UDC 502.1/504.054:678
DOI https://doi.org/10.32782/2226-0099.2025.143.1.41

BIODEGRADABLE PLASTIC: CURRENT TREND OR TODAY'S REQUIREMENT

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The article examines one of the main environmental problems of environmental pollution, which occurs due to the growth of fossil fuel use, increased greenhouse gas emissions into the atmosphere, and the deepening climate crisis, and requires the search for alternative solutions. One of the sources of environmental pollution, including increased greenhouse gas emissions, is plastic products. This is explained by the use of natural fossil resources for their production, their insufficient processing, slow decomposition in nature, which leads to the release of harmful substances into the atmosphere and the accumulation of plastic waste. In addition, plastic pollution negatively affects ecosystems, human health, and poses a direct threat to the preservation of biodiversity.

The development of the biodegradable plastic market has become an alternative solution to replace traditional plastics, including as packaging materials and other plastic products. Bioplastics are able to decompose under the influence of microorganisms, and at the same time turn into carbon dioxide, water and biomass.

Analysis of the global biodegradable plastics market predicts its growth, with 1.8 million tons of biodegradable polymers accounting for 2.87 million tons of bio-based plastics by the end of 2025. This will help reduce the amount of plastic waste that pollutes the environment, as when released into the environment, the materials decompose under the influence of microorganisms and natural processes, such as biodegradation, composting and aerobic processing.

Reducing the consumption of petroleum products for the production of biodegradable polymers will help reduce dependence on oil and reduce greenhouse gas emissions during its extraction and processing, reducing greenhouse gas emissions.

A regulatory framework has been developed at the international and European levels to regulate the development of the biodegradable plastics market.

Key words: *fossil fuels, environmental pollution, greenhouse gases, greenhouse gas emissions, climate change, biodegradable plastic.*

Дюдяєва О.А. Біорозкладний пластик: сучасний тренд чи вимога сьогодення

У статті розглянуто одну з основних екологічних проблем забруднення довкілля, що відбувається через зростання обсягів використання викопного палива, збільшення викидів парникових газів в атмосферу, поглиблення кліматичної кризи та вимагає пошук альтернативних рішень. Одним із джерел забруднення навколишнього середовища, в тому числі збільшення емісії парникових газів, є пластикові вироби. Це пояснюється використанням природних викопних ресурсів для їх виробництва, недостатньою їх переробкою, повільним розкладанням в природі, що призводить до виділення шкідливих речовин в атмосферу та накопичення пластикових відходів. Крім того, пластикове забруднення негативно впливає на екосистеми, здоров'я людей, несе пряму загрозу збереженню біорізноманіття.

Розвиток ринку біорозкладного пластика стало альтернативним рішенням щодо заміни традиційних пластиків, у тому числі в якості пакувальних матеріалів та інших пластикових виробів. Біопластик здатний розкладатися під впливом мікроорганізмів, і водночас перетворюватися на вуглекислий газ, воду і біомасу.

Аналіз світового ринку біорозкладаних пластмас прогнозує його зростання, причому до кінця 2025 року з 2,87 млн тонн пластику на біологічній основі 1,8 млн тонн складатиме об'єм ринку біорозкладних полімерів. Це сприятиме зниженню кількості пластикових відходів, що забруднюють навколишнє середовище, так як при потраплянні в навколишнє середовище матеріали розкладаються під впливом мікроорганізмів та природних процесів, таких як біологічне розкладання, компостування та аеробна переробка.

Зниження споживання нафтопродуктів для виробництва біорозкладних полімерів сприятиме зниженню залежності від нафти та скорочуватиме викиди парникових газів при її видобутку та переробці, знижуючи емісію парникових газів.

На міжнародному та європейському рівні розроблено нормативно-правову базу з метою регулювання розвитку ринку біорозкладних пластмас.

Ключові слова: *викопне паливо, забруднення навколишнього середовища, парникові гази, емісія парникових газів, кліматичні зміни, біорозкладний пластик.*

Relevance of the research topic. Against the backdrop of the continuous growth of fossil fuel use, the intensification of the climate crisis, the increase in greenhouse gas emissions and other pollutants, the problem of environmental pollution is becoming increasingly acute, which requires the search for effective alternative solutions.

