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RECYCLING OF POLYMER WASTE IN THE CONTEXT OF DEVELOPING CIRCULAR ECONOMY

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Abstract

The paper deals with the problem of recycling and a review of the problem field of handling polymeric materials is carried out, on the basis of which commonality for the European space of their disposal and recycling problems is shown. Ways of solving them are identified and the leading dynamics of European approaches to waste management compared to national ones are revealed. It is shown that the tempos of formation of polymeric wastes practically coincide with the tempos of their processing, which indicates an increase in the technogenic load on the environment as a result of the continued influx of polymeric materials into it. The structure and species priorities of polymeric wastes and damage to the most vulnerable sectors of the economy and ecosystems are identified, and the dangerous impact of their destruction on the environment is estimated. Comparison of the main methods of disposal of polymeric wastes used in the world made it possible to evaluate approaches to solving the problem of cyclical handling of polymeric materials wastes, the results of which would be a socio-economic and ecological effect, reducing the impact of the consequences of the destruction of polymer fractions of landfills on environmental quality, as well as significant saving non-renewable fossil raw materials. The expected performance is expressed quantitatively by calculating the integral indicator of the efficiency of polymer waste processing, taking into account the ratio of the sum of recycling effects, expressed in terms of value, to the capital and current costs of the project.

Keywords: **Recycling; Ecology; Environment; Polymer waste; Environmental economics.**

1. INTRODUCTION

The current state of the environment defines a new conceptual vision of the development of the economy of the future, suggesting a transition from a linear production model to a closed-cycle model, which makes it possible to fundamentally change the proportional dependence of production waste on production volume growth. Solutions to this task lie in the plane of the integrated use of resources, reducing the mass of recyclable production waste, their repeated (multiple) use or return to production through the allocation of useful fractions and disposal of irretrievable waste. Thus, waste recycling, as a component of a waste management system, can be considered as the most important, necessary, essential, inalienable property of the fourth industrial revolution.

According to the Antimonopoly Committee of Ukraine in 2016–2017 no more than 5.8% (2.8 million m^3 or 638 thousand tons) of garbage was received for recycling, of which 2.7% was utilized by thermal processing, and 3.1% by recyclable [1]. The total amount of recycled waste in the country is 10–12 times less than in EU countries, which leads to the formation of natural waste dumps.

A significant part of the waste is polymeric waste – a product of the use of materials produced on the basis of synthetic polymers. In the world, the reuse of such wastes as raw materials for recycling reaches 80%. According to the State Statistics Service of Ukraine [2], over 40 thousand tons of polymer waste accumulates annually in the country, in the structure of which 31% is polyethylene, 20% is polyethylene terephthalate, 17% is laminated paper, 14% – polyvinyl chloride, 10% – polypropylene, 8% – polystyrene. The rising cost of primary raw materials, increasing the amount of waste, toughening of environmental standards actualize the problem of recycling polymer waste. At the same time, the polyethylene market in primary form is represented by a small number of players, among which three companies occupy more than 90% of the market. The polymer recycling market is less concentrated and is represented by a large number of companies with small market shares. Considering the annual growth of the market of polymeric materials, the share of waste will constantly grow, which actualizes this study.

The characteristics of these wastes, as well as the dynamics of their accumulation, can be considered as factors stimulating the development and supply of innovative technologies for their processing, increasing the operators of the market for secondary polymers and processing facilities, as well as the formation of consumer responsibility mechanisms for the disposal of polymer waste.

The aim of the paper is to study and activate the mechanisms of recycling polymer waste in Ukraine. In accordance with the objective, the assigned tasks determine the logic of the work's construction and include: analysis of the legal architectonics of the polymer waste recycling process; classification characteristic of polymeric waste; assessment of the availability of collection, transportation, sorting, processing, disposal, storage and processing of polymeric waste; the definition of the scopes of products of recycling polymer waste; study of the availability of modern technologies to companies for the recycling of polymeric waste; analysis of the cost characteristics of polymeric waste recycling.

