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ENVIRONMENTAL IMPACT ASSESSMENT OF PETROLEUM-BASED BIOPLASTICS

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ABSTRACT

Throughout their life cycle, petroleum-based plastics are associated with many environmental issues, including greenhouse gas emissions, marine, and terrestrial persistence, pollution, and more. On the other hand, bioplastics are a rapidly growing class of polymeric materials that are often presented as alternatives. However, bioplastics are also associated with important environmental issues such as greenhouse gas emissions and adverse land use changes that need to be properly assessed difficult to assess. Bioplastics are considered both a potential solution and a new source of harmful environmental impacts, mainly as a result of the use of agricultural biomass.

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Introduction.

Disposal options for plastic products have been neglected in the past and, due to their extremely high resistance to natural degradation, plastics have accumulated in large quantities in aquatic and terrestrial ecosystems [1]. Even with urgent and concerted action, hundreds of millions of metric tons (Mt) of plastic waste are predicted to accumulate in the environment in the coming decades. To curb this trend, coordinated global action is needed to reduce plastic consumption, increase reuse and recycling rates, and accelerate innovation in sustainable substitute materials. While the first two points are largely based on consumer education and awareness, polymer scientists play an important role in offering environmentally friendly alternatives to the ubiquitous petroleum-based plastics [2]. Bioplastics (bio-derived and/or biodegradable) and recycled plastics can be excellent candidates, but their properties often fall short of expectations. As a result, the global use of such 'green plastics' is still only a small percentage of all plastics produced in the world. A possible strategy to reverse this trend is the addition of nanoparticles, which are known to improve many of the processing properties of the original polymer matrix [3]. In recent decades, numerous studies have been carried out to find optimized compositions of green polymer nanocomposites (PNA) based on bioplastics, if there are no recycled plastics, the attention of the scientific community has mainly been focused on performance. The actual durability of this new class of materials was deliberately neglected. Recent review articles analyzing the state of the art on this topic are from 2008 and 2013, and Civancik-Uslu et al. mainly refer to micro-sized fillers and fibers. Here, we aim to fill this gap by comprehensively reviewing the environmental impact literature of PNC based on bioplastic and recycled plastic [4]. The goal is to provide quantitative information to guide the correct selection of materials and processes to produce truly sustainable PNC. Thus, the analysis is limited to studies in which exposure to green PNAs and their components, i.e., green polymers and nanopar, articles, is quantified through a standard life cycle assessment (LCA). The latter is a widely accepted methodological framework for assessing the resources used and the environmental impact throughout was given product's life cycle, from acquiring raw materials through production and use, to waste management, including disposal and recycling. With this holistic approach, materials that are mistakenly perceived as environmentally friendly can have a greater impact than materials with the worst reputation. For example, petroleum-based polyolefins with well-established processing technologies can provide more sustainable results than 'green' biopolymers such as poly (lactic acid) (PLA) and polyhydroxyalkanoate (PHA), which pay for fertilizers used to grow corn. they are received.

The global consumption of plastics has increased over the years, especially because they are light, strong, relatively inexpensive, and durable. The plastics industry produces about 300 million tons of plastic, which is used once a year and then thrown away [5]. Due to the durability and low degradability of these polymers, discarded plastic waste can be stored for hundreds or thousands of years. In addition, of the total amount of plastic produced, only 7% is recycled, while about 8% is incinerated and disposed of in a landfill. In 1975, the National Academy of Sciences estimated that 14 billion pounds of garbage are either dumped underground or buried in the oceans every year. As a result, oceans and land are contaminated with plastic [6]. Over 10 million tons of plastic waste are dumped into the oceans alone, which is why most of the man-made waste that litters the oceans consists of man-made plastics.

Reports suggest that plastic can now be used as a geological stratigraphic indicator of the anthropocene [7]. This man-made debris threatens the safety, integrity, and sustainability of the ocean. In general, plastic waste contributes to the environmental problem, the problem has not yet been solved.

Many alternatives are now available to reuse [8] and recycle existing plastics, and a significant amount of current research is directed toward completely replacing plastics with more sustainable alternatives. At the same time, there is already a large amount of plastic waste in the environment that needs to be disposed of. In addition, the recycling of plastics [9] has not been effectively adopted. In addition, only plastic can be contaminated before MDD.

Bioplastics are emerging to be highly controversial when it comes to determining their impact on the environment. While bioplastics are often hailed as excellent alternatives to conventional plastics, they are also associated with shortcomings [10].