This problem is also exacerbated by the growing costs of maintaining old and creating new landfills. Today, there is an urgent need to use more environmentally friendly methods of processing and disposing of waste. The limited resources of fossil fuels and the problem of recycling certain items affect the production and use of new types of packaging and certain products [1].

One of the most promising solutions is the use of new modern materials, such as biodegradable plastic. Such an innovative solution has great potential to change a person's lifestyle, make it safer, and form an environmentally conscious and responsible society.

Problem statement. One of the sources of environmental pollution, including increased greenhouse gas emissions, is plastic products, which are an integral aspect of our lives. The use of such natural resources as oil, gas, coal for their production, their insufficient processing, slow decomposition in nature lead to the release of harmful substances into the atmosphere and the accumulation of plastic waste. This negatively affects ecosystems and human health, threatens the preservation of biodiversity.

Materials and research methods. To achieve the goals of the article, expert assessments, statistical data, literary sources on plastic pollution of the environment were analyzed, alternative solutions were found to reduce the impact and consequences of this pollution, the development of the global market and the Ukrainian market of biodegradable plastics and the regulatory framework for its regulation were considered.

Research results. The paper presents the results of the analysis of the plastic products market and experience in finding alternative solutions to reduce the negative impact of this sector on the environment.

A significant share of the plastic products market is occupied by packaging materials. The development and production of these materials with increased compost ability characteristics is directly related to the growth of costs for products from petrochemical raw materials. Moreover, the expectations of the consumer market for these products are supplemented by the requirements of society for packaging and products with improved environmental properties. Due to the emergence of a large number of new materials on the consumer market, understanding and needs for their compost ability have become more relevant.

Most polymers are made from such natural resources as oil, gas, coal. This production is extremely harmful, as a result of which a large amount of carbon dioxide is released, the emissions of which negatively affect the environment. In addition, the polymers used today have a very long decomposition period. For example, the decomposition period of a plastic bottle is 450 years, a plastic straw – 200 years, a toothbrush – 500 years [2].

Composting, as a method of recycling and/or disposal of waste, including at home, is now used in many leading countries of the world and, according to experts, the pace

of its implementation will increase over the next decade. The leader in this direction is the United Kingdom, where, thanks to an improved waste management infrastructure together with modern technologies for the production of compostable products, a closed cycle for packaging and products is being implemented.

One of the alternative solutions to the problem of environmental pollution by plastic, replacing conventional polymers used for packaging, has been the development of biodegradable materials [3, 4].

Biodegradable plastic is made from biological material, such as plants, biological waste, capable of decomposing under the influence of microorganisms, and at the same time turning into carbon dioxide, water and biomass.

An important difference between bioplastics and conventional polymers is that they can completely decompose into harmless substances in a short period of time (up to three months). There is a misconception that such materials decompose when released into nature and completely disappear in a matter of weeks. However, in reality, the process can last for different periods and require special conditions.

There are two types of biodegradable plastics, depending on the method of their decomposition.

The first type is biodegradable materials, which, under special conditions, decompose into water, carbon dioxide and organic compounds under the action of microorganisms. The decomposition occurs quickly, within a few months.

The second type is compostable materials. They decompose into water, carbon dioxide, as well as inorganic compounds and biomass in compost pits under the influence of microorganisms, as well as high temperature and pressure. This occurs at the same speed as the decomposition of conventional organic waste. As a result of the decomposition process, no toxic residues are created.

But, as noted above, any bioplastic needs the right conditions for rapid decomposition.

The environmental friendliness of bioplastics lies not only in the short period of its decomposition, but also in the fact that during its production many times less greenhouse gases are released into the atmosphere.

Although, the production and use of bioplastics also has disadvantages. These are:

• The production of biodegradable materials is much more expensive than the production of conventional plastics.

• Special conditions are required for the proper processing of bioplastics. Most often, they are created by high-temperature composting plants. Without them, bioplastics do not decompose in conventional landfills and even emit dangerous methane gas.