2. MATERIAL AND RESEARCH METHODS

The theoretical basis of the study are the classic position of environmental economics, the theory of environmental management, economic and environmental analysis, scientific works of domestic and foreign experts in the field of waste management. The work is based on the system analysis toolkit, which allows: to highlight the components of the national paradigm of waste management policy, their interconnection and interaction; conduct informational, organizational and economic analysis of the problem; to take into account the synergistic interaction of all elements of the waste management system of a particular type, which made it possible to formulate the author's vision of managing the entire system, rather than individual components. To solve the problems posed, general scientific and empirical methods were applied, namely: methods of analysis and synthesis - to study the waste management processes in their systemic representation, quantify the lost benefits from the underdeveloped market of secondary polymers, statistical analysis methods – to determine economic processes and phenomena in the field of polymer waste processing and the use of recycled products, methods of comparison and analogies – in a comprehensive study of waste generation processes and their further use; method of technical and economic calculations – in assessing the indicator of the integrated efficiency of recycling polymer waste. The information base of the study was the official statistics on the functioning of the polymer market in Ukraine.

3. ANALYSIS OF THE LITERATURE

The study of waste management from polymeric materials, as the most aggressive environmental pollution in terms of chemical composition of sources, devoted to the work of authors who have considered in compared recycling and waste disposal system [3], which allowed to characterize the positive effects of recycling on the environment on the basis of energy from garbage – biogas from sewage sludge or food waste and refuse derived fuel from polymeric waste [4, 5].

The constantly growing volume of industrial and domestic use of polymers stimulated the search for ways to utilize the plastic fraction in municipal solid waste [6]. The main methods of processing waste from polymeric materials are the mechanical recycling of polymeric materials to produce a plastic product in the form of secondary raw materials [7, 8] and chemical recycling associated with the conversion of waste polymers into petrochemical raw materials and other products [9, 10].

Studies show [11, 12] that mechanical recycling of polymeric materials is currently the most common, since it does not require complex chemical processing of waste. However, the chemical method requires less time and energy to process [13]. At the same time, the types of polymers used are quite diverse, which implies the development of new processing technologies [14].

The distribution of polymeric wastes, taking into account their formation, accumulation and processing depending on the chemical composition and technological properties, was carried out by [15], which developed recommendations for effective management measures, processing and recycling plastic waste. The basis for the efficient management of polymeric wastes is the selection of appropriate processing technologies that make it possible to obtain secondary raw materials of appropriate quality. This issue is devoted to research, the purpose of which is to select technologies for the processing of all types of polymer waste [15].

An important aspect in the further study is the economic evaluation of the methods used to manage waste from polymeric materials, since research on the economic evaluation of the recycling of plastic waste is rather limited. The papers [16, 17] deal with the assessment of the economic impact of alternative plastic waste management systems, taking into account the life cycle of polymeric materials. A key area of assessment of the economic consequences and environmental benefits of the used methods of managing waste from polymeric materials (collection, sorting, transportation, waste management, incineration and processing) is the analysis of the costs and benefits of the environmental impact of the selected systems. However, the field of solid household waste processing requires significant investments and the development of new models for their treatment, which will eliminate debris and get both energy and economic benefits [5]. This approach is consistent with the principles of a closed-cycle economy, focused on improving the efficiency of resource use and the management of household and industrial waste, reducing their disposal by processing and using secondary raw materials [18].

4. ANALYSIS OF PROCESSING OF POLYMERIC WASTES AND CONSUMPTION OF POLYMERIC MATERIALS

The analysis of the legal architectonics of the polymer waste recycling process has witnessed the successful application of legislative measures in the European Union (Directive, 2008), which establishes the basic requirements for waste management, disposal and recycling, and most importantly helps to avoid waste generation and use waste as a resource. In Ukraine, the process of waste management is regulated by the Law of Ukraine "On Waste" [19], which does not define the concept of recycling, but denotes such concepts as "recycling of waste" associated with changing the physical, chemical or biological properties of waste in order to prepare their environmentally sound storage, transportation, recycling or disposal, as well as "waste management", with regard to the use of waste as secondary material or energy resources. The need for a legal definition of "recycling" is justified by the fact that as a result of recycling, it is possible to carry out any technological operations related to recovery, in which waste is processed into products not only for use as secondary resources, but also for initial purposes [20]. The legal framework should meet the current challenges of the environmental situation, which will make it possible to set clear long-term goals for public waste management policy in the conditions of an incompletely functioning waste management infrastructure.

