

Scientific and technical journal «Technogenic and Ecological Safety»

REVIEW ARTICLE
OPEN ACCESS

A REVIEW: INVESTIGATION OF PLASTICS EFFECT ON THE ENVIRONMENT, BIOPLASTIC GLOBAL MARKET SHARE AND ITS FUTURE PERSPECTIVES

N. Mozaffari¹, A. Kholdebarin², N. Mozaffari^{1*}¹Islamic Azad University, Science and Research Branch, Tehran, Iran²Trier University, Trier, Germany

*Corresponding email: niloofar.mozaffari1991@gmail.com

UDC 332.368

DOI: 10.5281/zenodo.2600664

Received: 28 February 2019

Accepted: 18 March 2019

Cite as: Mozaffari, N., Kholdebarin, A., Mozaffari, N. (2019). A review: investigation of plastics effect on the environment, bioplastic global market share and its future perspectives. *Technogenic and ecological safety*, 5(1/2019), 47–54. doi: 10.5281/zenodo.2600664.

Abstract

Plastics play an important role in modern life and in the plastic market base industry and economy. Recently, the consideration of pollution in the environment with plastics, especially micro-plastics and nano-plastics has been increased. Both micro-plastics and nano-plastics are the sources for pollutants in the environment. However, bioplastics provide good quality products and can be a good alternative for the traditional type of plastics. Bioplastics are divided into two main groups of biodegradable and bio base, or both. The new bioplastic will reduce environmental impacts like carbon footprint, reduce fossil fuel consumption, decrease greenhouse gas, and provide a new waste management method based on recycling. The production of bioplastic is compared to all types of plastics shows that bioplastic production only has one percent of 320 million tons of other types of productions. In recent years and due to rising demand, the market is growing. Also, the effect of education and advertisement, and public awareness will help the bioplastic industry, economy, and market to grow faster in the future. In addition, it is so important to reduce the dependency on fossil resources by the innovation of bioplastic. Methodology of this paper is to review different articles about bioplastics, summarize the main aspects of bioplastic effects, introduce different types of bioplastic, show economic perspective of bio plastic, and summarize different point of views about future of bioplastic production. As a result, review of different articles show that bioplastics can replace with traditional plastics and bioplastic market share show positive perspective in future. Results show that Increase in public awareness and also high demand of consumers, encourage producers to have more and higher quality products. But, lack of legislation, standards, land competition, production cost, acceptable quality standards, and public trust cause limitation for future development. Therefore, it seems that successful bioplastic market need more effort and time to find the way in social, industrial, and economical aspects.

Keywords: environment; micro-plastic; nano-plastic; bioplastic; global market; economy.

1. Problem statement.

Generally, plastics implicate a polymer or polymeric materials composed of repetitive units or monomers which lead to macromolecular chain [1]. At the beginning of the 20th century, polymeric materials have been the center of industrials' attention and grown as one of the significant types of engineering materials [1]. Plastics can be found in the wide range of applications in toys, vehicles, dressing, manufacturing materials, electronics, packaging, and hygiene products [2].

Polymerization, polycondensation, and polyaddition are the various sorts of reactions which can be used to synthesize the polymeric macromolecules. The growth of polyvinyl chloride (PVC) polymer by the unsaturated vinyl chloride monomer is the basis of polymerization. Unsaturated vinyl chloride monomers produce reactive radicals through adding energy which is interlock to each other leading the macromolecule chains [1]. Commonly, the most discovered plastics in the environment are including polyethylene (PE), polyvinyl chloride (PVC), polypropylene (PP), polyethylene (PET) and polystyrene (PS) [3, 4]. So, the diversity in the compound leads to potential risks in the environment [3, 5].

Thus, increasing the utilization of plastics and their high degree of stability to the thermal and chemical decay leads to the accumulation of these materials in the environment [2, 6]. Although, there are many attempts to recycle these present plastics [2, 7], a

fraction of them can be recycled, while the rest of them reach the landfills [2, 8].

There are several types of plastic such as micro-plastic, nano-plastic and bioplastic owing to their different physical properties [2, 9].

Micro-plastic. According to NOAA, micro-plastics are small plastic particles with less than 5mm in size [10]. Primary micro-plastics and secondary micro-plastics are the principal categorizations of micro-plastics. The primary micro-plastics are created deliberately for many uses in skin cleaner and air blasting in sizes between 1 μm and 5 mm [11]. The secondary micro-plastics are made through the cleavage of large plastic particles in the environment [12].

