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THE CIRCULAR PLASTICS ECONOMY AND THE INSTRUMENTS TO IMPLEMENT IT

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ABSTRACT: The purpose of this paper is the identification and analysis of the multidimensional consequences of implementing the concept of circular plastics economy in reality. The paper presents the concept of plastics and the history of development of the plastics industry. Selected negative environmental consequences of plastics consumption were indicated. This paper shows a rationale behind and key objectives of the Strategy for the plastics in a Circular Economy. It discusses the essence and scope of circular plastics economy. The proposed instruments for implementing the concept of circular plastics economy and the consequences of their application have been characterized in an integrated way. The paper attempts to answer the question whether and to what extent EU actions contribute to solving global environmental problems (oceans pollution, chemicals contaminations of waters and soils, destruction of ecosystems and landscapes). This paper is based on literature reviews and documents published by the European Commission.

KEY WORDS: circular economy, economic growth, single use products, plastics

Introduction

In 2018, the European Commission presented the concept of a circular plastics economy and initiated actions to reduce the use of plastics within the territory of the Community. The activities are to contribute to the development of circular economy and the reduction of environmental pollution by plastics. At the same time, they are completing the preference phase of the plastics industry, expressed both in preferential recycling rates and the unwritten principle of not raising the problem of differences and consequences of the use of particular materials. The implementation of new solutions will have significant economic consequences. The concept has a wide range of both supporters and opponents. There is strong opposition from plastics producers and businesses using plastic products. The aim of the paper is to identify and analyse the multidimensional consequences of the implementation of new solutions to the Polish legal and economic system.

Development and consequences of the use of plastics

Plastics are a group of several dozen materials created by synthetic polymers and modified natural polymers. The history of the emergence and development of the plastics industry is directly linked to the industrial revolution and technological progress. The first synthetic thermoplastic produced on an industrial scale was polyvinyl chloride (PVC). Vinyl chloride (monomer) was first obtained by H.V. Regnault in France in 1835, and polymerization was carried out in 1872 by E. Baumann. Pilot production installations were established in the 1930s in the USA and Germany. Mass production of plastics developed during World War II (Obłój-Muzaj et al., 1997).

Three plastics were invented in the 1930s. In 1930 DuPont produced polychloroprene, the first synthetic elastomer similar to industrially produced natural rubber. In 1898, H. Pechmann synthesized polyethylene. Industrial synthesis of polyethylene was developed by Imperial Chemical Industries Ltd. in 1933, and the process of repeated high-pressure synthesis introduced in 1935 made it possible to produce LDPE film. Low-pressure synthesis of polyethylene with the use of chromium oxide was invented in the 1950s (Trossarelli, Brunella, 2003). The introduction of the first synthetic fibre, nylon, by DuPont, was a significant milestone in the development of the plastics industry. The creation of this fibre is the result of research conducted by W. Carothers between 1930 and 1935. DuPont opened its first nylon factory in Seaford in 1939. Initially, nylon was used in the production of stock-

ings. During World War II, nylon was used to manufacture parachutes and tyres for B-29 aircrafts (DuPont).

In 1941, English chemists J.R. Whinfield and J.T. Dickson (Calico Printer's Association of Manchester) patented polyethylene terephthalate (PET) to initiate the development of polyesters. PET is used in the manufacture of precision instrument housings, bearings, drives, gearboxes, precision mechanics for the manufacture of small tolerance parts, plug housings, coil bodies, domestic appliances (reinforced with glass fibre), as well as kitchen utensils. In 1973, N. C. Wyeth patented the PET bottle, which is the primary packaging for liquid food in developed countries. Polyethylene terephthalate is also the basis for the production of polyester fibres such as polyester, dacron and terylene (Bellis, 2006).

Plastics are a highly differentiated group and as a result are classified according to many criteria, including: the origin of the primary ingredient (natural, synthetic), physicochemical properties, and use. The basic criterion of physicochemical properties allows the division of plastics into thermoplastics and thermosetting plastics. Within each category there are a dozen or so plastics (figure 1).