According to the National Waste Management Strategy until 2030, which implies a significant reduction in waste disposal and an increase in the level of their processing, as well as separate collection of household waste, such types as solid, household, industrial, hazardous, construction, agricultural, electronic and other waste. This strategy is based on EU standards envisaged by the Association Agreement with the EU, it should be the basis for the future development of a regulatory framework in the field of ecology, as well as the preparation of national and regional plans for implementing the strategy, which can be considered as a new look at the problem of waste in the context of diversification of secondary sources energy and material resources [21].

The problem of polymer waste is the result of mass production of plastics, which began in the middle of the last century. The absolute increase in plastic production amounted to about 296 million tons over the past 50 years (Ellen MacArthur Foundation, 2016). The growing need of the global economy for polymeric materials has led to the fact that by the beginning of the 90s, the production of plastics and steel became equal. In 2017, according to the PlasticsEurope (Association of Plastics Manufacturers) [21], the regional structure of polymer production was as follows: Europe – 18.5%, Commonwealth of Independent States (CIS) – 2.6%, Middle East, Africa – 7.1% , North American Free Trade Area (NAFTA – North American Free Trade Area) – 17.7%; Latin America – 4%, Asia – 50.1% (China – 29.4%, Japan – 3.9%, Rest Asia – 16.8%). World consumption of plastics for the period 2007–2017 increased by 33.8% from 260 million tons to 348 million tons (Tab. 1).

Table 1.
Consumption of polymeric materials by region of the world, mln. tons [21]

Region / Country	2007	2017	Consumption increase/ decrease, %
Europe	65.0	64.4	- 0.92
CIS	7.8	9.0	+ 15.38
Middle East, Africa	20.8	24,7	+ 18.75
NAFTA	59.8	61.6	+ 3.01
Latin America	10.4	13.9	+ 33.65
Asia	96.2	174.3	+ 81.19

Spheres of the use of polymeric materials are various. Plastics are widely used in construction, agriculture, medicine, furniture and woodworking industry, water supply, automotive, aviation, shipbuilding, instrument making, electronics, consumer and office equipment, transport, communications, rocket and space industries. However, more often, they are in demand in the industry of packaging.

