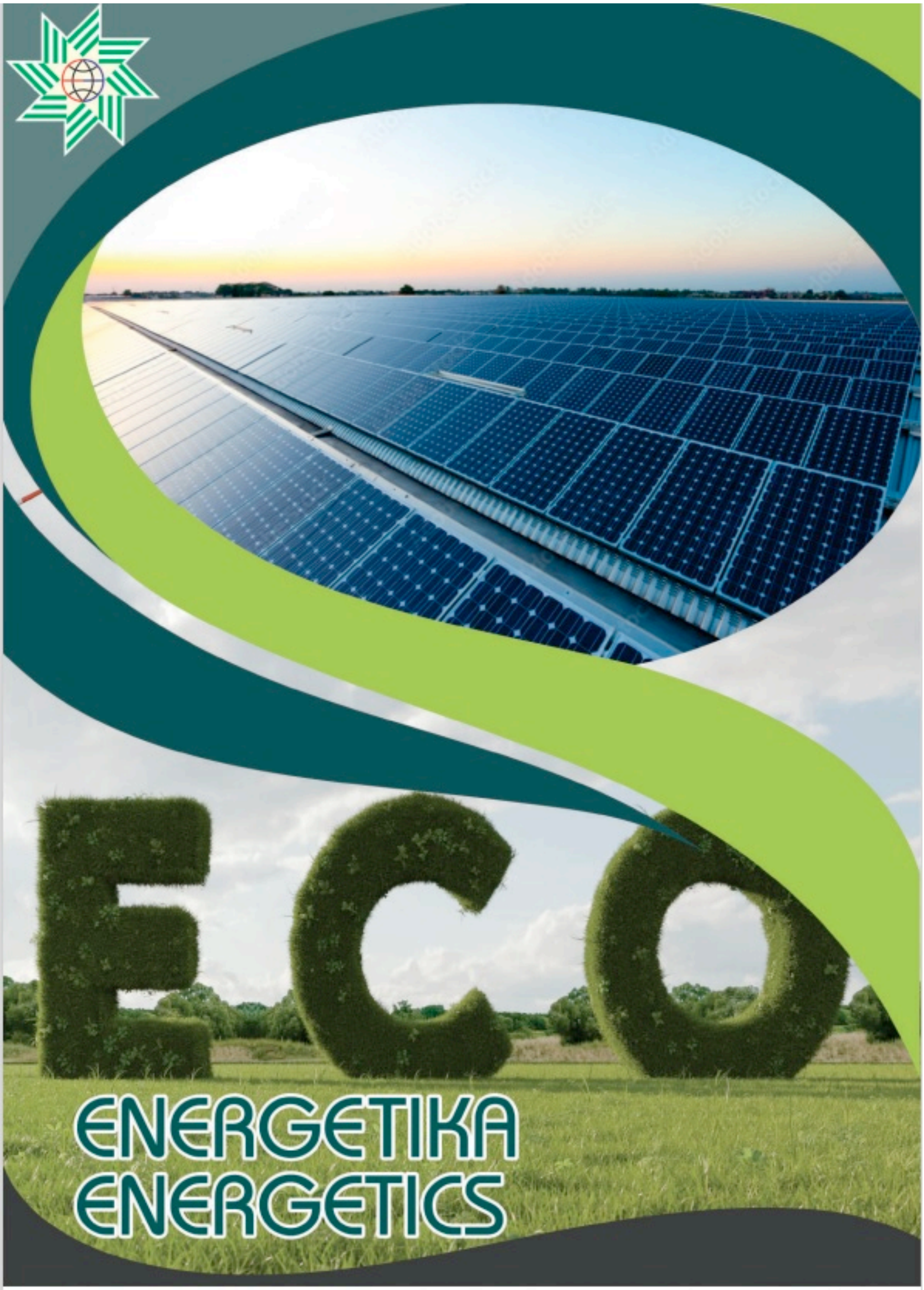
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Tel.: 99412 538-23-70,
99412 538-40-25 Fax: 99412 538-51-22

E-mail: info@ieeacademy.org
ekoenergetics@gmail.com
Internet: http://ieeacademy.org
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The role of recycling in reducing plastic Waste and its effects on the ecosystem

A.A.Khalilova, G.I.Guliyeva
Azerbaijan University of Architecture and Construction, Baku, Azerbaijan,
xelilova.afet@mail.ru , guliyevagunes361@gmail.com

Abstract: Plastic waste is one of the problems that have the greatest impact on the environment in modern times. Their long decomposition time leads to the damage of soil and water ecosystems, the spread of microplastics and the loss of biodiversity. Recycling is a sustainable approach to reduce the amount of plastic waste, minimize its negative impact on the environment and conserve raw materials. This article examines existing technologies for plastics recycling, evaluates their application areas and potential benefits. Also, the importance of recycling for biodiversity and human health is widely discussed.