Studies in marine environment reported that micro-plastics ingestion is mortal in terms of environment because of having perilous substances [13–16]. In another word, there are two sources which are relevant to the existence of perilous substances in micro-plastics. One source is a substance which is used deliberately as a new material to produce plastics. The other source is a substance which is adsorbed to the plastics surface in the environment, and it might be absorbed into the plastic structure gradually [16].

Moreover, it is reported that application of sewer sludge and compost including micro-plastics through the decline of the plastic parts causes micro-plastics to remain in the soil for many years [16]. In addition, micro-plastics can affect human health. Utilization of

cosmetics and use or keeping the plastic parts or surfaces covering ingestion of dust in connection with surfaces are the ways that human can be exposed [16].

Nano-plastic. With a large amount of consideration to the micro-plastics, there are several studies to the investigation of the separation of plastics less than 1 µm in size [17–20]. Nano-plastics are particles which are made through the decay of plastic parts to gain the size of 1 nm to 1 µm [17].

It should be noted that the term «nano-plastics» and «nanomaterials» are not the same owing to their production routes and physical and chemical properties. According to the International Standard Organization, nanomaterial is produced purposefully in order to possess special properties such as their size, shape, surface area, and combination for commercial uses [17, 21–24]. On the other hand, nano-plastics are made by ablation of micro-plastics [17]. Additionally, due to the unintentional of this process, nano-plastics are not relevant to the other natural or anthropogenic materials [17, 25].

Based on different studies, due to the high ability of transition across the lung and gut epithelial tissue, nano-plastics are calamitous rather than micro-plastics [13, 26]. Without a doubt, it can be seen the nano-plastics litters in the oceanic part and their invasion into the marine species [27]. Generally, more than 90 % of the ingested nano-plastics in the organ is exorcized through the faces; while, only tiny particles (below 150 µm) remain across the gut epithelium, leading cause of health problem [26].

Eventually, many benefits and opportunities have been created in the field of development of bioplastic by nanotechnology. Furthermore, the most significant properties of manufactured bioplastics are strength, pliability, and resistance [28, 29].

Bioplastic. Nowadays, production of bioplastics become important by increasing fossil fuel price and also increasing the environmental impact of traditional plastics. These events lead the society and government to be more concern about this issue. Bioplastics are also produced by using renewable resources like sugar, starch, or celluloses, and in some case by mixing this material together for a different purpose. This biotechnological process can reduce energy and raw material consumption in production procedure [30].

Bioplastics are made from renewable resources and produced by a range of microorganisms. There is a different type of degradable plastics:

- photodegradable bioplastics that are sensitive to light and using ultraviolet radiation can cause further bacterial degradation;
- compostable bioplastics which are decomposed biologically and do not leave any toxic elements;
- biodegradable bioplastics that break down into biogases and biomass by microbial activities [9].

Bioplastics are divided into three groups with different characteristics:

- bio-based (or partly bio-based), non-biodegradable plastics, such as bio-based polyethylene (PE), polyethylene, terephthalate (PET) (so-called drop-in solutions), bio-based technical performance

polymers, such as numerous polyamides (PA), or (partly) bio-based polyurethanes (PUR);

- biobased and biodegradable plastic such as PLA, PHA, PBS;

- plastics that are based on fossil resources and biodegradable such as PBAT [31].

According to predictions, the global bioplastic market will grow at a rate of 20 to 25 percent per year. This environmentally friendly material has both advantages and disadvantages. Lower carbon footprint, energy efficiency, and eco-safety are some of the advantages. On the other hand, high cost, recycling, reducing raw material, misuse and lack of legislation should be mentioned as weakness. It should be mentioned that in order to eliminate these disadvantages and have a more sustainable market and industry, better recycling system, restrict legislation, and standardization and management should be applied [9]. According to figure 1, the bioplastics at the right are the most preferable as they are biodegradable and also compostable [9].



Figure 1 – Plastic spectrum in accordance with the data [9]

Bioplastic market faces different obstacles such as:

- misunderstanding and lack of knowledge;
- lack of industry to produce, and also lack of infrastructure for the end of life disposal in a landfill;
- limited amount of funding and legislation.