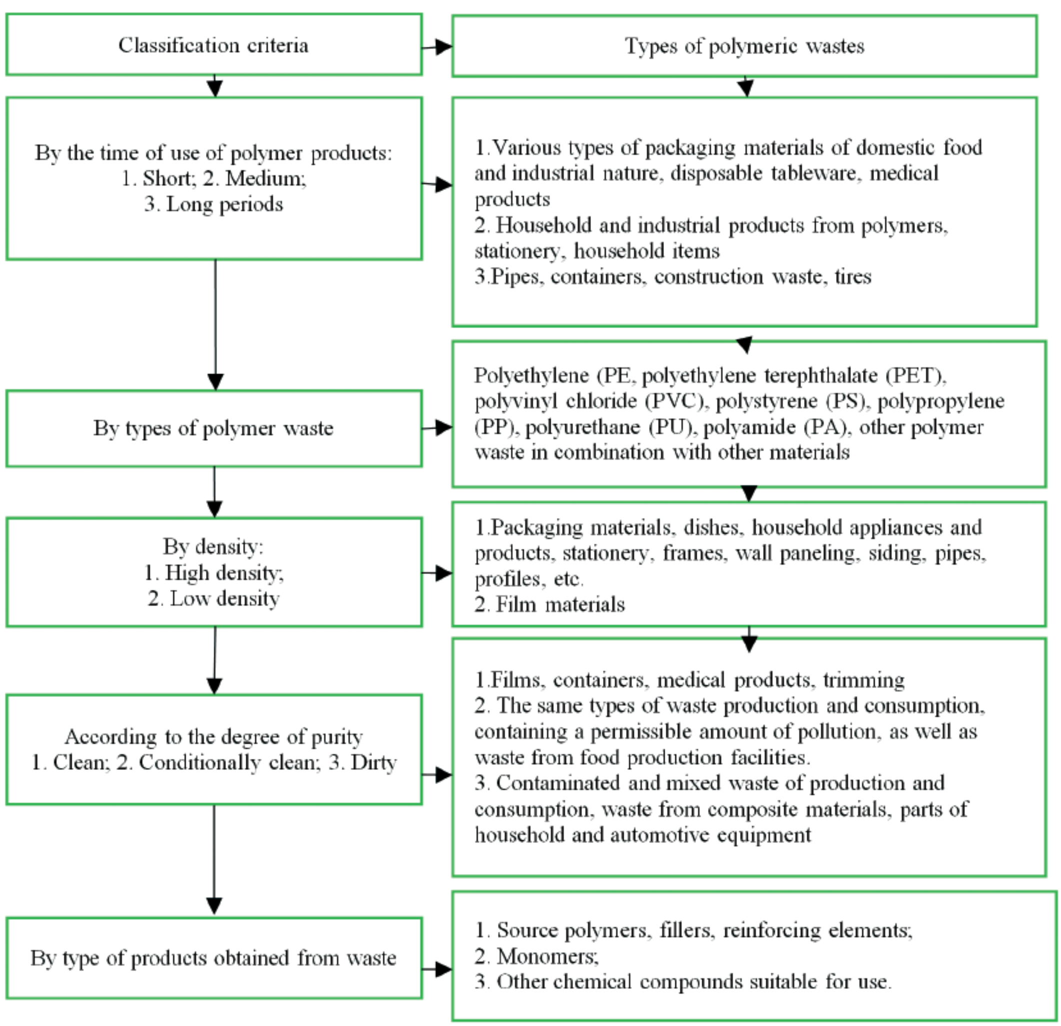

Figure 1.
Polymer Waste Classification

5. THE IMPACT OF POLYMERS ON THE ENVIRONMENT AND MECHANICAL PROPERTIES IN THE PROCESSING OF POLYMER WASTE

The rapid growth of the packaging industry witnessed an average annual growth in the global packaging market of 3% with a total annual turnover of USD 800 billion [22]. Currently, about 50% of all types of packaging materials are made from polymers. A large market share (about 60%) is occupied by flexible packaging (single-layer and multi-layer bags, sacks, big bags, shrink and stretch films), the remaining 40% is tough (banks, boxes, buckets, kits, bottles, tubes, cans, barrels, trays, glasses). According to experts' forecasts, the growth in demand for food packaging made of rigid plastics is about 5% per year and in 2017 reached USD 5.4 billion. The flexible packaging segment will grow by 3.4% per year and by 2020 will reach the figure of USD 248 billion [22].

Along with polyethylene and polypropylene, high-molecular-weight polyethylene terephthalate (PET) is commonly used as food and beverage packaging, the global output of which in 2015 was 20.7 million tons [22]. Products packaged in PET packaging, due to lower logistics costs, packaging strength, the ability to maintain product quality during the shelf life, are attractive from an economic point of view. However, most packaging plastics are discarded almost immediately after use.

The expansion of the use of polymeric materials is accompanied by an exacerbation of the problem of accumulation of various kinds of polymeric waste, which include products that have served their life, industrial and household packaging materials. Different purposes, terms, methods and scope of application allowed to systematize polymer waste according to a number of classification criteria (Fig. 1).

