Plastic Waste: Global Impact and Ways to Reduce Environmental Harm

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Abstract. The article considers the problem of plastic waste growth in global scale and ways to decline harmful consequences. Dynamics of the volume of non-degradable plastic and the distribution of waste on land and water are analysed. Negative effects of plastic waste on different types of bioresources and human health are identified. In this context, the author presents paradox of "plastic trap": a contradiction between positive properties of plastic and global problems of its use. Based on literature review, it is shown that the water environment is most heavily polluted, and it can lead to the situation "there is more plastic in a sea than fish". It is actualized, that to get out of the "plastic trap" it is necessary to combine the efforts of the state, business and society. State regulation of plastic production and consumption, development of recycling technologies and creation of biodegradable plastic analogues are suggested as a key restoring ways.

1. Introduction
Plastic is widespread material used by humanity. It has become indispensable in a wide variety of industries and everyday life. World plastic production has already exceeded the production of such materials as textiles, paper and aluminum. However, the widespread production, use and disposal of plastics has become a serious threat to environment. Ecological problems require taking measures for a more rational life cycle of plastics (from production to processing) and the development of eco-friendly materials.

The negative impact of plastic waste growth can be reduced by common efforts of government authorities, businesses and citizens. In the context of modern concept of sustainable development, the problem of waste reduction is particularly relevant. To leave for future generations a good environmental heritage it is need to take serious technological, financial and psychological measures.

The purpose of this study is to analyze the key points of plastic waste influence on the environment and to identify ways to minimize harmful consequences. The objectives of the study are study the dynamics of plastic waste and its distribution on land and water; identify areas of plastic waste harmful influence; consider the progressive experience of state regulation and plastic recycling; review researches about using of natural components for production of biopolymers.


2. Plastic in biosphere: degradation impact on ecosystem and human health

The use of plastic has a very wide range: packaging, food industry, medicine, electronics, textiles, building and others. Global plastic production has grown from 2 million tons in the 1950s to 400 million tons in 2015, with half of all plastic produced in the past 13 years (figure 1). The growth of population and scale of production will increase the manufacturing and consumption of plastic. Largest amount of plastic is used for packaging and in the future turns into waste. The most volume of plastic waste is products made of polyethylene, polypropylene, polyvinyl chloride, polyethylene terephthalate, polycarbonate and polystyrene [1]. Every year, only 14-18% of the total amount of plastic waste is collected for reuse (recycling) and 24% is disposed. The rest of waste is incinerated, dumped in landfills or released into the environment [2]. In the EU, about 30% of plastic is recycled, in the US – about 10%, while in most developing countries this is done on a very small scale [3].

![Figure 1. World production of plastic by economic sectors (millions of tons)](image)

Primary plastic is produced by processing raw oil from which monomers are extracted and then subjected to polymerization. Depending on the nature of polymer, plastic products are divided into two main groups: thermoplastics (melt when heated and return to original state when cooled, its production is more than 90% of the total output of plastics) and reactoplastics (have a linear structure of molecules and at a certain curing temperature they acquire a mesh structure, more resistant to mechanical and temperature effects) [4]. For production of plastics, various fillers are used that give valuable properties (heat resistance, acid resistance, strength, anti-static) as well as increase hardness, increase durability, reducing cost. Additives such as plasticizers, dyes, lubricants, catalysts and other substances are also introduced. Some substances, such as bisphenol A, brominated flame retardants, cadmium/barium or lead stabilizers, have a serious negative impact on human health and nature [4]. However, most of the used additives do not decompose, break down or change during mechanical processing and are resistant to temperatures. This fact significantly complicates the process of recycling plastic products, making it more time-consuming and expensive. Consequently, the competitive opportunities of secondary plastic in comparison with primary are reduced.

The analysis of literature allowed to identify the main categories of negative impact of plastics:
1) Climate change and deterioration of hydro- and biosphere;
2) Depletion of biotic resources and biodiversity;
3) Acidification and photochemical oxidation of environment;
4) Increase of oil and electricity power consumption.
5) Toxicity to humans and growth of garbage.

The production of plastics causes serious damage to ecosystem: about 400 million tons of greenhouse gases (CO₂, CH₄, O₃ and N₂O) released into the atmosphere per year [4]. The situation is worsened by the emissions of open burning of plastic waste and the entry into soil and groundwater of their decomposition products, the process of which can take several hundred years. The formation of greenhouse gases leads to climate change. Increased temperatures are expected to change the division of the environment: pollutants enter different matrices (air, soil, water, sediment) and can increase the
toxicity of certain compounds, such as persistent organic substances. Currently, the leaders in the amount of waste are the countries of North America and Europe, Australia and China (figure 2) [5]. More plastic is formed in these areas. In these countries, efforts are being made to reduce the use of plastic bags and introduce other restrictive measures for the production and use of harmful polymers. This can be described as a "payment for progress and comfort" or a "costs of civilization".