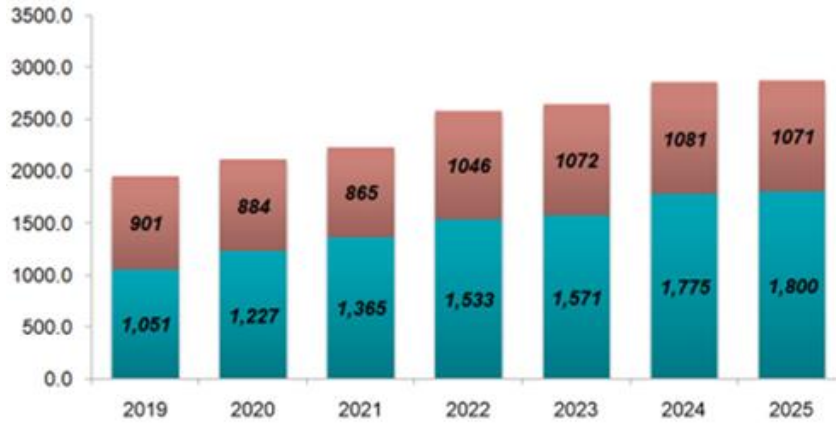
• Incorrectly processed bioplastics can contaminate an entire batch of properly processed conventional plastic.

• The successful use of bioplastics requires a strong environmental awareness of society and organized separate waste collection.

• Bioplastics are not recycled for reuse [5].

Analysis of the use of biodegradable plastic in Ukraine shows that its active growth occurred in 2020 – a period of spreading public awareness aimed at reducing the negative impact on the environment through rational consumption and increasing requirements for the environmental friendliness of packaging materials. With the adoption in 2021 of the Law of Ukraine “On Restricting the Circulation of Plastic Bags in Ukraine”, the development of the biodegradable plastic market at the state level was stimulated. Moreover, given the presence of a “rich” raw material base and the created favorable conditions, this market became attractive for investment. Unfortunately, the full-scale military invasion of Ukraine slowed down this process.

The international company European Bioplastics, in collaboration with Nova-Institute, conducted a marketing study of the global biodegradable plastics market and made a forecast of its growth, which is presented in the figure. By 2025, the world will have capacity to produce 2.87 million tons of bio-based plastic, of which the market volume of biodegradable polymers will be 1.8 million tons [4].



Biodegradable plastic market capacity, thousand tons

Market capacity of bio-based, non-biodegradable plastics, thousand tons

Fig. 1. Forecast capacity indicators of the global bioplastics market for 2021-2025 [6]

Promising areas of development of the biodegradable plastic market in the near future will be the segments of polylactic acid (PLA), bio-based polypropylene and polyhydroxyalkanoates (PHA).

According to the forecast of the consulting company Mordor Intelligence, the average annual growth rate of the global bioplastics market by the end of 2025 will exceed 15 %.

A significant share of the consumer market for plastic products is made up of disposable tableware and packaging materials.

The prospects for the use of biodegradable disposable tableware are great. Firstly, this will help reduce the amount of plastic waste that pollutes the environment. Today, this waste poses a serious threat to marine animals and birds, so the transition to biodegradable tableware can be a step towards solving this problem.

Secondly, biodegradable tableware decomposes naturally when it enters nature. It has the ability to decompose under the influence of microorganisms and natural processes such as biodegradation, composting and aerobic processing. In the presence of moisture and oxygen, it can completely decompose within several months or years, depending on the material. Thus, the use of biodegradable plastic tableware reduces the burden on landfills and helps reduce the volume of waste.

Thirdly, the use of biodegradable tableware will contribute to reducing the consumption of petroleum products used to produce plastic tableware. Such production requires a significant amount of oil, which is a raw material for production, which negatively affects its reserves. Oil is a limited fossil natural resource, the extraction and processing

of which have serious environmental consequences. Biodegradable materials used to create tableware are an alternative to petroleum products, thus reducing dependence on oil and reducing greenhouse gas emissions during its extraction and processing, reducing greenhouse gas emissions.

