, food , and even the air we breathe, micro plastics can be found in food and can be inhaled, consumed (via ingestion of micro plastics in seafood and other food products covered in Goal 2), and come into touch with the skin. Ingesting or breathing microplastics into the body can cause damage to cells or trigger immunological and inflammatory responses in different organs, all of which can have an adverse effect on health (JOHNSON, OKURE, DOZIE, & KABIR, 2023). Improving medical systems, extending access to high-quality healthcare services, stimulating health awareness, making investments in healthcare infrastructure, giving priority to preventive measures, and tackling social and economic variables of health are all things we can work on to get SDG 3 accomplished. SDG 3's goal of ensuring healthy lifestyles for all can be achieved by putting these strategies into practice.

Recent studies have found tiny plastic particles, both large and small, in treated drinking water and wastewater. This is a concern for achieving clean water and sanitation goals (Goals 2 and 3) set by the World Health Organization. The WHO has confirmed the presence of these microplastics in both tap and bottled water, and is investigating potential health risks. The amount of microplastics in treated drinking water can vary widely, depending on the water source, treatment plant setup, and detection methods used. In bottled water, refilling plastic bottles can cause tiny particles to shed from the container itself. Even though wastewater treatment plants remove a high percentage (90-99%) of microplastics, they still act as a source of plastic pollution.

Microplastics released from wastewater treatment plants can enter the environment directly through discharged water or indirectly through the use of treated sewage sludge as fertilizer. The vast amount of microplastics entering these plants, from sources like laundry and cosmetics, makes it challenging to achieve sustainable water management for everyone, despite the high removal rates (Perveen et al.).

The European Commission has acknowledged the need for the advancement of science, technology, and innovation (STI) as a requirement for putting the new Agenda into practice (Nilsson et al., 2015). Digital, automation, bio, and nanotechnologies, as well as artificial intelligence (AI), have already demonstrated their broad effects and global potential in the water industry (Messner et al., 2019). The next generation of water system management, which will secure sustainable water supplies in the future, must adopt scientifically and technologically driven solutions as opposed to the conventional wisdom. The achievement of SDG 6 may be jeopardized, nonetheless, since capitalizing STI for the formulation of strategies and policies for water systems remains difficult (Meramo, Pasutto, & Sukumara, 2024).

SDG 12, which stands for “responsible consumption and production”, seems to encourage a lot of "cut and paste" strategies in relation to the ways mentioned above. The most noteworthy is that not many have created reliable indicators unique to SDG 12 (Nepal, Phoumin, & Khatri, 2021). Therefore, it has not yet been embraced to use the whole systems approach that is seen to be essential for the SDGs to succeed (UNEP, International Resource Panel 2017). "Material footprint, material footprint per capital, material footprint per GDP" are metrics included in the SDG 12 sub-indicators. The concept of material footprint is crucial for comprehending transboundary consequences because, unlike assessments of domestic material consumption (DMC), it accounts for the use of raw materials in other nations via global supply networks (Choudhary et al., 2021).

Only this goal 14 (indicator 14.1.1b plastic debris density) explicitly addresses plastics; microplastics (i.e., plastics smaller than 5 mm) are not addressed. Currently, there is no international protocol or standardization of ways to assess (micro) plastic contamination, despite the fact that it is widely acknowledged as a global issue that affects almost every freshwater and marine ecosystem worldwide (Lange et al., 2021). Currently, citizen scientists' eye observations are the primary method used to quantify floating plastic marine trash (>2.5 cm). However, new research has suggested using citizen scientists to assist in quantifying floating debris by having them participate in marine debris clean-ups led by groups like Litter Intelligence, International Coastal Cleanup (ICC), and Marine Debris NOAA.

Major problems still exist for all areas and socioeconomic levels, making SDG 14 one of the least researched and under-implemented SDGs. Four of the seven targets in SDG 14 namely, targets 14.2, 14.4, 14.5, and 14.6 were supposed to be completed in 2020, but no nation has yet to complete all four. While Target 14.6 (stop harmful subsidies) reported the largest gains, Target 14.4 (sustainable fishing) has suffered from the slowest progress and has only been accomplished by the Marshall Islands, Papua New Guinea, and Tuvalu(Fritsche et al., 2020). But aim 14.6, as mentioned in the previous section, relates to IUU fishing, which is addressed by target 14.4. Therefore, the majority of the other SDGs won't be achieved if SDG 14 isn't progressed towards.