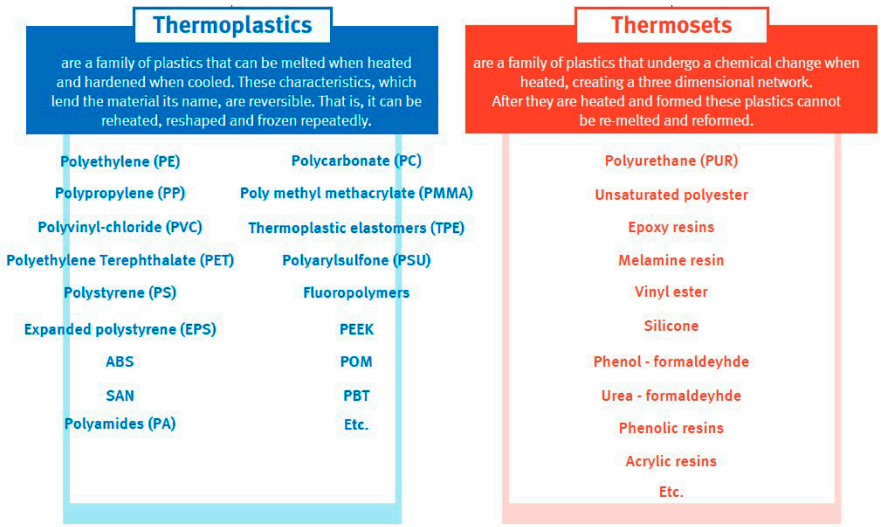

Figure 1. Categories of plastics

Source: Plastics – the Facts, 2018.

Plastics have found their application in all spheres of life. They are used in construction, medicine and cosmetics, electronics, automotive, energy, aviation industries, and many others. Combined with other materials, they cre-

ate particularly difficult to recycle multi-material plastics (combinations of different plastics, plastics with paper, aluminium, glass or rubber).

Notwithstanding numerous objective benefits (high functionality, low costs, low weight), the use of plastics has had negative health (conducted studies indicate that PET causes endocrine disruption and consequently its carcinogenic effect – see: L. Sax, Polyethylene Terephthalate May Yield Endocrine Disruptors in: Environmental Health Perspectives, http://ehp.niehs.nih.gov/0901253 [30-05-2019]), environmental and economic consequences (in sectors such as tourism, fisheries or shipping). The source of the negative environmental and economic consequences of using plastics include the following:

- generic change of the waste stream,
- creation of new categories of pollution.

The essence of the generic change of the waste stream is the appearance in the waste of substances not present in the natural environment, with a very long period of disintegration (even thousands of years depending on the conditions in which it takes place), during which numerous chemical substances are released into the environment, leading to secondary contamination. According to the available estimates, 8.3 billion tonnes of primary plastics have been produced worldwide since the 1950s, most of which have been deposited in landfills or released into the environment in an uncontrolled manner. In medium and highly developed countries, the share of plastics in municipal waste increased from less than 1% in 1960 to more than 10% in 2005 (Geyer, Jambeck, Law, 2017).

A generic change in the waste stream after World War II took place as a result of three processes:

- the development of disposable products,
- the use of materials other than natural materials in the manufacture of packaging,
- increasing use of packaging having marketing functions.

The category of single-use products comprises a wide variety of commonly used, rapidly disposable products that are discarded and become waste after a single use. These include packaging, disposable tableware, cosmetics, medical and hygiene products and disposable clothing. The widespread use of these products has made it possible to ensure the desired hygiene standards and reduce the number of various infections. At the same time, it caused a significant increase in the mass of waste generated.

Packaging waste is the dominant part of municipal waste. In highly developed countries, the share of packaging waste in the municipal waste stream is over 40%. In Poland in 2017, 11,969 million tonnes of municipal waste were generated, of which 5.7 million tonnes were packaging waste (47.62%).