Keywords: Plastic waste management, Recycling technologies, Environmental sustainability Impact of microplastics, Biodiversity protection, Chemical recycling, Mechanical recycling.

1.INTRODUCTİON

Plastic is a synthetic, organic polymer made from fossil fuels such as gas and oil. According to the United Nations Environment Program, more than 460 million metric tons of plastic are produced every year. Plastic is used in almost all consumer and industrial activities, from construction and vehicles to electronics and agriculture. Improperly disposed plastic waste pollutes and harms the environment, becoming a widespread driver of biodiversity loss and ecosystem degradation. It threatens human health, affects food and water security, burdens economic activities and contributes to climate change. Macro-plastics (particles larger than 0.5 mm) accounted for 88% of global plastic leakage into the environment in 2019, amounting to approximately 20 million metric tons, and contaminating entire ecosystems. Most of the world's plastic pollution comes from single-use products such as bottles, caps, cigarettes, shopping bags, cups and straws. The sources of pollution are mainly from land, urban and rainwater runoff, dumping, industrial activities, tire wear, construction and agriculture. Plastic pollution in the marine environment is primarily caused by runoff from land, but can also include paint spills from shipping, discarded fishing gear, etc. includes [1, 2, 5].

2. EXPERİMENTAL DETAİL

Due to solar radiation, wind, currents and other natural factors, plastic breaks down into microplastic (smaller than 5 mm) and nanoplastic (smaller than 100 nm) particles. 'Primary' microplastic particles are also shed as a result of wear and tear by products such as synthetic textiles and tyres. Nanoplastics can enter living organisms by crossing cell membrane walls. Many countries lack the capacity and capacity to properly manage plastics and waste, and the burden often falls on the local level. This impact is disproportionately felt by islands, developing countries, indigenous peoples, local communities, women and children. This problem is exacerbated by the global trade in plastic products and waste, where infrastructure is insufficient for safe and environmentally sound management [3,4].

The plastic revolution that began in the 1950s led to a cumulative production of 8,300 million tons (MT) of plastic products and a huge amount of plastic pollution (6,300 MT). According to a Pew Trust report (p. 25), about 59% of plastic waste generated in 2016 was "managed" (that is, recycled, incinerated, or placed in designated areas that are reasonably well managed). The remaining plastic waste can be observed scattered all over the world. Some plastic (about 3-5% per year) seeps into the world's oceans, where it is ubiquitous and now a global environmental focus. Plastic waste permeates every marine habitat and is widely consumed by marine animals. Marine mammals and turtles entangled in plastic debris, mostly discarded or lost fishing gear, have produced remarkable images of the dangers of plastic pollution. Meanwhile, the impact of plastic waste on human health is still debated, but it is clear that humans are consuming microplastics through seafood. Even more worryingly, projections show that new plastic production (and consequently waste) will double by 2040 if no action is taken [3,5,4].

Principles of Biofermentative Recycling Technology

Bioenzymatic recycling allows plastics to be reused in a more environmentally sustainable and energy-efficient manner by breaking them down with the help of microorganisms and the enzymes they produce. One of the microorganisms most commonly used in the degradation of plastics is the bacterium Ideonella sakaiensis. This bacterium is particularly sensitive to polyethylene terephthalate (PET) plastic. Through the enzyme PETase, the bacterium I. sakaiensis splits the PET polymer into terephthalic acid and ethylene glycol, which accelerates the recycling process. Since these biological processes operate at much lower temperatures and pressures than traditional chemical methods, energy consumption is also low [5, 6].

Advantages of Biofermentative Recycling

- **Low power consumption**: Biofermentative processes do not require high temperatures and pressures, which reduces energy consumption.
- **Environmental safety**: Unlike chemical recycling, this method does not create harmful by-products or toxic waste.
- **Fast and efficient process**: Biofermentative methods require less time due to the ability of microorganisms to break down plastics quickly and efficiently.
- **Multiple areas of application**: This approach can be used to recycle different types of plastics, especially PET.

