Ekoloji 27(106): 571-578 (2018)

# Ecological Aspects of Managing the Processing of Plastic Products and Packaging Based on Improved Biotechnology

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**Abstract**

The level of plastic production is growing rapidly - more than half of plastic waste and plastic products have been manufactured in the last 25 years. In the future, the situation will only worsen, and therefore scientists urge both industrialists and the authorities of all states to reconsider strategies for using and processing plastics. The uncontrolled handling of polymer wastes of consumption and production causes serious damage to the environment and forms not only the environmental, but also the economic problems of future generations, violating the fundamental principle of sustainable development. This article discusses innovative technologies for processing polymer waste consumption and production. Production and biotechnological methods for processing foam plastic, PET and some other types of plastic are considered, including the five most common production methods for handling polymer waste. The study notes that the need to return production and consumption wastes is obvious both in terms of environmental safety and economic feasibility. The authors of the article emphasize that in the conditions of the increasing role of the environmental factor, the problems of managing the processing of plastic products and packaging should be solved in a complex of economic, administrative and social mechanisms. At the same time, it should be understood that the problems of managing the processing of plastic products and packaging are very dynamic and it is necessary to conduct further research in this direction, primarily in the development and improvement of biotechnologies.

**Keywords:** ecology, utilization, plastic products and packaging, natural resources

Larionova AA, Filatov VV, Zaitseva NA, Zhenzhebir VN, Palastina IP, Kurbatova AI, Glagoleva LE (2018) Ecological Aspects of Managing the Processing of Plastic Products and Packaging Based on Improved Biotechnology. Ekoloji 27(106): 571-578.

## INTRODUCTION

Today, about 300 million tons of plastic garbage goes annually to landfills of the Earth, most of which is not decomposed by soil microbes and remains in an almost untouched form for dozens and even hundreds of years. Many plastic particles fall into the waters of the World Ocean, where they penetrate into the stomachs of fish and birds and often become the cause of their death. "Most plastic brands do not decompose by microbes in any form, and therefore all the garbage that we have created will accompany us for hundreds, if not thousands of years. Our estimates of the mass of this garbage make us think about how we use these materials and how getting rid of them", Lindemann (2017).

Jenna Yambek and her colleagues, comprehensively examining how the plastics and rubber industry developed from the 1950 to the present, found that there are now about 6.3 billion tons of plastic garbage present on Earth, whose weight will double to the middle of century. As the calculations of scientists show, this part of the chemical industry grew at a record pace throughout its existence: if in 1950, world enterprises produced only 2 million tons of plastic products, then in 2015 this figure reached 400 million

 Received: 28 May 2017 / Accepted: 23 Aug 2018

tons, which is 200 times more. Accordingly, every year the volume of plastic production grew by about 8% (Zotov 2016).

This makes it extremely unprofitable to distinguish the plastics industry from the steel and cement industries, most of whose products have been used for their intended purpose for decades.

At the same time, only the economic and administrative mechanisms implemented by the state act exclusively on the rational motives of the behavior of market actors and are therefore not able to cope with the task, since they do not cover social and emotional motives. Recently, ideas on the development of environmental education have been actively promoted, which will make it possible to influence the social motives of market actors (Lukina 2012, Valeeva et al. 2018).

## METHODOLOGICAL FRAMEWORK

In this work, desk research methods were used. The methods of analysis and synthesis used to identify the state of the problem of managing the processing of plastic products and packaging, the induction method, which provided an opportunity to summarize modern practice and scientific research in the field of studying the environmental consequences of using plastic products and packaging, the deduction method used to identify socio-ecological economic aspects of waste management, a systematic and comparative approach, which allowed to consider the problem in a comprehensive manner, taking into account international experience , To identify the main trends in these processes, to identify the key ones, whose influence can be decisive in the coming years.