So, it seems that this young market needs government support and also a governmental collaboration with brand owners or companies that use bioplastics as raw material [32].

2. Materials and methods.

As Environmental impacts and also non degradable characteristics of traditional plastics which is the most important weakness of this products lead to increase public and environmentalist concerns for the future, this review is done in order to compare weakness and strength of bioplastic with conventional plastics. Therefore, different articles are reviewed and summarized during this research. Moreover, different statistical information and graphs are also used from scientific articles and official websites in order to compare economical and global market condition and future point of views of both products.

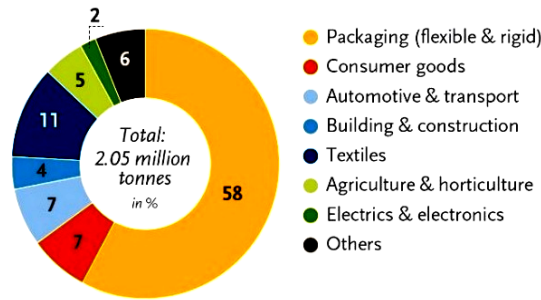
3. Results and discussion.

3.1. Global market share, Production capacity, and Bio plastic market (Dynamic market growth). As shown in figure 2, packaging has the highest market share with almost 60 % of total bioplastic production capacity [33]. According to figure 2, the textile industry is the second market segment that uses almost 11 % of bioplastic production. Automotive and transport and consumer goods

have an equal amount (7 %) of bioplastic consumption. The Electronics segment has less amount (2 %) in comparison to the other market segments.

According to figure 2, most of the total bioplastic market share is related to packaging. Moreover, researches show that using bioplastics in other industrial sectors like textile, building, and construction, and the automobile industry is going to be increased [33].

Figure 3 also shows that bio-based/non-biodegradable plastics like Bio-PET30 and BIO-PE are the most useful type of bioplastics in packaging industries. Most of biodegradable plastics (Starch Blends) are used in agriculture and horticulture market.



According to job market analysis by Europa Bio in 2016, the bioplastic industry helps the countries to have employment growth and also it has provided 23,000 jobs in Europe in 2013 and this amount will be increased to 300,000 by 2030 [33].

Figure 4 shows us the industrial chain and process from the agricultural land to the market. According to figure 4, biochemical companies use agricultural products like sugar cane, and vegetable oil in order to produce resin. In the next step convertors, sections change resin to different bioplastic products. The traders buy these bioplastic products and introduce and sell them to consumers.

Table 2 – Bio plastics capacity in different market segments for 2017 (in accordance with the data [31])

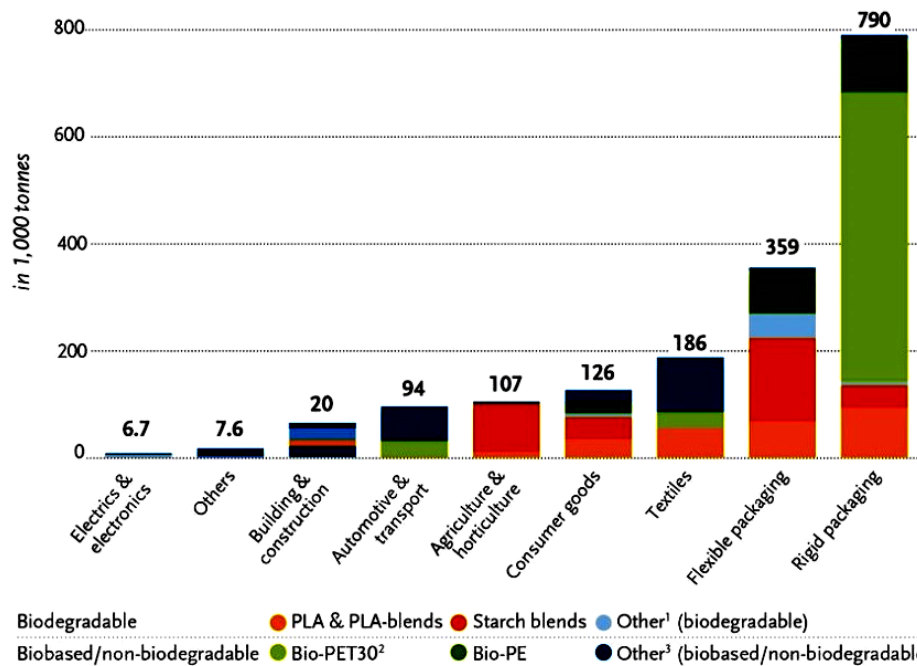


Table 3 – Different types of bio plastic capacity in industries 2017 (in accordance with the data [31])