Table 2.
Dynamics of formation and recycling of plastic waste in the world [21]

Year	Volume of waste generated, *mln. tons*	Temp waste,%	The volume of recycled waste, *mln.tons*	Temp recycling,%
2007	158.5	-	100.1	-
2008	160.3	1.1	112.0	11.9
2009	175.6	9.5	122.9	9.7
2010	177.6	1.1	124.3	1.1
2011	193.2	8.8	135.2	8.8
2012	209.0	8.2	146.3	8.2
2013	222.0	6.2	155.4	6.2
2014	230.4	3.8	161.3	3.8
2015	247.2	7.3	173.0	7.3
2016	267.6	8.3	187.0	8.1
2017	285.6	6.7	199.9	6.9

According to the data given in ASGARD [23], from 2007 to 2017, the amount of plastic waste in the world increased by 1.8 times, the volume of their processing, including sorting and disposal at landfills, have doubled (Tab. 2).

As results from Table 2, the tempos of formation of polymeric wastes practically coincide with the tempos of their processing, which indicates an increase in the technogenic load on the environment as a result of the continued influx of polymeric materials into it.

Today, out of 9 billion tons of plastic produced in the history of mankind, only 9% is recycled. If the existing model of plastics consumption and waste management is preserved, about 12 billion tons of plastic waste will be accumulated in the environment by 2050, and the unchanged production rate will lead to an increase in oil consumption at 20% of world consumption [24].

According to the State Statistics Service of Ukraine (2017), in 2017 more than 48.6 thousand tons of polymer waste accumulated in the country, in the structure of which polyethylene waste amounted to 31%, PET – 20%, laminated paper – 17%, polyvinyl chloride (PVC) – 14%, polypropylene – 10%, polystyrene – 8%.

Durability and resistance to decomposition - properties that make plastics versatile for use. However, their qualities are the cause of a number of externalities.

Each year, about 13 million tons of plastic fall into the oceans, causing great harm to biodiversity, the economy and, potentially, human health. Since most plastics do not biodegrade, they eventually break down into small particles as a result of mechanical action, turning into a microplastic. Once in the body of fish, microplastic is included in the food chain and has a negative impact on human health, the consequences of which are still poorly understood. According to experts [25], in 2014 the ratio of the mass of polymer waste in the oceans to the mass of its fish stocks was 1:5, and with the continuing trend of pollution of the seas by 2050 as 1:1. Plastics falling on the surface of the oceans, due to the preservation of resistance to the effects of the marine environment and extremely slow decomposition under the influence of ocean currents, form huge floating islands of plastic debris, as shown in Fig. 2 [26].

The annual economic damage caused by plastic waste pollution costs the tourism, fishing and shipping sectors of the Asia-Pacific region USD 1.3 billion. The amount of plastic waste from beaches and coasts in Europe is estimated at 630 million euros per year. According to research, the total economic damage caused to marine ecosystems annually as a result of plastic pollution is at least USD 13 billion [23].

The destruction of waste polymers in the conditions of deposition at landfills is quite slow and this process is poorly understood. There are several types of destruction of polymeric waste placed on landfills: mechanical, photo-oxidative and biological. The degradation products of polymeric materials serve as the basis for the formation of a number of new chemical compounds, including toxic ones. Some of them (about 10%) remain in the body of the landfill, the remaining 90% enter the environment in the form of gaseous and dissolved compounds in the filtrate. In the composition of the products of degradation of polymeric wastes under conditions of landfill, toxic copper compounds, phosgene, and carbon oxysulfide were identified. The release of toxic substances from the combustion of polymeric materials is another very serious danger associated with their use. So, when burning 1 kg of polymer, gaseous toxic substances enter the environment, the amount of which is enough to poison the air in a room of 1500–2000 m^3. The most dangerous toxicant released from plastic waste during combustion or exposure to solar radiation is dioxin – one of the most toxic technogenic substances, which has a potent mutagenic, immunosuppressive, carcinogenic and embryotoxic effect.