Sources of information of this study:

- Data of ONN, Green Peace organizations;
- Analytical Reviews: Waste Management Market. NRU Higher School of Economics Development Center;
- Statistics of Rosstat (EMISS);
- Open data of the Ministry of Environment, Rosprirodnadzor;
- Expert assessments and opinions

## RESULTS

### Environmental Implications of the Use of Plastic Products and Packaging

The latest data from UN environmentalists indicate that each year about 13 million tons of plastic waste are released into the ocean. Attempts to stop the catastrophic trend have been going on since the middle of the 20th century. According to Green Peace, more than 100 million tons of plastic products are produced annually in the world, and 10% of them eventually end up in the global ocean (Garbage island in the ocean has increased 100-fold, 2018).

Colossal accumulation of garbage of anthropogenic origin floating on the surface of water is the Great Pacific Garbage Patch, which is located in the North Pacific between Hawaii and California and is formed due to currents that “demolish” ocean garbage into this relatively calm ocean (The South Pacific Gyre 2016).

In addition to the Great Pacific Garbage Patch, there are four more giant garbage accumulations in the Pacific, Atlantic and Indian Ocean, each of which, together with the Great Pacific, corresponds to one of the five main systems of ocean currents.

Today, scientists count in the World Ocean hundreds of millions of garbage islands that already have a solid surface.

Researchers are proposing various methods to combat the pollution of the world ocean with plastic, as scientists from Holland plan to implement an interesting innovative project and build a floating island of garbage in the ocean, a large platform-raft collected from garbage that accumulates in certain areas in the Pacific Ocean and, in particular, between Hawaii and California. If all this garbage is recycled, then the size of the island can be comparable to Hawaii. Specialists from the Netherlands have already come up with the name of the future innovative island - Recycled Island (Garbage island in the ocean 2011).

Construction is planned to be divided into three technical stages: garbage collection, garbage recycling and the actual construction of the island. Specially equipped vessels will be engaged in garbage collection and processing. Machines (relatively portable) have already been invented for the processing of microplastic from the sea into plastic sheets that can be reused, i.e. to recycle plastic. It is technically possible to equip vessels for catching and processing floating waste with special installations (A dump that doesn’t exist: the Big Pacific garbage patch and its smaller brothers 2015).

But, for now, according to the forecasts of the British Ellen MacArthur Foundation, by 2025 for every three kilograms of fish in the world's oceans will fall on a kilogram of garbage, and by 2050 the mass of waste will be higher than the total weight of all fish on Earth. Plastic accounts for 80 percent of all garbage in the oceans. Under the influence of sunlight it breaks up into small particles, plastic microgranules accumulate on their surface resistant toxic substances. Scientists found plastic garbage in the stomachs of 90% of the seabirds whose carcasses were found on the east coast of North America, according to a press release from Canadian University of British Columbia (Plastic debris poisoned 90% of seabirds in North America 2017).

**Economic and Social Aspects of Plastic Processing and Packaging Management**

The total number of daily emitted plastic products in the USA, EU, Norway and China reaches 37 thousand tons, in Russia - no more than 10 thousand tons. Existing plastic recycling technologies can only partially solve the environmental problem. The level of plastic production is growing rapidly - more than half of plastic waste and plastic products have been manufactured in the last 25 years (Spiridonov 2017). In the future, the situation will only worsen, and therefore scientists are calling on both industrialists and the authorities of all states to reconsider strategies on how plastic is used and processed. Most of these measures are needed by the United States, where only 9% of plastic waste is recycled, compared to 30% in Europe and 25% in China. As the researchers emphasize, they do not offer to completely abandon the production of plastic, but call for a set of measures to be developed that would encourage industrialists to use existing plastics stocks (Geyer et al. 2017).

According to the British edition of The Guardian, the EU has adopted a new ecological superstrategy, within which it is necessary to solve the problem of recycling plastic waste much harsher than previously planned, an ambitious plan has been made to make them completely "reusable or recyclable" by 2030. This haste in the EU decision regarding the development of a new environmental superstrategy is due to the fact that from January 2018 China has banned the import of plastic trash to its processing because it is harmful to its own environment. And now, because of this, the prospects for further "greening the environment" have plummeted among EU countries that care about the green economy. The listed problems - unsolved, undecided, and simply "sent for export" - are often revealed suddenly. As now, when China suddenly blocks the EU to imitate environmental friendliness at its expense, and EU citizens report that they will have to pay an additional tax on plastic, "because this is the only way to plug the EU's budget hole of 13 billion euros". At these moments, the gap between the reality in which a modern citizen of a developed country lives and the world he imagines appears (Golovanov 2017).