Materials and Reagents

The plastic samples used in the study were mainly obtained from industrial waste and commercial products. PET plastic is mainly derived from water bottles and other disposable containers, while PP and PS plastic is derived from food packaging and other industrial products. Ideonella sakaiensis, Pseudomonas putida, and Bacillus subtilis bacteria were selected as microorganisms. These bacteria have been shown to be effective in biodegrading plastics in previous studies. Chemicals used in research include phosphate-buffered buffers, nitrogen and carbon sources, and solid media such as agar-agar [7, 8].

Implementation of the Biofermentative Degradation Process

The biofermentative recycling process is based on the interaction of microorganisms with plastic waste. Plastic samples were first cleaned and then added to special laboratory media to create conditions for the growth of microorganisms. In the first phase of the study, plastic samples were sterilized and inoculated in a special fermentation medium. These environments are enriched with the nutrients and energy sources necessary for microorganisms to efficiently break down plastics [9].

Decomposition Conditions and Experimental Conditions

Experiments to monitor the bioenzymatic degradation of plastics were carried out at 30°C, stirring at 150 rpm. All experiments were carried out in periods of 30, 60, 90 and 120 days. At the end of each cycle, plastic samples were collected and analyzed by measuring dry weight. As plastics biodegrade, the weight of the material decreases, indicating that the plastic is broken down by microorganisms. In addition, the physical and chemical properties of the plastic material, including molecular weight, were analyzed by infrared spectroscopy (FTIR) and scanning electron microscopy (SEM).

Assessment of Biodegradation

Several methods have been used to estimate the degree of fragmentation. First, the mass loss (biolife or rate of weight loss) of the plastics was measured. In addition, the analysis of the main chemical products resulting from the decomposition of plastics by microorganisms was also carried out. FTIR spectroscopy was used to monitor the change of functional groups in the degradable plastic. SEM was used to visually evaluate the structural changes of the plastic surface. The activity of microorganisms and the effect of enzymes also play an important role in the process of biological degradation of plastics, and these changes have been analyzed accordingly [1,4,10].

Environmental Impact Assessment

A life cycle assessment (LCA) was applied to assess the environmental impacts of the study. LCA is an all-stage methodology for assessing the impact of bioenzymatic recycling on ecosystems. This allows to evaluate the environmental, social and economic aspects of the process. Within the LCA method, the amount of energy used, water consumption, carbon footprints and other environmental indicators were measured.

Statistical Analysis and Analysis of Results

All results obtained in the study were analyzed statistically. t-test and ANOVA (Analysis of Variance) methods were used to determine how the decomposition rate changes over time. As a result of these analyses, relevant statistical data were obtained regarding the efficiency of bioenzymatic recycling and the rate of decomposition of plastic waste.

Ensuring the Validity of Results

To ensure the reliability of the study, all the experiments were repeated three times and the discrepancy between the results was evaluated accordingly. (Figure 2) Controlled conditions and procedures for each of the experiments were exactly replicated. Also, the microorganisms and types of plastic used have previously given reliable results [4, 5].

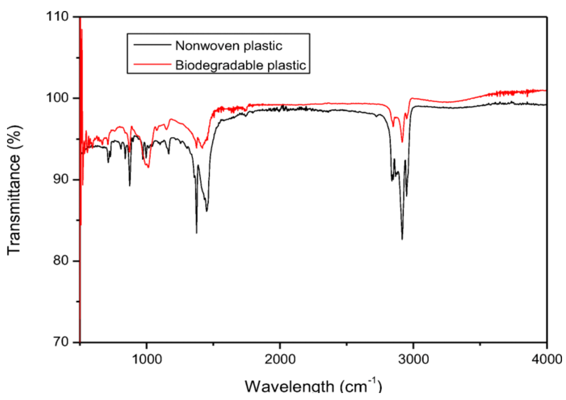

Fig.2. Graphic representation of the investigation of plastic balls in infrared spectroscopy

3. CONSOLUSION

Plastic waste has become one of the most serious environmental problems of the modern era. The recycling of plastic materials and the management of these wastes are of vital importance in terms of environmental protection. Biofermentative recycling technology is particularly noteworthy as an approach that ensures the recycling of plastic waste in an environmentally safe manner. The main advantages of this technology include low energy consumption, no harmful by-products, and fast and efficient process.

*Ideonella sakaiensis*and other microorganisms' ability to degrade plastics offers a promising prospect for biological management of plastic waste. Also, the application of this technology can help reduce plastic pollution in the ecosystem by enabling the recycling of plastics on a larger scale. Research shows that bioenzymatic degradation of plastics not only reduces waste, but also conserves natural resources and reduces carbon footprints.

In addition, when the environmental effects of bioenzymatic recycling are examined with the life cycle assessment (LCA) methodology, it is seen that this method significantly reduces negative impacts on the ecosystem. The large-scale application of bioenzymatic degradation of plastics can provide sustainable solutions, both environmentally and economically.