The weight of plastic packaging introduced to the market amounted to 1.03 million tons, which constituted 8.6% of the total weight of municipal waste and 18% of the total weight of packaging waste. (Environment, 2018). Reducing the use of packaging is a prerequisite for addressing the problem of municipal waste. It is justified to create and disseminate solutions (by introducing legal regulations and conducting educational activities) for the sale of products without packaging in the case of which the consumer brings their own reusable containers to the store (an example of a store selling products without packaging is: Original-Unverpackt-Supermarkt, Wiener Straße 16, Berlin-Kreuzberg, also see: https://original-unverpackt.de/supermarkt/). A significant part of the mass of packaging placed on the market is not used to protect products, but is used in marketing functions. Such packaging is heavy and materially diverse, which makes it a difficult waste to recycle.

The pollution of the oceans and coasts should be mentioned among the types of pollution caused by the widespread use of plastics. It is estimated that every year a few percent of the world's plastics production reaches the oceans. The results available in this respect are characterised by significant differences. The comparative analysis of the available estimates clearly shows that the European Commission uses the estimates of the highest values biased and exaggerates the problem on a European scale in order to gain social acceptance for the introduced systemic changes. The estimate set by the European Commission in the *European Strategy for Plastics in a Circular Economy* estimates the weight of plastic waste reaching the oceans at 4.8 to 12.7 million tonnes per year, including 150,000 to 500,000 tonnes of EU waste (COM(2018)28 final; Jambeck et al., 2015). Alternative studies (Lebreton et al., 2017) estimate the mass of plastic waste flowing into the oceans by rivers at between 1.15 and 2.41 million tonnes per year. In addition, the authors of the study indicate that most of the 20 most polluted rivers, responsible for 67% of pollution, are located in Asian countries with rapid economic growth and poorly developed waste management systems.

Plastic waste shipped through ocean and sea currents forms "artificial islands" (figure 2). The largest of them is located between Hawaii and California. The Great Pacific Garbage Patch covers surface area of 1.6 million square kilometres and contains over 1,8 trillion pieces of plastic about weight 80.000–100.000 tones (Lebreton et al., 2018).

Ocean and sea pollution is classified according to the following criteria:

- the size of the waste: microplastics (0.05-0.5 cm), mesoplastics (0.5-5 cm), macroplastics (5-50 cm), megaplastics (anything above 50 cm),
- the type of plastic constituting the waste: type H (hard plastic, plastic sheet or film), type N (plastic lines, ropes and fishing nets), type P (preproduction plastics (cylinders, spheres or disks)), type F (fragments made of foamed materials) (Lebreton et al., 2018 and The Ocean Cleanup).

Figure 2. Areas of plastic accumulation in oceans
Source: The Ocean Cleanup.

Plastic microwaste constitutes a particular hazard. It is produced as a result of crushing larger waste and comes from microparticles added to products (e.g. cosmetics, detergents, paints), oxydegradable plastics, tyres, textiles or plastic granulates (COM(2018) 340 final). Such contaminants enter the bodies of marine animals and subsequently also to human bodies. As part of the work on the revision of the EU Directive on the quality of water intended for human consumption (*OJ L 330*), the introduction of mandatory monitoring of the presence of micro-plastics in drinking water is under consideration. The decision to establish the obligation is hampered by the lack of common methods of detecting pollution, as well as insufficient recognition of the different health consequences of human consumption of micro-plastics.

Plastics industry

The broadly treated plastics industry includes manufacturers of plastic raw materials, plastics processors, manufacturers of machines for plastics and their recycling and plastics recyclers. According to the data of PlasticsEurope AISBL, the world plastics production is estimated at 348 million tonnes (without PET, PA and polyacryl-fibers) in 2017. The biggest plastics producers are China – 29%, Europe – 18.5% and NAFTA countries – 17.5% of global production. In 2017, European producers produced 64.4 million tonnes of

plastics (without PET, PA and polyacryl-fibers). For comparison, in 2016 only 8.4 million tonnes of plastic waste were collected in order to be recycled inside and outside the EU, representing 2.48% of global and 18.5% of European plastics production. In Europe, the industry is made up of around 60,000 entities. The European plastics industry has an annual turnover of €350 billion and contributes €32.5 billion to Member States' budgets through public levies. The industry employs over 1.5 million people (Plastics – the Facts, 2018).