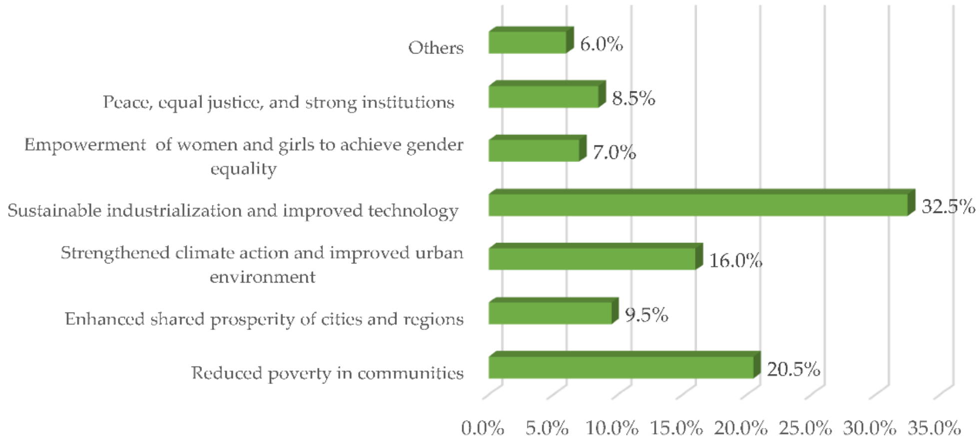

Figure 4. Aspects of SDGs (Kalfas, Kalogiannidis, Chatzitheodoridis, & Toska, 2023).

According to Figure 4 results, 32.5 percent of respondents are considerably more concerned with the SDGs' goals of sustainable industrialization, enhanced technology, and community poverty reduction (20.5%), as well as more action on climate change (16%) and better urban environments (Dahiya, Katakojwala, Ramakrishna, & Mohan, 2020).

Suggestions for Shifting Away from Plastics Based on Petrochemicals

Petroleum-based plastics' high stability and non-biodegradable nature have long been known to contribute to environmental problems such pollution, their continued use in terrestrial and aquatic ecosystems, and the production of greenhouse gases (de Oliveira Neto, Correia, Silva, de Oliveira Sanches, & Lucato, 2019). The research and implementation of biopolymers as an environmentally friendly and economically viable substitute for synthetic plastics is imperative, given the extent of the eventual depletion of petrochemical sources and the global environmental pollution caused by the manufacturing of synthetic plastics such as polyethylene materials (PET) and polypropylene materials (PP). The main source of energy used globally is fossil fuels. In spite of this, fossil fuels are finite resources with negative environmental effects that lead to climate change and a host of health problems.

DISCUSSION

Emission of Greenhouse gases in manufacturing of petrochemical based plastics

Devastating environmental issues include plastic pollution, deforestation, water pollution, species extinction, climate change, global warming, and resource depletion currently demand for quick remediation. The burning and use of petroleum fossil fuels by humans to create chemicals and fuels for our modern times is thought to be one of the main causes of global warming, as it has resulted in a considerable rise in atmospheric carbon dioxide (CO_2) emissions. Natural biomass, or fuels and chemical compounds derived from plants, can be regarded as carbon neutral in this sense since plants absorb CO_2 during their growth and release little to no CO_2 when they decompose after use. Therefore, one strategy to lower CO_2 consumption and slow global warming is to produce chemical compounds obtained from biomass (Arana, Franco, Joshi, & Sedhai, 2020).

Mitigation Strategies to reduce GHG emission

One of the main problems with plastic pollution is micro-plastic contamination, which harms the ecosystem, particularly the marine environment. Due to the widespread use of plastics manufactured from petroleum throughout the past century, both their production and consumption have resulted in enormous emissions of CO_2. Over 97% of plastics are still petroleum-based because they are more affordable and durable than bioplastics, despite the development and use of some bioplastics (Perera, Ratnaweera, Dasanayaka, & Abeykoon, 2023). That being said, it is evident that the environment is contaminated with plastic due to these plastics made from petroleum.5-7 these polymers degrade into microplastics when disposed of due to exposure to ultraviolet light and physical mechanical force. Precisely, the size of nano-plastics is on the nanometer scale (1×10^{-9} m), which is comparable to the COVID-19 virus. Specialized research is being done since it has been discovered that phthalic ester, a chemical used as a plasticizer, is hazardous to human health (Ummer et al.).

Renewable energy sources technology

The manufacturing of plastics that are not recyclable derived from petroleum has not decreased despite the explanation of the mentioned concerns. This means that although research and practical applications of biodegradable plastics. Plastics that can eventually break down into CO_2 and water and return to nature need to be increased, the manufacturing and consumption of non-biodegradable plastics must be limited. If, on the other hand, real plastic products like plastic bags and packaging are made of biomass and are biodegradable, then so are coating materials and color paints. This is because, even in the case of a biodegradable plastic product, its exterior will prevent the product from breaking down for thousands of years if the paint or coating is made of non-biodegradable chemicals derived from petroleum. For this reason, it is also required to produce these coating ingredients and color paints using natural biomass or plant material. Plastics, resins, rubber, textiles, color paints, and cosmetics are among the many petroleum-based chemical goods used in modern life (Adeleye et al., 2020).