There are proposals for a consolidated international plan of action to address the problem of plastic waste. Experts at the United Nations Environment Program (UNEP) recognize that the problem has been exacerbated by prolonged inactivity. Under the auspices of UNEP, the World Marine Debris Campaign has started. The example of the Italian city of Kapannori with a population of 46,700 is indicative. In 2007, a zero waste strategy was introduced here. For ten years, the volume of garbage was reduced by 40%. At the same time, only 18% of waste falls on landfills. It is worth noting that such a strategy requires certain investments and should include mechanisms to finance the fight against garbage. Alternatively, the polluter pays principle. For an industry with an annual revenue of $ 750 billion, it can be quite effective (Golovanov 2016).

More than 40 countries have established legal restrictions and bans on the use of plastic bags in their territories. For example, in Germany there is a whole list of both rewards and fines regarding the handling of polymers (Spiridonov 2017). Residents who properly sort the waste, much less pay for utilities. Creative Japanese actively used recycled plastics in construction and in other areas. There are practically no such laws in Russia. According to current estimates by environmentalists and economists, Russian industrial enterprises produce approximately 26.5 billion plastic bags. If all of them were collected, it would be possible to cover an area that is three times the size of Moscow (Rukina and Filatov 2017a).

Meanwhile, from August 28, 2017 in Kenya, a ban on the use of plastic bags came into force. Recall, the organization for the protection of the environment WWF and the Global Footprint Network published a report, according to which, on August 2, 2017, humankind exceeded the expenditure of resources that the planet can recover in a whole year. In this regard, Greenpeace Russia launched the campaign "Package? - Thank you, no!" The goal of the campaign is to call upon the largest supermarket chains to abandon plastic bags. Anyone can support the program by sending a

**Table 1.** Plastic recycling methods ( Popov et al. 1998a, 1998b , Zotov 2007)

| | Method | Content | Advantages / disadvantages of the method |
|---|---|---|---|
| 1 | Mechanical method (recycling) | Plastic waste is sorted by type, condition, pollution. The sorted material is pre-crushed, and then re-sorted, washed and dried. The prepared raw material is processed in thermal installations until the formation of a melt of uniform consistency. The molten material is fed into the extruder to form secondary products or intermediate granules, which are then used as raw materials for new production. | Mechanical recycling is widely used for the production of polymer fibers, plastic containers and packaging products. |
| 2 | Hydrolysis method | Splitting of waste polymeric materials with aqueous acid solutions under the influence of high temperature. The main hydrolysis process is carried out in a special vacuum reactor, where ground raw materials, purified from impurities, are fed. As a rule, the crushing of plastic waste is carried out in several stages, as a result of which particles of several tens of microns are formed. | Quite energy-intensive due to significant water consumption and long duration of the production process. In the case of the organization of large-scale processing of waste all energy costs are paid off. The advantage of the method are also low requirements for cleaning and sorting plastic waste. |
| 3 | Glycolysis method | Glycolysis is a type of hydrolysis method, and its main features are the use of glycol in the depolymerization process and the presence of elevated operating temperatures (up to 300 degrees). To reduce the time of chemical reactions, various catalysts are used, which also affect the characteristics of the product obtained. | The advantages of the method include low requirements for waste preprocessing (cleaning, sorting plastics) and almost complete waste-free production. But the technological features of this method do not allow to use it for the further production of food plastic. |
| 4 | Methanolysis | The method involves the splitting of plastic waste with methanol. The process takes place in a reactor under pressure at high temperatures. | The method of methanolysis refers to the processes of increased explosive and chemical hazards, as a result of which it is used mainly in highly specialized production cycles of polyesters. Methanolysis requires careful preparation of raw materials, and is also costly in terms of energy consumption. |
| 5 | Pyrolysis | The method of thermal destruction of plastic waste in the absence of air. As a result of this process, the raw material is depolymerized (decomposed into monomers). To ensure the reaction does not require prior cleaning and sorting of waste. The pyrolysis technology, being one of the most promising methods of plastic waste management, is constantly being improved and finds effective implementation in domestic and foreign practice. | Thermal destruction meets all modern sanitary and hygienic and environmental standards. In addition to splitting plastic, pyrolysis plants can recycle other organic waste. One of the products of pyrolysis is fuel gas, the realization of which can be a source of additional income. |