In 2017 in Poland, in the sector of rubber and plastic products production, 8,722 entities were conducting economic activity, including 2,361 entities employing more than 9 employees. The sector's production value amounted to PLN 94.2 billion and the added value to PLN 5.6 billion gross, which constituted 0.28% of the GDP. The sector employed 220 thousand people (Statistical Yearbook of Industry, 2018).

Instruments restricting the use of plastics

Responding to the risks posed by the widespread use of plastics and their uncontrolled release into the environment, the European Commission presented in January 2018 the *European Strategy for Plastics in a Circular Economy*, including the concept of building a circular plastics economy.

The Circular plastics economy is a development of the basic concept of circular economy defined in the Europe 2020 Strategy and the Closing the loop communication – An EU action plan for the circular economy (COM(2015) 614 final). The implemented measures and regulations are oriented towards products with a particularly negative impact on the natural environment (including water environment): single-use plastic products and fishing gears.

The theoretical foundations of the economy with a closed plastic cycle are endogenous theories of economic growth, assuming economic growth achieved through the created innovativeness. The concept provides for three directions of action:

- shaping a smart, innovative and sustainable plastics sector where design and manufacturing take full account of re-use, repair and recycling needs, boost growth and employment in Europe and contribute to reducing GHG emissions and the EU's dependence on imported fossil fuels,
- shaping the support of citizens, public authorities and industry for sustainable and safe consumption and production patterns of plastics,
- abandonment or reduction of the use of plastics where this is technologically possible and economically feasible (see details: COM(2018) 340 final, p. 6-7 and next).

The package of measures adopted by the European Commission for the implementation of the concept of a circular plastic economy:

- increasing the minimum required recycling rates for packaging waste,
- reducing the environmental impact of certain plastic products,
- introducing new categories of own revenues of the EU budget discouraging the use of plastic packaging and motivating the development of recycling of plastic packaging.

Following the amendment of the Packaging Directive (OJ L 283, EU L 150/141) the minimum recycling targets for all packaging waste have been increased (table 1). For plastics, the increase in the minimum required recycling rate is 27.5% by 2025 and 32.5% by 2030. Despite a significant increase, the required minimum recycling rates for plastics are lower than those set for other categories of packaging waste.

Table 1. Minimum recycling targets for packaging waste

Material contained in packaging waste	minimum recycling targets		
	applicable	no later than 31 December 2025	no later than 31 December 2030
plastics	22.5	50	55
wood	15	25	30
ferrous metals	50	70	80
aluminium	50	50	60
glass	60	70	75
paper and cardboard	60	75	85

Source: OJ L 365 and OJ L 150/141.

The second element of the package is measures to reduce the environmental impact of certain plastic products. A catalogue of actions is set out in the Directive on the reduction of the environmental impact of certain plastic products (he so-called Single Use Plastic Directive (SUP)), (OJ L155/1). The Directive aims to prevent and reduce marine waste from disposable plastic products and fishing gear containing plastics by complementing the measures foreseen in the Plastics Strategy, addressing identified gaps in existing actions and legislation and ensuring that the EU's systemic approach to the problem is further strengthened. Action to prevent the generation of pollution covered by the Directive and to eliminate pollution from the environment is intended to contribute to the creation of new jobs, as well as to improve technical and scientific skills and the competitiveness of the industry. Fourteen categories of disposable products are covered by the regula-

tions (table 2). Using the criterion of product impact on the marine environment, they were divided into three categories and the applied instruments were differentiated:

- products for which sustainable alternatives are available – EU action aims to promote less harmful alternatives,
- products for which there are no sustainable alternatives available – EU action aims to reduce damage by better informing consumers and making producers financially responsible for environmental impacts,
- products that are already well captured – EU action aims to ensure that they are introduced into an existing (or planned) separate collection and recycling scheme (COM(2018) 340 final).