Biomass-based chemical products

The premise that all chemical goods originating from petroleum should be replaced with natural chemicals derived from biomass is the foundation for presenting a range of biomass-based chemical substances such as bioplastics, paints, coatings, lubricants, and plasticizers. Consequently, the idea of "no more petroleum, no more fossil fuel" is put out into reality. Initially, it attempts to define plastics, incorporating words such as biodegradable, biomass, and bioplastic polymers (Leal Filho et al., 2022).

Plastic pollution is mostly caused by this class of polymers, which has been created and used for more than a century. As previously stated, this kind of plastic still makes up more than 98% of the plastic produced today. Thus, every day, the pollution caused by plastic is getting worse very quickly. The following plastics are common examples: Polyester ($[C_3H_6]n$), polyamide ($[C_2H_4]n$), polyvinyl chloride (PVC: $[C_2H_3Cl]n$), polyethylene terephthalate, also known as PE (PET: $[C_{10}H_8O_4]n$), and polystyrene (PS: $[C_8H_8]n$). These polymers go by the name "general plastics" in short. Despite being derived from petroleum, this class of plastics can break down naturally. PBAT (polybutylene adipate-co-terephthalate), PBS (polybutylene succinate), and PVA (polyvinyl alcohol) are common examples. Recently, the fields of agriculture, film, etc., have applied these biodegradable plastics (Mishra, Rani, Cavallaro, & Hezam, 2023).

There's a type of plastic made from plant materials (biomass) that doesn't actually break down naturally. An example is the new biomass polyethylene shopping bag used in Japan. While these bags are better for the environment because they reduce reliance on fossil fuels, they still create plastic waste. Ideally, plastics would be both made from renewable materials and biodegradable. Some examples of these better plastics include PHA, PLA, and plastics made from starch or cellulose.

Table 2. Challenges, Remedies, and Benefits in the Implementation of Bio-based Polymers

Challenges	**Remedies**	**Key Benefits**	**Implementation**
Cost-effectiveness of bio-based polymers	The availability of inexpensive carbon-rich precursors and improvements in biological synthesis techniques	Accessibility and economical	Production of Mixed Culture Polyhydroxyalkanoates (PHA)
Consumers don't emphasize environmental concerns.	Development of bio-based polymers with comparable or superior performance to conventional	Consumer Acceptance and Performance Balance	packaging materials derived from plants that have comparable barrier qualities to those of conventional polymers
Restricted market acceptance determined only by sustainability	Product Innovation includes better antibacterial properties and innovative packaging.	Enhanced Functionality, Market Penetration	Biofilms with enhanced antibacterial activity and ethylene absorption

Importance of Addressing This Issue for Environmental Sustainability

The utilization of renewable energy sources is not without its challenges, even if they present a potential way to reduce greenhouse gas emissions. A notable limitation is the erratic nature of some renewable energy sources, such as wind and solar energy, which can be impacted by seasonal variations in the weather (Morte, Ofélia de Queiroz, Morgado, & de Medeiros, 2023). Furthermore, utilizing renewable energy may not be as widely implemented due to regional limitations. For example, areas lacking sufficient sunlight or wind power may find it challenging to make the full switch to renewable energy sources. Further discouraging investment for certain stakeholders is the potential upfront expense of installing renewable energy infrastructure, such as wind turbines or solar panels. Concerns over resource availability and the environmental effects of extraction and processing are also raised by the use of rare earth metals and other minerals in renewable technology. To overcome these constraints and increase the efficiency of renewable energy in lowering greenhouse gas emissions and moving the world closer to a cleaner, more sustainable energy future, creative solutions will be needed, such as energy storage technologies, grid modernization and sustainable resource management techniques (de Schutter et al., 2019).

Petrochemical Products Relevance with the SDGs

The ideas that "biodegradable products are all good" and "petrochemical-based products are all bad" have become increasingly polarised in recent years. These days, producing industrial goods requires using less energy and renewable resources, especially those derived from agriculture. Bioplastics are gaining popularity because they address two key environmental concerns: they're renewable, made from plants instead of fossil fuels, and some are biodegradable, taking up less space in landfills. Plastics create pollutants and physical risks throughout their manufacture, during their useful lives, and after they are disposed of, all of which have an influence on the ecosystem and environment. Bioplastics have substantially lower carbon emissions and need less energy during manufacture than petroleum-based polymers. Thus, it is seen that bioplastics with a smaller carbon footprint and a renewable source are replacing polymers derived from fossil fuels (Kyei, Eke, Nagre, Mensah, & Akaranta, 2023).