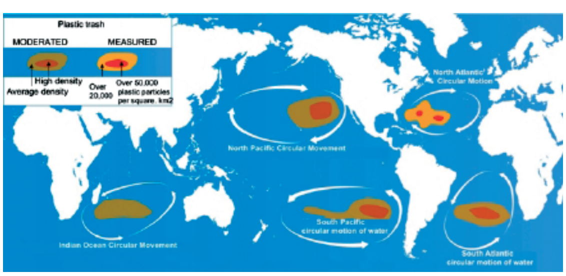

Figure 2.
The accumulation of plastic garbage in the oceans [23]

Plastic pollution is becoming more and more threatening in its scale and consequences. However, taking into account that the absolute majority of monomers used in the plastics industry are derived from hydrocarbon minerals, plastic waste must be included in the reuse cycle, and not transported to landfills.

6. TECHNOLOGY OF PROCESSING OF POLYMER WASTES AND RECYCLING EFFICIENCY ASSESSMENT

The main methods of disposal of polymeric wastes are mechanical and chemical recycling, as well as energy recovery. The technological chain for recycling plastics waste begins with the separate collection and identification of waste suitable for recycling, and their sorting by type of plastic. The data of foreign experience clearly indicate that the processing of the polymer component of municipal solid waste can be profitable and not affect the quality of the environment.

Depending on the task, the cyclical nature of the handling of polymer waste can be achieved through the use of horizontal or cascade recycling.

Recycling in a closed circuit (horizontal recycling) is a system in which a certain mass of material is reused to produce the same product. Such a scheme is suitable for recycling waste high-density polyethylene (HDPE) and polypropylene (PP), since the products produced from these polymers do not change their properties. The recycling process in this case consists only in grinding and granulation.

Open-circuit recycling (cascade recycling) is a recycling system in which a certain mass of one type of material is converted into a product of another type. Thus, the technology of processing mixed polymer waste includes sorting, grinding, washing, drying and homogenization. The most commonly used methods of polymer processing are associated with the mechanical method of processing plastic waste on the basis of grinding and physico-chemical method with the formation of powdered materials.

A schematic line for the processing of PET bottles is shown in Fig. 3 In order for recycling of polymeric wastes to become a full-fledged link in the waste management system in Ukraine, a necessary condition is the availability of production facilities ensuring the functioning of the system for the return and reuse of waste. In addition, a significant argument in favour of increasing the recycling of plastic waste in the country is the possibility of assessing the reduction of costs from environmental damage due to the withdrawal of non-renewable resources, i.e. oil and gas, which are primary raw materials in the production of polymers. Calculations showed that in the production of 1 ton of high-density polyethylene (LDPE) oil consumption is about 17.55 tons worth USD 8,529. Therefore, the prevented environmental damage caused by recycling 1 ton of polymer waste in real terms is 17.55 tons of oil saved.

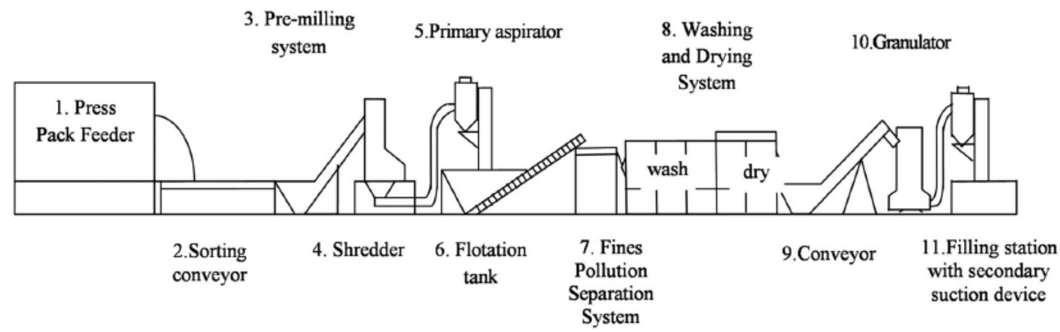

Figure 3.
PET Bottle Recycling Line

It should be noted that the efficiency of polymer waste recycling is determined not only by minimizing the damage from environmental disturbances due to the withdrawal of non-renewable resources, but also in the context of the aggregate socio-economic and environmental effect obtained from the waste recycling process as an indicator of the recycling integral efficiency (recycling efficiency indicator – REI) [18, 30].