Table 2. Single-use items covered by the SUP Directive

Cam	Restriction of use	Market restrictions	Product design requirement	Labelling requirements	Extended producer responsibility	Purpose of separate collection	Knowledge dissemination measures
Food containers	x				x		x
Beverage cups	x				x		x
Cosmetic swabs		x					
Cutlery, plates, stirrers, straws		x					
Balloon sticks		x					
Balloons				x	x		x
Packaging and wrappings					x		x
Beverage containers and lids thereof			x		x		x
Beverage bottles			x		x	x	x
Tobacco product filters					x		x
Hygienic articles: wet wipes					x		x
Hygienic articles: sanitary towels							x
Lightweight plastic shopping bags					x		x
Fishing gear					x		x

Source: COM(2018) 340 final.

Seven instruments will be used to achieve the objectives of the SUP Directive:

- instruments directly interfering with the market mechanism: restrictions on use, market restrictions,
- instruments indirectly interfering with the market mechanism: design requirements, labelling requirements, extended producer responsibility, separate collection targets, and dissemination of knowledge.

The SUP Directive contains the following special measures:

- the mandatory level of separate collection of beverage bottles required under Article 9 from 2025 – 77% and since 2029 – 90%,
- in accordance with Article 6, with regard to beverage bottles, each Member State shall ensure that from 2025 beverage bottles which are manufactured from polyethylene terephthalate as the major component will contain at least 25% recycled plastic and from 2030 at least 30% recycled plastic (OJ L155/1).

As a consequence of the above legal regulation, beverage bottles with a capacity of up to three litres (including their caps and lids) made of PET and other plastics have obtained the status of a separate packaging category. In order to achieve that objective, Member States may establish deposit-refund schemes or separate collection targets for relevant extended producer responsibility schemes. The regulations relating to beverage bottles are to be seen as an attempt by the EC to offset the low recycling rates of plastic packaging waste.

Beverage containers with a capacity of up to three litres, glass or metal beverage containers, beverage containers intended and used for food for special medical purposes that have caps and lids made of plastic may be placed on the market only if the caps and lids remain attached to the containers during the products' intended use stage.

The third element of the package of measures to make the concept of a circular plastics economy a reality is the proposal to introduce new own resources of the EU budget since 1 January 2021, including:

- 20% share of revenues from the Emissions Trading Scheme,
- a collection rate of 3% applied to the new Common Consolidated Corporate Tax Base (CCCTB),
- own resources based on plastic packaging waste (COM(2018) 325 final).

Own resources based on plastic packaging waste will be a national contribution to the EU budget, calculated on the basis of the amount of plastic packaging waste not subjected to recycling. It is proposed to set a collection rate of €0.80 per kg of packaging waste. The actual collection rate may not exceed EUR 1,00 per kilogram.

This instrument will contribute to improving the cost-effectiveness of plastics recycling, reducing the plastic waste stream, enhancing the sustainability of plastics and stimulating innovation, competitiveness, and job cre-

ation. It is used to implement the concept of extended producer responsibility in the real world. In order to minimise the payment, it is expected that Member States will set the required recycling rates for packaging waste above the minimum levels required under Community law and that businesses will take action to maximise the recycled weight of waste.

The EU budget's own resource revenue based on non-recycled plastic packaging waste is projected to be between 2021 and 2027 with an average annual budget of €7 billion, representing 4% of the total EU budget. Member States will be entitled to 10% of the amount of revenue they receive to cover their collection costs (COM(2018) 325 final).

Consequences of the implementation of the concept of a circular plastics economy for Poland

The implementation of circular plastics economy will result in multidimensional positive and negative economic, social, environmental, and political impacts.

The application by the European Commission of restrictions on use and market restrictions constitutes a significant interference in the market mechanism and a departure from the free market economy. It should be expected that both in Poland and the rest of the Community it will result in the cessation of economic activity by a significant group of entrepreneurs manufacturing disposable plastic products. The continuation of economic activity by the indicated entities will be conditioned by the implementation of the technology of production of single-use products from materials other than plastics, which, due to their limited availability and necessary investment outlays, may be highly difficult.