In comparison to conventional polymers, PLA, being a biodegradable polymer, requires two-thirds less energy during the production step, produces no net increase in CO_2 gas during the biodegradation step, emits fewer greenhouse gases during landfill degradation , and reduces greenhouse gas emissions by a quarter. Consequently, PLA stands to be among the best options for replacing traditional plastics (Tehseen et al.). Biodegradable polymers are often not suited for landfilling or anaerobic digestion, despite the fact that at this stage of the disposal cycle, they are less environmentally hazardous than petroleum-based polymers. This is because anaerobic digestion can produce methane. Composting, anaerobic digestion, recycling, waste-to-energy generation, landfilling, and release of debris into the environment are only a few of the facilities that are included in combining the processing of bioplastics with disposal infrastructures (Cubas et al., 2023). The primary causes and important conclusions are emphasized for the two distinct phases during which the environmental consequences of bioplastics are studied, namely "during the generation" and "at the completion of life,

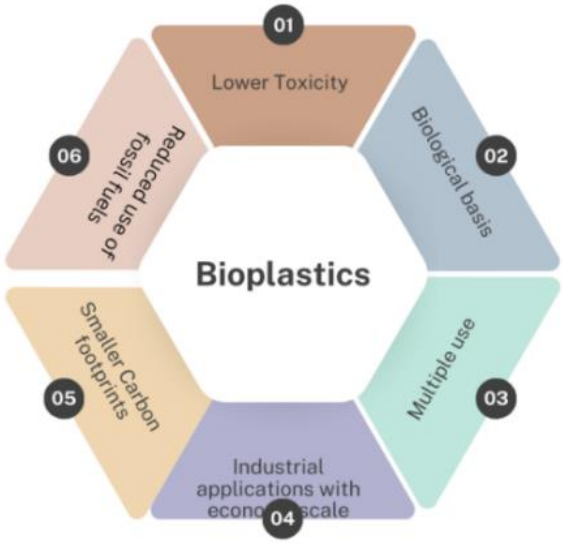

Figure 5. Advantages of biobased products.

Developing Sustainable Alternatives:

Comprehensive sustainability assessments are actually necessary for many different types of policy and business decisions. Some examples of these decisions include those pertaining to biofuels (European Commission, 2009a), chemicals (European Commission, 2006), and the Eco-Design Directive (European Commission, 2009b). Since every United Nations member state has endorsed the 2030 Agenda and is required to include the SDGs into their national strategies, the SDGs offer a great foundation for an internationally recognised methodological framework. Specifically, it has been feasible to develop a globally applicable collection of indicators by making use of the 169 SDGs of the 2030 Agenda (Ofélia de Queiroz, Morte, Borges, Morgado, & de Medeiros, 2024). These indicators were only available in an imprecise form before to the 2030 Agenda's implementation. In light of this, the methodological approach that is being provided here provides a substantial opportunity for time savings in addition to increased accountability. Due to the fact that both of these factors lower the obstacles that were previously in the way of a methodical evaluation of societal benefits, they can both significantly increase the frequency and attention given to benefit studies.

CONCLUSIONS AND RECOMMENDATIONS

Sustainable alternatives to petrochemical-based plastics are vital for achieving the SDGs and addressing global environmental challenges. These alternatives offer environmentally friendly options that reduce dependence on fossil fuels and minimize negative impacts on the planet. The promotion of bio-based materials, renewable energy sources, and circular economy practices is essential for creating a sustainable future. By continuing to explore and implement these innovative solutions, we can make significant strides toward international sustainability initiatives and a more resilient and eco-friendly world. While this study highlights the benefits of sustainable alternatives, it also has several limitations. The long-term performance and scalability of bioplastics and other sustainable materials are still under investigation. Economic and social factors, such as market acceptance and policy support, were not exhaustively covered and could significantly influence the implementation of these alternatives.

FURTHER STUDY

Future research should focus on addressing these limitations by conducting empirical studies on the long-term performance and environmental impacts of bioplastics. There is also a need for comprehensive economic analyses to understand the cost-effectiveness and market viability of sustainable alternatives. Further exploration of policy frameworks and incentives that can promote the adoption of sustainable practices is crucial. Integrating circular economy concepts and waste minimization techniques should remain a priority to enhance resource efficiency and sustainability.

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