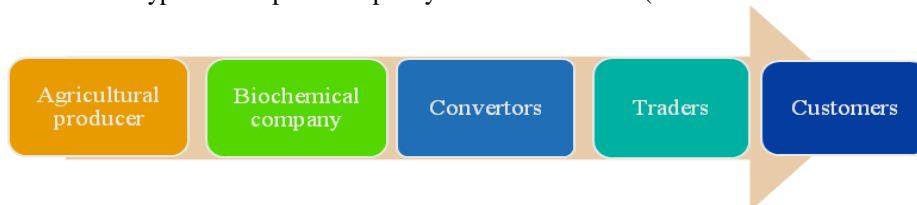


Table 4 – Bio plastic industry chain (in accordance with the data [31])

3.2. Future perspectives and development challenge of bio plastic. Bioplastic capacity and quality show great potential in the future for several reasons. The first reason is their lower carbon footprint compare to other traditional types of bioplastic. The second one is that the energy efficiency of bio plastics

is higher than normal plastics. Due to oil shortage and oil value fluctuation, the price of the plastics made from oil is not constant. The third reason is «Eco safety»; it means that by using bioplastic, the emission of greenhouse gasses will be decreased. So it will help to reduce global warming [9].

Bioplastic has a closed loop of resource consumption which increases energy and resource efficiency. New industries and market demands lead to the production of compostable material with the additional end of life duration like PLA, PHA, or PBS [33].

Except for lots of advantages of bioplastics, there are some disadvantages. Nowadays the cost of bioplastics is higher than traditional plastics. But it is predicted that we have a reduction in cost due to large-scale production. Furthermore, if the bioplastics are not separated from normal waste, they will contaminate the recycling process. Also, there are too many countries that do not have law or legislation about production,

usage, and waste management of their bioplastic products. Finally, there is still too many misunderstanding about bioplastic concept and its degradation or compost ability, and also some producers use the name of bioplastics to increase their sells [9].

According to the latest market data revealed by European Bioplastics [31] in cooperation with the research institute nova-Institute in (figure 5), New biopolymers like PLA (polylactic acid) and PHAs are 100 % bio-based and biodegradable (Polyhydroxyalkanoates) and help the economy of bio based and biodegradable to grow. Approximately 10 % – 15 % bioplastics of the total plastic market will increase its market share to 25 % – 30 % by 2020, and it will be over 10 billion by 2020 [9].

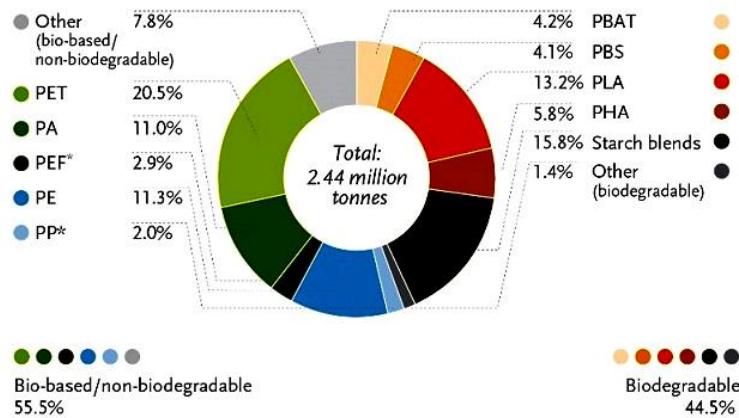


Figure 5 – Global production capacities of bio plastics in 2022 (by material type), in accordance with the data [31]

It is also having a growth and production capacity of 50 % by 2022. Bio-based, non-biodegradable plastics, currently contain 56 percent (1.2 million tons) of the global bioplastics production capacities, and including bio-based PE (polyethylene) and bio-based PET (polyethylene terephthalate), and PA (polyamides). According to figure 5, it is predicted that the production of P.E will continue to grow. The production of PET is changed to increase in production of PEF (polyethylene furan ate), in recent years, which is a new polymer that it is expected to enter the market in 2022 [33]. According to figure 5, the first useful bioplastic is PET which is related to the bio-based/non-biodegradable group. In the second place, Starch blends which are in Biodegradable group are used in market and industries.