letter addressing retailers on the organization's website (Living Planet Report 2017).

The main reasons why recycling plastic for its reuse is gaining in popularity are the following: the long disintegration time of synthetic polymers under natural conditions (from 100 to 500 years); complex, heterogeneous composition of polymer waste and little knowledge of their impact on the environment during a long stay in nature. The impetus for this is the relatively high raw material value of waste plastics, which makes it possible to turn waste recycling into a profitable type of business. In order to increase the profitability of the production process, the technology of processing polymer waste is constantly being improved, becoming more and more safe and environmentally friendly (Technology of processing of plastic waste 2017). Note the social aspect of waste management, for example, the form of Real Madrid and Manchester United football players is made using recycling technology from Japanese plastic bottles. Also, the entire uniform of the Japanese team, which during the Olympics 2020 will, along with the rest of the athletes, live and train on the bulk islands created from recycled waste will also be made from recycled plastic.

The goals that are pursued by the development of the technology of recycling waste polymeric materials are the following: maximum reduction of export of plastic to landfills; reduction of environmental pollution by plastic; cheapening of various production processes through the use of plastic recycling; search for new uses of recycled plastics (as fuel, building materials).

## Promising Technologies for Processing Plastic Products and Packaging

According to the results of the study, it was revealed that today in the world practice recycling of plastics is carried out in various ways, in particular by biotechnological and production methods. Consider the five most common production methods for handling polymer waste.

Biotechnological methods of processing foam, PET and some other types of plastic are recognized as one of the promising areas for waste recycling.

Chinese and American biologists have unexpectedly discovered that the caterpillars of the mealworm and the larvae of Indian barn moths can digest polystyrene, polyethylene and potentially other types of plastic, which can make them the primary means of combating plastic pollution of the Earth. Ordinary flour worms served as food in Chinese restaurants are able to partially digest these polymers (Yang et al. 2015). "This is a truly

revolutionary discovery. In my opinion, we managed to achieve the most serious breakthrough in environmental science over the past 10 years," Wei-Min Wu from Stanford University (USA) commented on his discovery in an interview with the American television channel CNN (Scientists have found caterpillars that can feed on polyethylene and foam 2015).

Over the past two years, scientists have discovered several species of insects whose larvae were able to solve the problem of processing foam, PET, and some other types of plastic. For example, two years ago, Chinese biologists discovered that the favorite dish of many visitors to Chinese restaurants - caterpillars of britty mealworms - could eat foam, PET, and some other types of plastic. The discovery of bacteria in their intestines, capable of decomposing plastic, gave the first hope for a quick cleaning of the Earth from debris. It turned out that the wax moth can eat polyethylene at a record speed - in about half a day about 100 milligrams of a pack were eaten, which is thousands of times faster than plastic decomposition with the help of bacteria and other insects. Japanese molecular biologists have discovered an unusual bacterium that can process lavsan and other types of plastic, and extracted enzymes from them that are responsible for the decomposition of these polymers (Biologists have discovered bacteria that can devour "bottle" plastic 2016, Yoshida et al. 2016).