Another advantage of using biodegradable tableware is the possibility of increasing awareness and responsibility of consumers regarding the state of the environment, problems associated with waste, especially plastic, and their impact on ecosystems. Traditional plastic tableware takes hundreds of years to decompose, which leads to the accumulation of garbage in landfills, pollution of water and natural resources. Biodegradable tableware, in turn, decomposes faster and does not cause as much harm to the environment. In addition, the production of biodegradable tableware, as a new sector of the economy, can create new jobs and support economic growth in regions where there is access to raw materials for its production. Biodegradable disposable tableware, as an alternative to traditional plastic tableware, has a high degree of recycling. After use, it can be collected and composted, which will allow obtaining valuable organic fertilizer to restore soil fertility. This, in turn, will reduce the amount of waste going to landfills or landfills, will contribute to increasing the level of waste recycling and recycling. Biodegradable tableware does not contain toxic substances that can be released during the decomposition of plastic tableware and is safer for human health.

One of the key aspects of the environmental friendliness of biodegradable tableware is the reduction of greenhouse gas emissions. During the decomposition of organic materials used for its production, significantly fewer greenhouse gases are released than during the decomposition of plastic. This is an important solution to the problem of the deepening climate crisis. In addition, most manufacturers in the member states of the European Union prefer to implement sustainable production models based on the principles of the circular economy.

Today, increasingly on the shelves of supermarkets and in retail chains on the packaging you can find such terms as “biodegradable”, “compostable”.

The misleading nature of these terms, their insufficient understanding by the consumer, led to the development by the European Commission of the standard EN 13432:2000 Packaging – Requirements for packaging recoverable through composting and biodegradation – Test scheme and evaluation criteria for the final acceptance of packaging [7]. The standard defines the requirements for packaging that can be recycled through composting and biodegradation. Moreover, these requirements relate to the biodegradability of the material or packaging, but not to the origin of the raw materials from which they are obtained. Therefore, if the material is of plant origin (i.e. biodegradable), this does not mean that it does not necessarily have to be biodegradable or compostable.

At the same time, if the material or packaging meets the requirements of the standard, it is compostable, and under proper composting conditions it will turn into compost, CO_2 and water, and leave no traces of microplastics.

The purpose of EN 13432 is to demonstrate that the packaging is made of compostable material and is one hundred percent environmentally friendly. Thus, companies producing packaging materials and packaging assure their consumers of their environmental awareness and environmental responsibility.

The importance of this standard is further enhanced by the fact that the volume of conventional plastic waste is constantly growing and poses a significant threat to natural ecosystems. Such initiatives to create rules and specific actions to reduce plastic waste pollution accelerate the transition to more environmentally friendly materials.

EN 13432 defines the requirements and procedures for determining the compost ability and aerobic processability of packaging (and its materials). According to this standard, a material can be defined as "compostable" if it meets the following characteristics:

– the decomposition of the material by at least 90 % occurs within 6 months when in contact with an environment rich in carbon dioxide;

– when in contact with organic materials, after 3 months the material must fragment into sizes less than 2 mm by at least 90 %;

– the material must not negatively affect or reduce the quality of the compost produced during the composting process;

– the material must have a low concentration of heavy metals;

– the pH value, content and concentration of nitrogen, magnesium, potassium, volatile solids must be within the established norms.

As already mentioned above, there are two types of composting: in industrial conditions and in home composting. The state of biodegradability in industrial composting conditions can be demonstrated at a temperature of 58 °C and a composting time of 6 months. Home composting is carried out at a temperature of 20 ºC to 30 ºC for 12 months.

EN 13432 is not mandatory, but its use by a company or brand of materials that comply with it demonstrates that they are environmentally responsible, which has a positive impact on the growth of their consumer market.

According to research conducted by leading European courier company Seven Senders, assessing the delivery of products purchased through e-commerce, the mentality of the end consumer has changed in recent years. Thus, seven out of ten European customers are willing to pay more for more environmentally friendly delivery, which is 16 percentage points more than in 2021.