Measures to reduce the use of plastics will have a direct impact on the functioning of the waste industry. The demand response for packaging waste recycling services will be determined by the interaction of the following factors: increasing recycling levels, the requirement to use recyclates for the production of new products, limiting the use of plastic packaging, and the amount of product fees. The relationships between variables are currently difficult to predict and require additional research.

The highly likely reduction in the use of plastic packaging will lead to significant problems in the functioning of plastics recyclers and a decrease in the efficiency of selective collection of plastics. The loss of competitiveness of plastics recyclers will be offset by the increase in demand for recyclers of other packaging materials. A widespread change in the packaging used in the initial period may cause difficulties in meeting the recycling obligation result-

ing from limited processing capacity and inappropriate separate collection systems. One should expect strong pressure exerted by entrepreneurs on communes to develop selective waste collection systems ensuring the availability of waste for recycling as well as high quality of secondary raw material.

Achieving the targets for selective collection of beverage bottles set out in the SUP Directive requires the introduction of new solutions to the waste collection system, including deposit systems. The estimates commissioned by the General Directorate for Environmental Protection indicate the cost of introducing a deposit system in Poland, covering beverage bottles, aluminium cans, glass bottles, multi-material packaging within the next 5 years at PLN 19-24 billion (the cost of collecting and transporting post-consumption waste) (Patorska, Paca, 2017).

Assuming that plastic packaging waste recycling is implemented at a minimum level resulting from directives and a constant 2% increase in the weight of packaging introduced to the market until 2030, the estimated Polish payment to the EU budget in 2021 will amount to PLN 2.98 billion (EUR 678 million) and by 2024 will increase to PLN 3.17 billion (EUR 720 million). As a result of the increase in the minimum level of recycling, the payment will be reduced from 2025 to PLN 2.11 billion (EUR 480 million) and from 2030 to PLN 2.10 billion (EUR 477 million). The projections do not take into account the abandonment of plastic packaging and the implementation by businesses of the recycling obligation both below and above the required minimum target level resulting from the Directive (figure 3).

The own resource contribution to the EU budget based on plastic packaging waste can be financed by the state budget or – what should be expected – transferred to producers of packaged products. The shifting of the burden to the introducing manufacturers requires modification of the algorithm for calculating the product charge in relation to plastic packaging. A new product fee will be charged for the weight of plastic packaging, which constitutes the difference between the weight of packaging placed on the market and the weight of recycled packaging. In situations where the producer does not reach the required minimum level of recycling, it seems justified to apply an additional penalty in the form of a surcharge added to the mass of packaging, for which the obligation has not been fulfilled. The product fee rate for plastic packaging should also be increased from PLN 2.70 per kilogram to not less than PLN 3.52 per kilogram (Piontek, Pokrywka, 2019).

In the technological dimension, it is possible to anticipate the manufacturers' resignation from plastic packaging in situations where their application is not necessary due to product parameters, and at the same time there

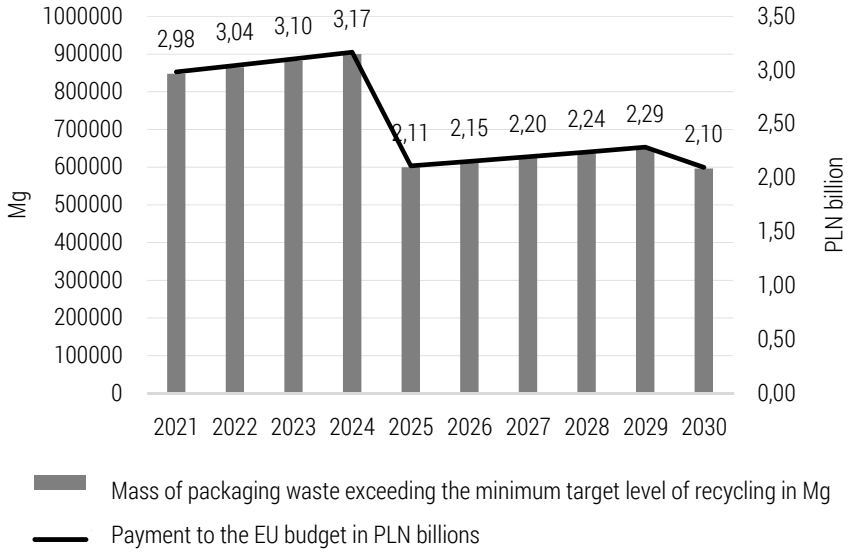

Figure 3. Projections of the Polish contribution to the EU budget from own resources based on plastic packaging waste for 2021-2030

Source: author's own work.

is a possibility of substitution with other plastic packaging. Increased recycling rates will contribute to the development of new packaging waste recycling technologies, allowing for recycling of secondary raw material with worse parameters.