The main danger is pollution of the World ocean, where the volume of plastic accumulates rapidly every year (according to various estimates, from 4 to 12 million tons as of 2010) [6]. According to available data, by the middle of the century, this garbage can exceed the total weight of all fish [7]. Indicated that 373 species wildlife has been affected by the entanglement and absorption of marine plastic debris [6]. The largest water accumulation of plastic is "Great Pacific Garbage Patch" identified by Charles Moore in the 1990s (in figure 3 it has a darker color). This is a "garbage island" floating between California and Hawaii. The scale of pollution is incredible: the area is 10 million square km, all waste floating in the Pacific Ocean together weighs as much as a thousand Eiffel towers [8].

This trend not only leads to the death of marine life, but also threatens human health through the food chain. So, adverse human health effects from micro- and nano-plastics in seafood may be caused by plastic particles themselves, or by additives and sorbed contaminants, such as persistent, bioaccumulative and toxic substances [6]. The economic consequences of water pollution include loss of revenue, the increase in cleaning costs, the reduction of fishing and the decline in tourist potential. Plastic remains can also pose a navigational hazard to fisheries and shipping.

It is expected that global warming will release microplastic particles currently frozen in Arctic sea ice [9]. Scientists also note that changes in the stratification structure of water column as a result of ocean warming [10] are likely to affect the vertical distribution of microplastics in aqueous medium. In addition, changes in the structure of precipitation and their increase according to the intensity and frequency of storm events related to climate change it is likely to affect the spatial patterns and speeds of movement of plastic debris and related chemicals into aquatic environment [11].

Thus, excessive plastic production and consumption is a global complex problem. "Plastic trap" is a paradox that lies in contradiction between the positive properties of plastic (its low price, strength and other) and the environmental problems arising as a result of clogging the ecosystem with plastic waste. In the context of transition to sustainable development and circular economy, it is necessary to solve the problems of plastic utilization, recycling and it replacing with more eco-friendly materials. This is a socio-economic task that must be solved in the trinity of government, business and society. It is impossible to solve the issues of financial or technological support of waste management in isolation from the psychophysical patterns of interaction of people in society [12]. The society needs to promote environmental responsibility of citizens and calls not to litter, separate waste and limit the use of "excess plastic". It's time to make a step towards reconciliation with nature and start "working on
mistakes”. Further directions to reduce the harmful plastic effects and perspective technologies are described.

3. Systematization of sustainable measures to reduce the harmful influence of plastic
To minimize the degradation impact of plastic on the ecosystem, the following areas can be identified.

1. State regulation of social and commercial processes in the sphere of plastic consumption and production (restrictive and financial methods).

   A number of developed countries have already introduced prohibitions on the use of plastic. For example, France has banned the use of single-use plastic bags in shops, markets and pharmacies since 2017. Manufacturers of products until 2017 could still pack goods in polyethylene, but not more than 50 microns thick. In Ireland, it is forbidden to issue plastic bags for free, they have high taxes and prices. In Germany, visitors are offered paper bags and fabric bags instead of polyethylene. A harsh law has been passed in Kenya, where the release, import and use of non-degradable packages is prohibited (violators face a fine of up to 40 thousand dollars and a prison sentence of up to four years). By 2020, a number of US States will ban drinks in plastic containers [1]. In Russia, there are no restrictions on the use of plastic.

2. Development of recycling technologies and use of plastic waste as raw materials.

   Plastic can be transformed into energy, fuels, chemicals, fillers and others (synthetic fibers, threads for carpets and clothing). Plastic wastes can recycle into valuable gas and liquid fuels by the through chemical recycling methods such as hydrogenation, chemical depolymerisation, gasification, thermal cracking and catalytic conversions [13].

   Crushed plastic can be used as a filler in the creation of concrete materials. In study [14] concludes that 1/5 of concrete can be replaced with waste plastic, as well as certain types of plastic can increase thermal insulation by 5% and reduce water adsorption in plastic-concrete. There have been innovative researches for using recycled plastic as filler in road construction in order to obtain a high-quality and durable coating. The introduction of plastic micro particles from waste into asphalt concrete increases the strength of the road surface [15]. There is also testing of asphalt roads with a rubber crumb filler. It is also proposed to use plastic waste in the production of bricks and paver blocks [16].