Biodegradable bioplastics can decompose into natural materials through microbial mechanisms and blend harmlessly into the soil. This decomposition process is aided by water and/or oxygen. For example, when a cornstarch-derived bioplastic is composted, the cornstarch molecules slowly absorb water and swell up when buried. This causes the starch bioplastic to break apart into small fragments that can then be easily digested by bacteria. However, some low-degrading or nondegradable bioplastics only break down at high temperatures or when treated in municipal composters or digesters. Moreover, some biodegradable plastics can only degrade in specific active landfill sites under certain definite and tried conditions. Decomposition during composting produces methane gas, a greenhouse gas many times more potent than carbon dioxide. This greenhouse gas contributes to the problem of global warming. Furthermore, producing bioplastics from plants such as corn and maize requires repurposing of land for producing plastic instead of fulfilling food requirements. A recent statistical study revealed that almost a quarter of the agricultural land producing grains is used to produce biofuels and bioplastics. As more agricultural land gets used to produce biofuels and bioplastics, there may be a significant rise in food prices, affecting the economically weaker sections of society. Moreover, a recent study, which compared seven traditional plastics, four bioplastics, and one made from both fossil fuel and renewable sources, determined that bioplastic production resulted in greater amounts of pollutants, owing to the fertilizers and pesticides employed in cultivating the crops, in addition to the chemical processing needed to turn organic material into the plastic. It was also found that bioplastics contribute more to ozone depletion than traditional fossil fuel-derived plastics. Furthermore, it has been found that bio-based PET, a hybrid bioplastic, is a potential carcinogen and also has pernicious toxic effects on earth ecosystems. At the same time, bioplastics also have eco-friendly characteristics. For example, the production of PLA saves two-thirds of the energy needed to make traditional plastics. Moreover, it has been scientifically established that during the biodegradation of PLA bioplastics, there is no net increase in carbon dioxide gas. This was evidenced by the fact that the plants from which they were produced absorbed the same amount of carbon dioxide when they were cultivated as was released during their biodegradation. Notably, PLA emits 70% less greenhouse gases when it degrades in landfills. Other studies have also found that substituting traditional plastic with corn-based PLA bioplastics can reduce greenhouse gas emissions by 25%. Such examples assure that the future production of new bioplastics can be accomplished by using renewable energy while substantially reducing greenhouse gas emissions [11].

The environmental problems caused by discarded synthetic plastics have paved the way for the search for substitutes. Bioplastics, which are both functionally similar to synthetic plastics and environmentally sustainable, are touted as promising new materials to address these problems. Bioplastic is a term used to refer to biodegradable plastics such as PCL or PBS; or may or may not be degradable but produced from biological materials or renewable feedstock, such as starch, cellulose, vegetable oils, and vegetable fats [12]. Like any other polymeric material, the degradability of bioplastics is also a factor of their composition, degree of crystallinity, and environmental factors, leading to degradation times ranging from several days to several years. For these reasons, the development of biodegradable bioplastics has gained attention in recent years. Based on degradation mechanisms, there are two main categories of biodegradable bioplastics, namely oxo-biodegradable and hydrobiodegradable. Oxo-biodegradable plastics are made of petroleum-based polymers mixed with a pro-degradant additive that catalyzes the plastic's degradation process. The additive is a metal salt (manganese or iron salts), which enhances the abiotic degradation process of the oxo-biodegradable plastic in the presence of oxygen. Presently, oxo-biodegradable plastics are mainly produced from naphtha, a by-product of oil or natural gas. Interestingly, the time taken by biodegradable oxo products to degrade can be ‘programmed’ at manufacture, like the methane or nitrous oxide industrial processes. The degradation of oxo-biodegradable plastics usually takes months to years. On the other hand, hydro-biodegradable plastics decompose hydrolytically at a rate faster than oxo-degradable plastics. These plastics can be converted into synthetic fertilizers Examples include bioplastics produced from plant sources (such as starch), and polylactic acid (PLA). The forthcoming paragraphs summarize the most recent literature on different types of bioplastics that have been or are currently being developed [13].

At present, one of the main factors polluting the environment is plastic packaging waste. In the 1960s, the amount of plastic waste in solid waste was up to 1 percent. But now this indicator is more than 12 percent. Most importantly, plastic waste does not decompose in nature for hundreds of years, and its amount increases every year [14]. Studies show that these wastes pollute the environment and waterways because they are not properly managed, penetrate the deep layers of agricultural soils, slow down the normal development of plants and cause a decrease in productivity.

In the middle of the last century, about 1.5 million tons of plastic were produced worldwide. In 1990, that indicator increased by 67 times and reached 100 million tons [15]. By 2015, this figure had increased more than 3 times and was equal to approximately 322 million tons.