Note that the arsenal of indicators for evaluating investment projects is quite large, each of them reflects the characteristics of a particular project, which allows the investor to determine the list of the most informative indicators and select the appropriate method of calculating them depending on the availability of a reliable information base [27]. This indicator is a prototype of an integral indicator of the efficiency of polymer waste processing, taking into account the ratio of the sum of recycling effects (economic, environmental and social), expressed in terms of value, to the capital and current costs of the project:

$$REI = \frac{E_{econ} + E_{ecolog} + E_{soc}}{K + C \cdot T} \qquad (1)$$

where is E_{econ} – income from the sale of produced secondary raw materials, USD; E_{ecolog} – reduction of the environmental tax for the disposal of municipal solid waste at the landfill, USD; E_{soc} – reducing unemployment benefits by creating new jobs, USD; K – cost of equipment for recycling, USD; C – operating costs, USD per year; T – the period of operation of the equipment (payback period), year.

To recognize the project as effective, the value of the defined indicator, the data for the calculation of which are given in Table 3, must exceed one.

Table 3.
Data for calculating the integral recycling efficiency (REI) of PET bottles [24, 25, 29]

No	Indicator	Value
1.	Capacity of PET bottles recycling line, t/year	365
2.	Cost of PET bottles recycling line, USD	100 000
3.	Maintenance costs for the PET bottle recycling line, USD/year	60 000
4.	The period of the line for the processing of PET bottles, year	2
5.	Cost of recycled plastic, USD/t	500
6.	Average unemployment benefit, USD / month	60
7.	Number of employees servicing the PET bottle recycling line, pers.	7
8.	Adjusted tax rate for disposal of polymer waste (as part of municipal solid waste) at the landfill, USD/year	2

As a result of the calculations performed by the authors, it was estimated that the volume of granulate production (product of PET bottles recycling) over 2 years will be 730 tons, the income from its sale is USD 365,000, the savings on the payment of environmental tax for placing PET waste at the landfill – USD 1460, reduction of unemployment benefits through the creation of 7 jobs for the maintenance of the PET bottle recycling line – USD 10.080.

Thus, the indicator of the integrated efficiency of PET waste recycling, taking into account its economic, environmental and social significance, is:

$$REI = \frac{365000\text{ USD} + 1460\text{USD} + 10080\text{ USD}}{100000\text{ USD} + 60000\text{ USD}\cdot 2} = \frac{36540\text{ USD}}{220000\text{ USD}} = 1.71$$

The obtained value REI > 1 indicates a very high efficiency of recycling PET waste.

Despite the understanding of the need to return polymer waste to the economic cycle of the economy, today in the world the share of recycled polymers is only about 10–15%. A serious obstacle inhibiting the activation of recycling of polymeric wastes is the problem of mixed raw materials. Even assuming that global refining rates increase from the current rate of 50%, the annual demand for primary raw materials will also increase. This is due to the fact that the construction of systems for the effective recycling of polymers does not belong to the national priorities of environmental safety not only in Ukraine, but also in Eastern Europe.

At the same time, the recycling of PET bottles in most European countries is a highly profitable business and is carried out on the basis of the principle of state regulation, which implies that producers of plastic packaging and packaging have a special tax, in which the cost of recycling is incorporated. With these funds, for example, 80–85% of used PET bottles are recycled in Germany.

In Ukraine, this tool does not apply. In addition, the lack of a culture of separate collection of household waste, despite the introduction of fines for unsorted garbage from 01/01/2018, as established by the amendment to the Law of Ukraine “On Waste” [19], makes recycling of polymer packaging unprofitable. According to experts, with sufficient capacity for processing PET waste from 200 thousand tons of polyethylene bottles and packages accumulated annually in the country, only 7% is recycled.