3. Elaboration of environmental materials that will replace plastic (biodegradable content).

   Technologies of biodegradable plastics are divided into four groups. The first is polymers extracted from biomass and natural polymers: starch, cellulose, sugar and proteins. The second is polymers produced by micro-organisms in the course of their vital activity (polyhydroxyalkanoates, bacterial cellulose). The third is polymers artificially synthesized from natural monomers (for example, polylactides). And the last group – traditional synthetic plastics with natural additives introduced into them [17]. Literature review allows to present the following natural materials that may be green substitutes to plastic.

   1) Starch, rice husks and sugar cane bagasse are used to synthesize carboxymethylcellulose and then subsequently convert this mass into a biodegradable film. Plasticizers such as glycerine and citric acid are also used to provide flexibility and strength of the film [18].

   2) Corn starch and polylactic acid as the base with epoxidized cardoon oil plasticizer for the production of a biodegradable film [19]. Corn is also used in the production of plastic cards, which is a step in green banking and increasing customer eco-responsibility [20].

   3) Some types of algae can be used in the production of eco-friendly polymers for dishes, packaging and toys. Scientists are looking for a new type of algae that produces the "right" variety of hydrocarbons and sugars [21]. If genetic engineering can breed such organisms, it could usher in a new era of consumer products that are completely free of fossil fuels.

   4) Chitin and chitosan (shrimps, shells and other crustaceans, mushrooms) are also sources of biopolymers. From chitosan and ginger starch with glycerine as a plasticizer, it is possible to produce food packaging [22]. Chitosan is also may be used in medicine, cosmetics, chemical and food industries, due to multifunctional properties.
5) Fibers from the stems and seeds of certain plants (flax, cane, hemp, soy, coconut, cotton, and others). The mechanical properties of natural fibers depend on the content of cellulose, the degree of its polymerization, and the angle of axial orientation of microfibrils (relative to the fiber axis). Fibers with a higher cellulose content, a higher degree of cellulose polymerization and a lower axial orientation angle of microfibrils have higher elastic modulus and tensile strength [23].

Another green trend is the use of baked dough dishes (plates, spoons, cups). Given that the volume of use of single-use plastic tableware is becoming a global disaster, the transition to "eatable tableware" is a step towards increasing eco-responsibility. This step is especially relevant in the context of increasing tourist flows and the development of food sector, which creates high anthropogenic risks [24]. The hospitality industry, both a driver of economic development and a plastic polluter, needs green transformation.

4. Discussion of research results
Summarizing the study, the following important points can be identified.

1. There is an exponential increase in the using of plastic, most of which is taken up by packaging. If the trend continues, more than 1.5 billion tons of plastics will be produced during 10 years (author's forecast). The main threat is to aquatic environment, where the volume of plastic accumulates rapidly every year. The pollution of land and water with plastic waste has an alarming scale: some kinds of flora and fauna are dying, microplastics are entering human food through the food chain.

2. The largest plastic pollution occurs in developed countries, China and touristic zones. However, the pollution problem is global, so humanity needs to assess the strategic risks of its habitat. The author considers state regulation of plastic production and consumption, development of recycling technologies and creation of biodegradable plastic analogues to be the main restoring ways.

3. Some countries have introduced restrictions on the using of plastic packets and increased environmental charges on plastic manufacturers. It is advisable to introduce financial incentives for companies that recycle plastic and produce eco-friendly materials (biopolymers, plastic substitutes).

4. Plastic can be used as a raw material for energy, fuel, fillers and synthetic materials. Crushed plastic is used in road construction and building materials production. Scientists investigate the properties of some natural materials to create biodegradable plastic analogues or composites (starch, corn, sugar cane, grain husks, algae, chitin, stems and seeds of plants).

5. Important social aspect is the formation of eco-responsibility of people. Even now, we need to stop excessive use of plastic: carry reusable shop-bags, reduce the volume of plastic disposable tableware, do not litter and separate waste. This is especially significant to bring up an eco-friendly generation, as young people receive a poor ecological heritage.

5. Conclusion
The study revealed the threatening impact of exponential growth of plastic waste on the ecosystem: almost all types of synthetic plastic are not biodegradable. The dominant part of plastic gets into the water environment, the rest pollutes the land. Through the food chain, plastic enters human food. The author formulates "plastic trap" paradox: there is contradiction between positive properties of plastic and global problems that arise as a result of clogging the environment with plastic waste. To improve situation the restoring measures are necessary: state regulation of plastic production and consumption, development of recycling technologies and creation of biodegradable plastic analogues. Study of properties of natural materials for creating biopolymers is the subject of perspective researches.

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