It should be mentioned that biodegradable production capacity growth rate is significantly higher than the Bio-based/biodegradable growth from 2017 to 2022 according to scientist prediction indicated in figure 6, and the total production is increased from around 2.054 million tons in 2017 to 2.44 in 2022 [31].

According to figure 7, Asia produces around 50 % of bioplastic around the world. In contrast, the least amount except Australia/Oceania is related to South America. Europe has second place in production capacity of bioplastics [33].

According to figure 8, it is clear that the amount of land used for growing renewable feedstock source for the bioplastic production is less than 0.02 % of the global agricultural area. Therefore, despite the predicted market growth, there is no competition between traditional agriculture and production of bioplastic, and around 97 % of global agricultural land area is used for pasture, feed, and food.

In order to increase the sustainable development of Europe’s bio-economy European bioplastics (EUBP) decided to change a linear economy to a circular economy, which has stricter rules, legislation, and measurement. Circular economy package and Action Plan has a different recommendation about sustainability by promoting the use of bio-based products and also collecting the bio-waste separately. According to the Ellen MacArthur Foundation, the circular economy changes the definition of bioplastic from «make, use, dispose of» concept to more a circular model based on «reuse, recycle or biodegradable».

So bioplastics are a good sample for bio-economy and the circular economy as they reproduce CO₂ and use renewable raw material to represent sustainable products [34] Table 1 and 2 indicate the optimistic and pessimistic point of view of bioplastic market share [32].

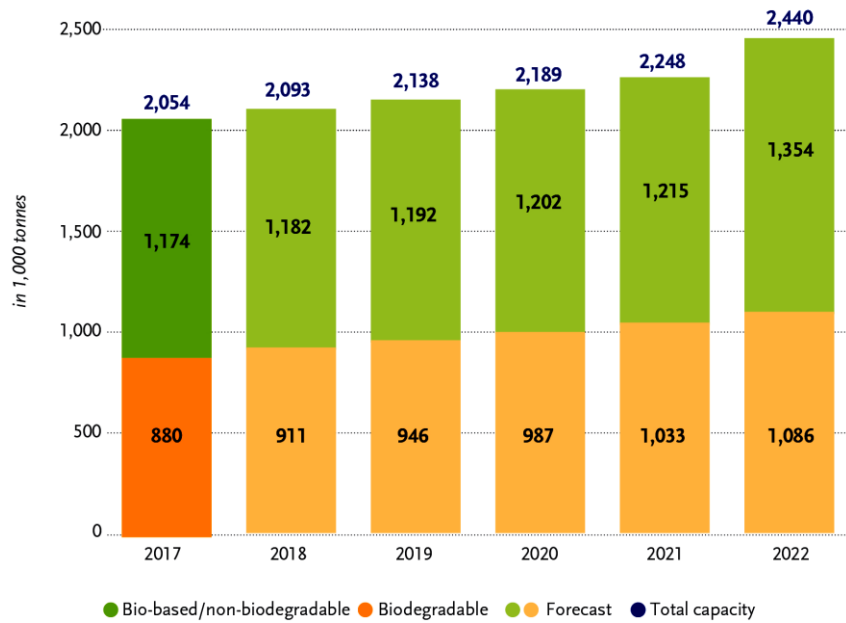


Figure 6 – Bio plastic production capacity (2017–2022), in accordance with the data [31]



Figure 7 – Bio plastic production capacity in different region, in accordance with the data [31]