The issue of plastic waste management is not only related to technological development, but also related to social and economic aspects. The contribution of each individual, company and state to this issue is very important. Plastic waste recycling should, of course, be expanded worldwide and supported by appropriate legislation, education and infrastructure development in this area.

Finally, the development of recycling processes will shape the future of plastic waste management, and biofermentative technologies will be an important step towards a more sustainable future. Reducing plastic pollution in the ecosystem and expanding bioenzymatic recycling will help restore the ecological balance and solve global environmental problems.

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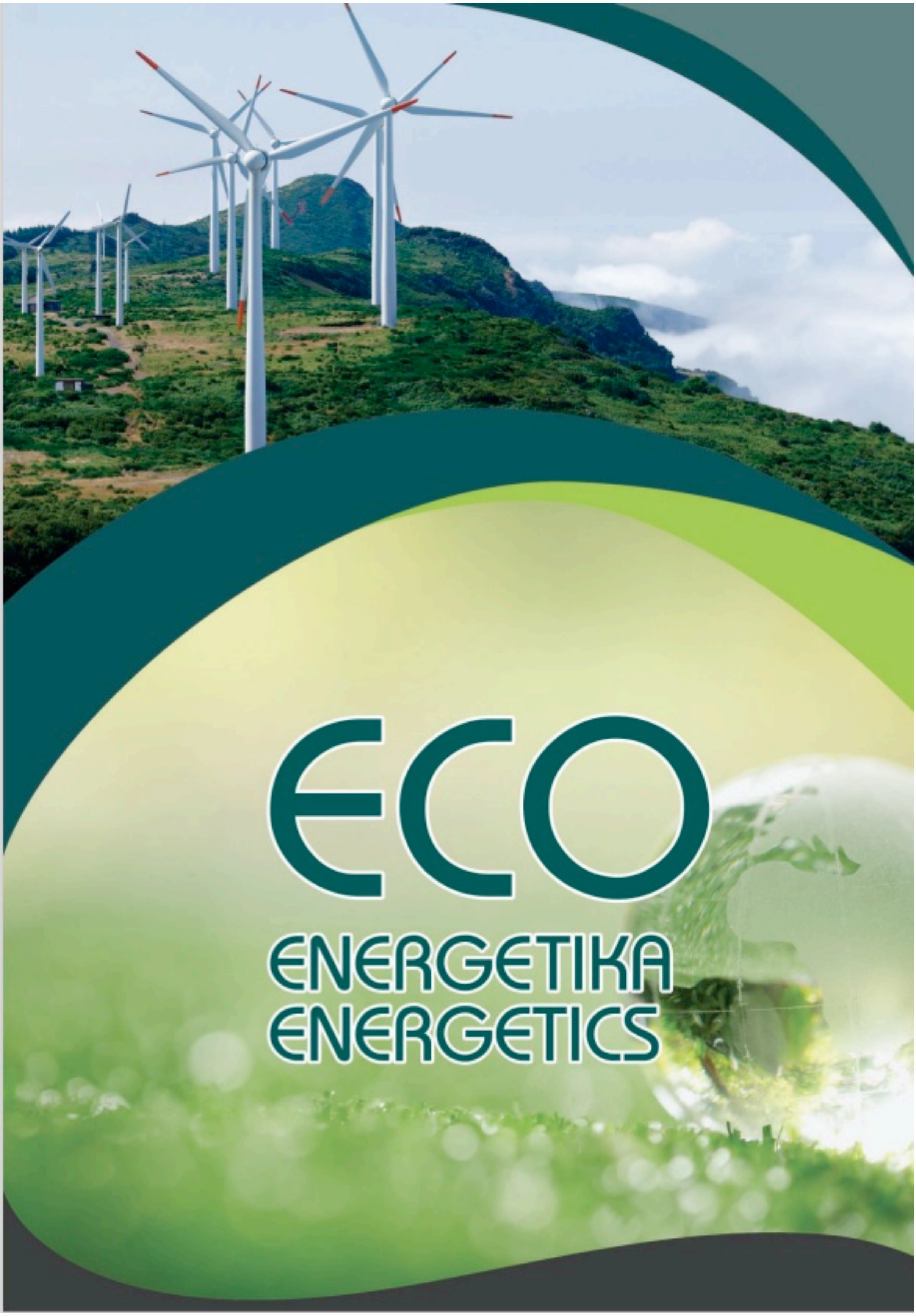
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