Consumer demand for green and environmentally friendly packaging is extremely stable and resilient throughout the changes that have occurred in public life over the past few years. Today, 86 % of consumers under the age of 45 are willing to pay a higher price for environmentally friendly packaging.

The regulation of the packaging materials and waste market in the European market is carried out in accordance with EU legislation, including all materials and packaging in commercial, domestic, industrial and other sectors.

The first rules on packaging and packaging waste were set out in Directive 94/62/EC on packaging and packaging waste (PPWD). This law defines what types of packaging can be placed on the EU market and sets out measures for the management of packaging waste. All packaging must meet essential requirements relating to its production, composition and suitability for reuse or recovery.

In November 2024, the European Parliament reviewed and in December finally approved the text of the Regulation (EU) 2025/40 of the European Parliament and of the Council of 19 December 2024 on packaging and packaging waste, amending Regulation (EU) 2019/1020 and Directive (EU) 2019/904, and repealing Directive 94/62/EC. On 22 January 2025, the PPWR was officially published in the Official Journal of the EU and will enter into force 18 months after its publication [8].

Taking into account the challenges of today, the text of the Regulation establishes new definitions and legal obligations regarding bioplastics, their biodegradability and compost ability. The main ones are:

"1. The Commission should adopt legislation to promote the use of bioplastics in packaging with a view to ensuring their use to replace recycled food contact materials

after consumption, where they are not available in sufficient quantities to achieve the minimum recycled plastic content targets.

2. There are new targets for the minimum percentage of recycled plastic in non-compostable plastic packaging. Packaging made from compostable materials is therefore exempt from these minimum percentage targets for recycled plastic in its composition, which in its final period, starting in 2040, will reach between 25 % and 65 % by weight depending on its composition and using."

This Regulation, as a legal document, will be mandatory in all EU countries. All plastic packaging in the EU will be recyclable or reusable.

Today, the market for plastics in Europe, including packaging materials and packaging, is:

– 2,400 companies producing plastic packaging;
– 40 % of plastic is used for packaging;
– by 2030, mandatory compliance with European standards for 100 % reusable plastic packaging, recyclable or compostable.

Furthermore, Directive (EU) 2018/852 of the European Parliament and of the Council of 30 May 2018 amending Directive 94/62/EC on packaging and packaging waste aims to improve "waste management in order to protect, preserve and improve the quality of the environment, protect human health, ensure a rational, efficient and sustainable use of natural resources, promote the principles of the circular economy, increase the use of renewable energy, increase energy efficiency, reduce the Union's dependence on imported resources, create new economic opportunities and promote long-term competitiveness. More efficient use of resources will also bring significant net savings for businesses, public authorities and consumers in the Union, while reducing overall annual greenhouse gas emissions" [9].

According to this Directive, by 2030, the recycling industry of European countries is obliged to adapt the targets set in Directive 94/62/EC of the European Parliament and of the Council on the recovery and recycling of packaging and packaging waste to decisions on increasing the recycling of packaging waste. In this context, a new understanding of the plastics market is being created, corresponding to a more sustainable form of production using more sustainable materials, with an emphasis on reuse and extending the shelf life of products.

Conclusions. The increase in greenhouse gas emissions into the atmosphere is one of the problems of environmental pollution. Among the main sources of this pollution are plastic products. This is explained by the use of natural fossil resources for their production, their insufficient processing, slow decomposition in nature, which leads to the release of harmful substances into the atmosphere and the accumulation of plastic waste, which negatively affects ecosystems, human health, and the planet's biodiversity.

The deepening of this problem requires the search for alternative solutions. One of such solutions is the development of the biodegradable plastic market. Bioplastic is able to decompose under the influence of microorganisms and natural processes under certain conditions, such as biodegradation, composting, and aerobic processing.

Analysis of the global biodegradable plastics market predicts its growth in the future. This will contribute to a reduction in the amount of plastic waste, a decrease in the consumption of petroleum products for the production of biodegradable polymers, which will reduce greenhouse gas emissions during their extraction and processing.

At the European level, the regulation of the biodegradable plastics market is carried out in accordance with European regulations, directives and standards. What is important for the production of biodegradable plastics and their recycling after their using.

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