Fuel from plastic waste has now become a reality (Plastic recycling: not only profit, but also benefit 2017). For example, several similar enterprises are actively operating in the USA. From 1 ton of plastic raw material, 3-5 barrels of synthetic oil of medium or light fractions can be obtained. Also currently, there are reverse (isometric) projects for the production of polymeric materials, in particular polyvinyl chloride, one of the most important plastics on Earth. Graham Hutchings (reported on the introduction in the industry of environmentally friendly methods of converting acetylene to polyvinyl chloride (The British chemist told how the Earth is preparing for life after oil 2017). These "green" reactions were discovered in the early 1980s, and only now they began to be introduced into production by industrialists in China and other countries. On the other hand, sooner or later there will be commercial companies that will use CO2 for the production of polymers and other organic compounds. Moreover, such enterprises already exist - Charlotte Williams of Oxford University recently founded the company Econic Technologies, which deals with commercial projects for the utilization of carbon dioxide (Technology of processing of plastic waste 2017).

**Approaches to Solving the Problem of Waste Disposal in Russia**

The problem of waste disposal in many countries, including and in Russia, is very serious. City dumps take up a lot of space, and in fact some of the garbage (for example, plastic) can be recycled, thereby saving raw materials. And if in developed European countries this issue is being actively solved by launching entire processing complexes, here in our country only a few small plants are functioning. And this is the main prerequisite for purchasing plastic processing equipment and launching our own highly profitable business. Today, the development of plastics processing is quite a profitable business, since the global demand for recycled plastics, according to experts from The Freedonia Group, will grow by an average of 6.5% annually. Moreover, according to their own forecasts, by 2018, the secondary plastic market will be more than 1.7 billion tons. And this is taking into account the fact that, at the same time, in the world, the volume of plastic that has been processed does not exceed 7% today.

The Ministry of Natural Resources and Ecology of Russia indicates that there is a categorical shortage of processing points in the country. There are small waste treatment plants, but this is not enough. They are not able to cope with large quantities of plastic, as they do not always have new and functional equipment. To get out of this situation, experts recommend building new modern processing plants that will meet international standards. Investors and entrepreneurs should think about this type of activity, because this is a very promising and highly profitable business. To engage in such work, you will need to obtain an appropriate license, as well as a conclusion from the Ministry of Natural Resources, but the state will not begin to repair any obstacles in the future (Rukina et al. 2018a).

The dynamics of waste generation and use / disposal compiled on the basis of Rosstat data are presented in **Table 2**, we note in general for the Russian Federation the indicators have higher values, due to the fact that not all market entities are obliged to provide reports on this area.

**Table 2.** Dynamics of formation, use, disposal of production and consumption wastes in the Russian Federation for 2008-2017

| Indicators | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 |
|---|---|---|---|---|---|---|---|---|---|---|
| Generation of production and consumption waste, mln. Tons | 3876.9 | 3505.0 | 3734.7 | 4303.3 | 5007.9 | 5152.8 | 5168.3 | 5060.2 | 5441.3 | 6 220.6 |
| The growth rate of waste,% | 99.4 | 90.4 | 106.6 | 115.2 | 116.4 | 102.9 | 100.3 | 97.9 | 107.5 | 114.3 |
| Use and disposal of production and consumption wastes, million tons | 1960.7 | 1661.4 | 1738.1 | 1990.7 | 2348.1 | 2043.6 | 2357.2 | 2685.1 | 3243.7 | 3 264.6 |
| The growth rate of use and disposal of production and consumption waste,% | 86.9 | 84.7 | 104.6 | 114.5 | 118.0 | 87.0 | 115.3 | 113.9 | 120.8 | 100.6 |
| The proportion of used and neutralized waste production and consumption,% | 50.6 | 47.4 | 46.5 | 46.3 | 46.9 | 39.7 | 45.6 | 53.1 | 59.6 | 52.5 |

Source: compiled by the authors

The positive trend that has emerged since 2013, the growth in the share of used and neutralized production and consumption wastes in total waste in 2017 slowed down. At the moment, there are 78 enterprises in our country in 28 regions of Russia. This is clearly an insufficient amount; the waste recycling industry should develop more actively. In 2018, 1 billion rubles of environmental collection funds were sent to the subjects of the Russian Federation to establish facilities for processing and sorting waste. These funds were collected from manufacturers and importers of packaging and redistributed to the creation of 22 objects in 15 regions of Russia with a total capacity of 875.85 thousand tons. In 2019, it is planned to create 39 objects in 22 regions of the Russian Federation with funds from the environmental fee. In Russia, the niche for recycling plastic is practically not occupied, which, given global trends, is quite attractive from a business point of view (Volkova 2018). Currently, the share of secondary raw materials in the raw material balance of the plastics processing sub-sector is no more than 2-3% (mainly polyethylene terephthalate).