Obviously, in order to intensify the recycling of polymeric wastes in Ukraine, it is advisable to organize their selective collection, i.e. separation of the polymer fraction of household waste into components in accordance with the existing labeling. Also, based on the principle of extended producer responsibility, a deposit system should be developed to collect polymer containers and packaging in order to encourage the consumer to return it to the seller. The introduction of these tools in the practice of handling polymer waste in Ukraine will be possible with appropriate information and legislative support.

7. CONCLUSIONS

1. Analysis of the situation in the field of formation of polymeric wastes revealed a steady growth trend of their accumulation in the environment, due to the fact that the temps of waste generation over the past decade have significantly exceeded the temps of processing and amount to less than 10%. Polymer wastes are extremely resistant to aggressive environmental factors, and their accumulation increases the risk of environmental and economic damage. This will lead to a further exacerbation of environmental and economic problems caused by an increase in the amount of polymer waste, in the structure of which more than half is composed of waste polyethylene and polyethylene terephthalate, and the remainder is polyvinyl chloride, polystyrene, polypropylene. The highest level of collection and processing is characterized by waste packaging materials made of polyethylene.
2. World practice indicates an increase in the production of polymer products from recycled materials, which completely replaces the raw materials in products whose production standards allow such a replacement. This trend will continue, but for this it is necessary to solve a number of issues related to the production of polymers as a result of waste processing with given physical and mechanical properties. A variety of polymeric wastes requires an investment in their disposal, which is a technically complex and expensive process. Therefore, the vast majority of this kind of waste is stored superficially, reaching 10–15% in the composition of solid waste at landfills. At the same time, the share of polymer waste in terms of occupied volume almost doubles, which at high temps of plastic consumption at present and in the future is not the limit. Considering the inertness of polymeric wastes to biodegradation and the continuous growth of their accumulation during relatively slow self-destruction, under the prevailing conditions one should expect them to be virtually uncontrollable over-toxic effects on the environment [31–33].
3. Recycling of polymeric wastes faces technological difficulties arising due to their thermodynamic incompatibility, obtaining a product with worse technological properties and requirements for sorting raw materials according to the homogeneity of the chemical composition. In addition, the need for the initial preparation and treatment of recycled waste almost doubles the cost of recycled compared to the feedstock.
4. Due to the fact that the manufacturer of the original polymer products does not participate in the recycling process and is not responsible for its further processing, the establishment of a recycling system requires a lot of organizational work and the establishment of unity of requirements for the objects of technical regulation. The criterion for the effectiveness of the actions taken will be the environmental effect obtained.
5. Existing technologies for the processing of polymeric wastes are rather complex and allow obtain-

ing various products, including non-polymeric substances, raw materials or scarce materials. However, the economic efficiency and environmental safety of most of the applied technologies must be confirmed by the results of pilot tests. As a rule, the production of a quality product from polymeric wastes is associated with high costs for its production. The prospect of increasing the share of recycling associated with the choice of an acceptable ratio of technological costs and the resulting product with given quality indicators.

6. Stimulating the development of plastic waste recycling in Ukraine will reduce the costs of environmental damage due to the withdrawal of non-renewable resources, which are the primary raw materials in the production of polymers. According to the estimates, the specific prevented environmental damage caused by recycling of polymeric wastes amounts to 17.55 tons of oil saved per ton of wastes.
7. The national strategy for dealing with polymeric wastes should be based on the principles of the responsibility of the producer for minimizing wastes, reducing the amount of their release into the environment by increasing the share of recycling and recycling. Continuing release into the environment of waste polymeric materials limits the ability of the national economy to transition from the principle of "take, make, waste" (get, use and throw away) to "reduce, reuse, recycle" (reduction, reuse, recycling), which is the baseline in cyclic economy, which is considered as the basis of sustainable development strategies.
8. Fulfillment of the objectives of the Polymeric Waste Management Strategy will require adaptation of national legislation to European directives, attraction of investments in the creation of infrastructural support for waste management, development of modern technologies for their processing with the aim of obtaining conditioned secondary raw materials, increasing the volume of collection and procurement, encouraging business entities to use waste-free and environmentally friendly technology.

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