Such a rapid increase in the production of plastic products has encouraged the increase of plastic waste at a greater rate. At present, important steps are being taken in the direction of reducing the rate of generation of plastic waste.

According to statistics, 500 million tons of plastic products are produced in the world every year. It takes 800 years for plastic and polyethylene products to decompose and disappear in the soil, and 400 years in the sea [16]. Also, even after half a century, the plastic solution continues to mix with the soil and pollute it. Plastic containers cause 120 million tons of extra waste every year. So, only 20 percent of plastic waste in the world is recycled. 90 percent of the waste thrown into the ocean is made up of plastic. 150 tons of plastic waste are thrown into the oceans every year. Large waste islands have formed in the oceans. There are currently 5 such islands. Two of them are in the Pacific, two in the Atlantic, and one in the Indian Ocean. Plastic waste causes the death of wild animals and birds, and fish. Every year, millions of sea creatures die due to plastic waste [17].

80 percent of harmful substances enter the human body from plastic waste. The basis of the composition of plastic products is bisphenol-A substance, which is dangerous for human health. 'Bisphenol A' is an organic compound belonging to the phenol group. Although this substance is poorly soluble in water, if it remains in tanks for a long time, it can diffuse into water and poses a threat to the human body.

According to the results of the experiment carried out by experts of the US National Toxicology Program years ago, this substance leads to several diseases, including the development of prostate and breast cancer. According to scientists, plastic containers are more dangerous after sun heating or reuse [18].

When plastic and polyethylene products are burned, a chemical substance harmful to the human body - dioxin - is released. Dioxin is formed from a combination of chemical substances with a similar structure. These compounds consist of hydrogen, carbon, oxygen, and chlorine atoms. Research has shown that dioxins are formed as a result of contact with plastic materials with hot water or direct heat. According to the International Cancer Research Institute, dioxin causes cancer. It is impossible to get rid of the substance that enters the body and accumulates in fat tissue. There are no drugs to reduce its effect.

Scientists also do not recommend storing and heating food products in plastic containers.

Polyethylene bags with an average usage time of 20 minutes make up approximately 10 percent of total waste. According to statistics, a family uses approximately 500 plastic bags per year. It takes more than 500 years for those packages to decompose [19].

Due to a large number of bacteria on the polyethylene, the food in the packages spoils faster. Condensation forms in a sealed transparent package and various fungi develop. When polyethylene products are frozen, toxins harmful to humans are released.

Every year, 4 trillion packages are used in the world, 1 and million polyethylene bags are thrown into the trash every 1 minute. They remain in the environment for a long time and do not rot.

Currently, in many developed countries, the appropriate legal framework is being created to reduce the use of plastic packaging, and the system of their collection and recycling is being improved. In many European countries, as the main measure, methods such as paying for plastic bags or applying an environmental tax to them are used. In addition, the promotion of the use of reusable cloth bags, bags that can be broken down by bacteria or other living organisms, is also among the measures take several measures have been taken in recent years to reduce plastic waste in the countries of the region. At the initial stage in Turkey, it is prohibited to provide free plastic bags with a thickness of 15-50 microns to users or consumers at all sales points. Georgia has banned the import, production, and sale of plastic bags with a thickness of fewer than 15 microns, and manufacturers have been required to mark the company's logo and name on the bags they produce. In China, the production, sale, and use of polyethylene bags with a thickness of fewer than 0.025 millimeters has been banned since June 1, 2008 [20].

In general, the use of plastic products has been restricted in 40 countries. In some countries, even tourists are not allowed to bring polyethylene products. In some countries, 60-70 percent of plastic packaging waste is recycled.

Conclusions.

A variety of bioplastics have been developed to address environmental issues associated with conventional petroleum-derived plastics – from well-known and well-studied biodegradable and/or bio-based plastics like PHB, PCL, and PLA to recent additions such as mycelium-based and chitin-based biopolymers. Importantly, however, bioplastics are associated with some shortcomings. Consequently, many biodegradable bioplastics end up in landfills, which decompose gradually and produce methane gas. For these reasons, people are starting to believe that bioplastics should be used only when needed, with tailor-made properties. However, we must weigh these environment-related shortcomings of bioplastics against the harms caused by conventional plastics. Studies, including several discussed in the present review article, show that the harms associated with bioplastics are still less severe when compared to conventional plastics. Moreover, as new types of bioplastics such as those discussed in this article keep becoming developed by academic and industry-oriented researchers, it is possible that the drawbacks of currently used bioplastics can be addressed adequately. To confirm the eco-friendliness of these new bioplastics, future studies should conduct thorough LCAs and LUC analyses. Such studies will help policymakers determine whether the use of new-generation bioplastics is indeed beneficial to the environment.

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