Recycling plastic waste in addition to increasing raw material resources contributes to solving environmental problems and in developed countries has an upward trend of development: in Europe, 30-35% of polymeric wastes of various raw materials are processed. From the point of view of the cost of secondary raw materials and the demand for it, the plastics market is extremely attractive to processors. However, the absence of a well-established system for collecting polymeric waste causes a low proportion of their recovery and disposal.

Strengthening state regulation in this area suggests that the direction of waste processing will be very promising in the near future. Depending on what plastics processing technologies will be introduced in production, the entrepreneur has the opportunity to sell further: PVC granules, flex (refined crushed plastic), chemical fiber, fuel.

The processing of plastic into fuel in Russia is still at the initial stage, since it will require an expensive process line.

## DISCUSSION

Previously, the authors of the article repeatedly investigated environmental problems in various aspects, primarily the use of production and consumption waste as a strategic resource for the future economy. Rukina and Filatov (2017b), economic aspects of waste recycling Rukina et al. (2018b), Rukina and Filatov, (2017c) and in the social aspect, (Zaitseva et al. 2016). Based on the results of the research, conclusions were made about the need to develop common approaches to managing the processing of plastic products and packaging, including through the improvement of biotechnology.

The need to return production and consumption wastes is obvious both from the point of view of environmental safety and economic feasibility, and is due to the concept of a closed-cycle economy (circular economy), the feasibility of which has found worldwide recognition today (Oreshina et al. 2017, Ushakov et al. 2018). An important role is played by the socio-environmental aspects (Bragin et al. 2018, Kevorkova et al. 2018, Lukina 2012) for example, the desire of producers of goods and packaging, consumers of goods to environmental friendliness.

As noted in research (Geyer et al. 2017, Makarova and Rodina 2016, Slat 2014), the processing of various waste fractions differs markedly in terms of profitability, energy saving in relation to the production of primary material, complexity of technological processes, etc. Biotechnological methods for processing foam plastic, PET and some other types of plastic are recognized as one of the promising areas for waste recycling.

## CONCLUSION

At the end of this study, I would like to cite data on the calculations of British analysts, which show that the

reuse of plastic packaging will save up to $ 120 billion each year. Reducing the production of plastic can increase the demand for more environmentally friendly reusable goods from other raw materials and make them cheaper by increasing the mass production. It is likely that due to the implementation of strategic measures to protect the environment through the introduction of biotechnological innovations in the processing of plastic products and packaging, it will be possible to reverse the situation in several years and stop or at least slow down the environmental catastrophe (Rukina et al. 2018c).

There are other futuristic and very pessimistic views on the problem of pollution. According to some scientists, irreversible changes are already occurring on our planet, we are facing a shortage of drinking water, global warming and other things that will make the Earth unsuitable for human life (Spiridonov 2017). In order to develop innovative technologies for the processing of polymer wastes of consumption and production, government support is required at all levels - federal and regional. It should be enshrined in legal acts and stimulated by budgetary funds

Summarizing the above, it should be noted that the introduction of biotechnological innovations in the processing of plastic products and packaging, ultimately, has the goal of improving the quality of life of the population, which can be measured by the dynamics of socio-ecological-economic indicators. For businesses, it is crucial to have a long-term vision of development, expressed in specific targets. The most important thing, both at the level of international organizations for environmental protection and at the level of management of individual regions, is the development of specific mechanisms for achieving the goals set. Tactical steps at all levels of government should be directly linked to strategic measures to optimize the processing of plastic products and packaging based on biotechnological innovations.

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