Reducing plastic consumption will result in a significant reduction in the calorific value of municipal waste (calorific value of plastics ranges from 13.69 MJ/kg for PVC to 42 MJ/kg for polyethylene (Wasilewski, Siudyga, 2013)), which will have an impact on the efficiency and legitimacy of operation of thermal waste treatment installations. The recovery process is carried out only under autothermal conditions, and thermal processing of waste with insufficient calorific value requires the use of fossil fuels.

The expected political effect will be the unwillingness of the public (as shown by the practice supported by the media) to act in the future by government teams implementing EU regulations. Poles are in the vast majority in favour of membership in the European Union and, at the same time, are opposed to the costs necessary to be borne in connection with the implementation of Community environmental policy.

Conclusions

The measures taken by the European Commission to build a circular economy for plastics should be considered highly desirable and making a real contribution to solving the problem of waste in its current form. The aforementioned actions are one of the few undertaken by the EU that are directly aimed at shaping sustainable consumption. Sustainable plastics consumption in the EU will contribute in a limited extent to addressing the global problem of oceans pollution.

The analyses carried out allowed to identify opportunities and threats related to the implementation of the concept of circular plastics economy in Poland. These include:

- opportunities:
  - reduction of consumption of non-renewable raw materials (crude oil),
  - preserving the value of the raw material in use,
  - reduction of the environmental pressure of consumption processes resulting from depositing plastic waste into the environment (oceans pollution, chemicals contaminations of waters and soils, destruction of ecosystems and landscapes),
  - development of separate collection of waste and increase in recycling rates,
  - developing the processing capacity of non-plastic waste,
  - shaping positive attitudes of citizens towards the management of waste generated,
- threats:
  - significant interference of the state in the market mechanism,
  - change in the structure of the market for regulated products and the efficiency of entities operating on this market,
  - high costs of implementation and functioning of new solutions burdening the public sector, entrepreneurs and citizens,
  - new fiscal instruments,
  - social opposition to new regulations,
  - different treatment of entrepreneurs introducing disposable products made of different plastics with the potential to undermine the principles of competitiveness and equal treatment of entities,
  - necessity to adjust the processing potential of waste to new market conditions.

The implementation of EU legislation requires changes to the existing legislation as well as introducing completely new solutions. Regulations creating extended producer responsibility systems should occupy a special place among the new solutions. The achievement of the objectives set out in the concept of a circular plastics economy is conditioned by the fact that

Member States' governments do not give in to the law-making process, lobbying of plastic producers as well as those introducing products in plastic packaging.

Examples of lobbying organisations acting in support of industry include The New Plastics Economy Global Commitment (The New Plastics Economy Global Commitment, https://www.newplasticseconomy.org/projects/global-commitment [24-07-2019] and PlasticsEurope, https://www.plasticseurope.org [24-07-2019]). One of the forms of lobbying conducted by the indicated entities is dissemination of opinions indicating positive aspects of using plastic products and contesting the activities of the European Commission, as well as other entities for their reduction. Particular emphasis is placed on plastics' role in climate protection. It should be noted that the studies on the consequences of the use of plastics presented by lobbying organisations are not cost-benefit analyses. They are not used to verify, but to prove the hypotheses adopted. This is confirmed, among others, by the statement of the authors of the analysis disseminated by PlasticsEurope: *the study is not a full Life Cycle Assessment (LCA) by strict definition of ISO 14040 and 14044; however the principles of the standard have been followed and the data for comparison within the case studies are extracted from public LCA databases* (Plastics' contribution, p. 5) This detail is noticed only by observant readers.