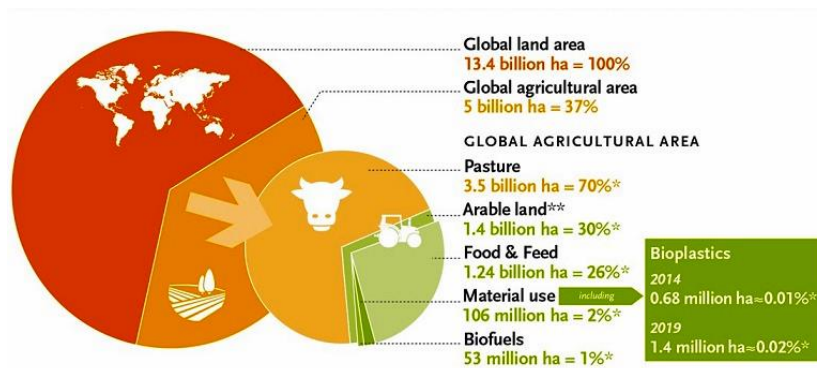


Figure 8 – Land use and bio plastics production 2017 and 2022, in accordance with the data [31]

Table 1 – Optimistic point of view on bio plastic market [34]

Economy	Utility of bioplastic	Technology trend	Public policy	Big picture
All sectors of manufacturing use bioplastics as production material	Bioplastics provide all plastics industry’s requirement for continued growth			Large brand owners move to advance sustainability and green packaging enterprise
Bioplastics use continues to grow and expand	Bioplastics show the unique advantages to brand owners and consumers	There is advance technology in bioplastic resources, production, and recycle	Government support bio based development	Due to increase in public awareness, most adults say that they would buy a product if it «was a little bit more expensive» because it was made with bioplastics
Plastics provide wide functionality, for all sectors	«Bioplastics has environmental advantages and end-of-life capabilities».	There is an increase in technology of bioplastic resources, production, and recycle	More than half of adults has the willingness to pay for bio plastic product	«We are still in evolution-not a revolution-within the plastics marketplace»

Table 2 – Pessimistic point of view on bioplastic market [34]

Economy	Utility of bioplastic	Public policy	Big picture
«Current ample resource of petroleum and natural gas with low price have had an impact on the research, adaptation and usage of bioplastics»	«Misunderstanding and confusion about «bio based» and «biodegradable» is a big limitation»	There is always a doubt about the bio based certification	Public awareness and knowledge is not enough
	There is a lack of infrastructure for end-of-life disposal options other than landfill	Lack of legislation, regulation, and testing standards for end-of-life options	«There is still misunderstanding and confusion about origins/feedstock/disposal and production»
		«Debate about food VS fuel VS plastics persist»	

Conclusion and recommendations.

Due to new technology, industry, and an increase of public awareness about the environmental effect of common plastics, it seems that bioplastic market share and production can grow in the future:

1. High competition in markets.
2. Increase in consumer demand.
3. Degradable characteristic of bioplastics, Encourage the producer to use bioplastics in their products.

Although it is predicted that a bioplastic market share is increased, it should be noted that there are many limitations can eliminate this progress. The main problems may be due to:

1. Lack of legislation, standard, and governmental support will cause a problem for future development.
2. According to the land use data in figure 8, there is still some debate between traditional agriculture for pasture, food, and feed and on the other side the cultivation for biomaterial.
2. Production cost.

3. Society assurance and trust on benefit.
4. Quality of bio-based plastic products.

According to the optimistic and pessimistic point of view, it seems that bioplastic market as a new aspect will face a different challenge, and needs more time and effort to be an acceptable term among social, industrial, and economical point of views.

Acknowledgements.

This review paper was carried out at the Department of Environmental science in Trier University in Germany. Our deepest gratitude goes to the advisor, Professor Dr. Klaus Fischer for his constant guidance and valuable support during the whole process of our project.

Conflicts of Interest.

The authors declare no conflict of interest in preparing this article.

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Н. Мозаффарі, А. Холдбарін, Н. Мозаффарі