It should be noted that disposable plastic products were widely promoted on the Polish market by international corporations in the 1990s and after the year 2000. Their use and consumption was presented as an expression of innovation and modernity. Despite the negative experiences of highly developed countries, these activities did not meet with the opposition of state authorities responsible for environmental protection and sustainable development.

Literature

Bellis M. (2006), *The History of Polyester*, http://inventors.about.com [30-05-2019]

Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions, *A European Strategy for Plastics in a Circular Economy*, COM(2018)28 final

Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions, *Closing the loop – An EU action plan for the Circular Economy*, COM(2015) 614 final

Council Directive 98/83/EC of 3 November 1998 on the quality of water intended for human consumption, OJ L 330

Directive (EU) 2018/853 of the European Parliament and of the Council of 30 May 2018 amending Directive 94/62/EC on packaging and packaging waste, OJ L 150/141

Directive (EU) 2019/904 of the European Parliament and of the Council of 5 June 2019 on the reduction of the impact of certain plastic products on the environment, OJ L155/1

DuPont, *Our history*, http://www2.dupont.com/Phoenix_Heritage/en_US/1939_c_detail.html [29-05-2019]

Environment 2018 (2018), GUS, Warsaw

European Parliament and Council Directive 94/62/EC of 20 December 1994 on packaging and packaging waste**,** OJ L 365

Geyer R. et al. (2017), *Production, use, and fate of all plastics ever made*, "Science Advances" Vol. 3, No. 7, e1700782, DOI: 10.1126/sciadv.1700782 [30-05-2019]

Jambeck J.R. et al. (2015), *Plastic waste inputs from land into the ocean*, "Science" Vol. 347 Issue 6223, p. 768-771

Lebreton L. et al. (2017), *River plastic emissions to the world's oceans*, "Nature Communications" No. 15611, http://doi.org/10.1038/ncomms15611

Lebreton L. et al. (2018), *Evidence that the Great Pacific Garbage Patch is rapidly accumulating plastic*, "Scientific Reports" No. 4666, https://doi.org/10.1038/s41598-018-22939-w

Obłój-Muzaj M. et al. (1997), *Polichlorek winylu*, Wyd. Naukowo-Techniczne, Warszawa

Patorska J., Paca D. (2017), *Analiza możliwości wprowadzenia systemu kaucyjnego opakowań*, Deloitte, opracowanie na zlecenie GDOŚ, Warszawa

Piontek W., Pokrywka T. (2019), *Systemowa rewolucja*, in: *Energia i recykling. Gospodarka obiegu zamkniętego*, No. 5(17)

Plastics – the Facts (2018), *An analysis of European plastics production, demand and waste data*, PlasticsEurope AISBL, www.plasticseurope.org [29-05-2019]

Plastics' contribution to climate protection, PlasticsEurope AISBL, www.plasticseurope.org [29-05-2019]

Proposal for a Council Decision on the system of Own Resources of the European Union, COM(2018) 325 final/ 2018/0135 (CNS)

Proposal for a Directive of the European Parliament and of the Council on the reduction of the impact of certain plastic products on the environment, COM(2018) 340 final/ 2018/0172 (COD)

Sax L. (2009), *Polyethylene Terephthalate May Yield Endocrine Disruptors*, Environmental Health Perspectives, http://ehp.niehs.nih.gov/0901253 [30-05-2019]

Statistical Yearbook of Industry – Poland (2018), GUS, Warsaw

The Ocean Cleanup, https://theoceancleanup.com/great-pacific-garbage-patch/ [30-05-2019]

Trossarelli L., Brunella V. (2003), *Polyethylene: discovery and growth*, Dipartimento di Chimica IFM dell'Università di Torino Via Pietro Giuria 7, 10125 Torino (Italy), https://www.researchgate.net/publication/228813221 [30-05-2019]

Wasilewski R., Siudyga T. (2013), *Odzysk energetyczny odpadowych tworzyw sztucznych*, "CHEMIK" No. 67(5), p. 435-445