ОГЛЯД: ДОСЛІДЖЕННЯ ВПЛИВУ ПЛАСТМАС НА ДОВКІЛЛЯ, ГЛОБАЛЬНИЙ РИНОК БІОПЛАСТИКУ І ЙОГО ПЕРСПЕКТИВИ НА МАЙБУТНЄ

Пластмаси грають важливу роль в сучасному житті, а також в індустрії та економіці ринку пластмас. Останнім часом зростає увага до забруднення навколишнього середовища пластмасами, особливо мікропластиками й нанопластиками. І мікропластики, і нанопластики є джерелами забруднення довкілля. Проте, біопластики забезпечують хорошу якість продукції і можуть бути хорошою альтернативою традиційному типу пластмас. Біопластики поділяють на біорозкладні і ті, мають біологічну основу. Новий біопластик зменшить вплив на довкілля, наприклад, вуглецевий слід, скоротить споживання викопного палива, скоротить викиди парникових газів й забезпечить новий метод управління відходами, заснований на переробці. Виробництво біопластика у порівнянні з усіма видами пластмас показує, що на виробництво біопластика доводиться тільки один відсоток від 320 млн. т інших видів продукції. В останні роки у зв'язку зі зростанням попиту на пластик, ринок зростає. Крім того, вплив освіти і реклами, а також обізнаності громадськості допоможе біопластичній промисловості, економіці і ринку розширюватись швидше в майбутньому. Крім того, дуже важливо зменшити залежність від викопних ресурсів за допомогою інновацій біопластику. Методологія цієї статті полягає в огляді різних публікацій, в яких досліджені проблеми біопластика, узагальненні основних аспектів біопластичних ефектів, представлені різних типів біопластика, демонстрації економічної перспективи біопластику й узагальненні різних точок зору на майбутнє виробництво біопластика. В результаті огляду показує, що біопластик може замінити традиційні пластмаси, а частка ринку біопластика показує позитивну перспективу в майбутньому. Результати показують, що підвищення обізнаності громадськості, а також високий попит споживачів спонукають виробників отримувати більш якісні товари. Але відсутність законодавства, стандартів, конкуренції за землю, виробничих витрат, прийнятних стандартів якості і суспільної довіри створюють обмеження для майбутнього розвитку. Тому, схоже, що успішному ринку біопластику потрібно більше зусиль і часу, щоб знайти вихід в соціальних, промислових і економічних аспектах.

Ключові слова: довкілля; мікропластик; нано-пластик; біопластик; глобальний ринок; економіка.

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Н. Мозаффарі, А. Холдебарин, Н. Мозаффарі

ОБЗОР: ИССЛЕДОВАНИЕ ВЛИЯНИЯ ПЛАСТМАСС НА ОКРУЖАЮЩУЮ СРЕДУ, ГЛОБАЛЬНЫЙ РЫНОК БИОПЛАСТИКА И ЕГО ПЕРСПЕКТИВЫ НА БУДУЩЕЕ

Пластмассы играют важную роль в современной жизни, а также в индустрии и экономике рынка пластмасс. В последнее время возросло внимание к загрязнению окружающей среды пластмассами, особенно микропластиками и нанопластиками. И микропластики, и нанопластики являются источниками загрязнения окружающей среды. Тем не менее, биопластики обеспечивают хорошее качество продукции и могут быть хорошей альтернативой традиционному типу пластмасс. Биопластики разделяют на биоразлагаемые и те, которые имеют биологическую основу. Новый биопластик уменьшит воздействие на окружающую среду, например, сократит углеродный след, потребление ископаемого топлива, выбросы парниковых газов и обеспечит новый метод управления отходами, основанный на переработке. Производство биопластика по сравнению со всеми видами пластмасс показывает, что на производство биопластика приходится только один процент от 320 млн. т других видов продукции. В последние годы в связи с ростом спроса рынок растет. Кроме того, влияние образования и рекламы, а также осведомленности общественности поможет промышленности биопластика, экономике и рынку расти быстрее в будущем. Кроме того, очень важно уменьшить зависимость от ископаемых ресурсов с помощью инноваций биопластика. Методология этой статьи заключается в обзоре различных публикаций, в которых исследованы проблемы биопластика, обобщении основных аспектов эффективности биопластика, представлении различных типов биопластика, демонстрации экономической перспективы биопластиков и обобщении различных точек зрения на будущее производство биопластика. В результате обзор показывает, что биопластик можно заменить традиционные пластмассы, а доля рынка биопластика показывает положительную перспективу в будущем. Результаты показывают, что повышение осведомленности общественности, а также высокий спрос потребителей побуждают производителей получать более качественные товары. Но отсутствие законодательства, стандартов, конкуренции за землю, производственных затрат, приемлемых стандартов качества и общественного доверия создают ограничения для будущего развития. Поэтому, похоже, что успешному рынку биопластика нужно больше усилий и времени, чтобы найти выход в социальных, промышленных и экономических аспектах.

Ключевые слова: окружающая среда; микропластик; нано-пластик; биопластик; глобальный рынок; экономика.