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Microbiological degradation of plastics

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Abstract: Plastics are long chain synthetic polymers produced based on fossil fuels such as oil and natural gas. Due to their properties, like lightness, durability, strength, flexibility, and low production costs, they have become indispensable in everyday life. Every year, the amount of polymers produced increases, in 2020 only in Europe 49.1 million tonnes of polymers were produced. With the increasing production of plastics and their widespread use, a global problem with the accumulation of waste in the natural environment has arisen. In Europe, synthetic waste is mostly incinerated (42.6%) and recycled (34.6%). In the natural environment, plastics can be degraded both by abiotic processes and by biodegradation (Fig.5.). The susceptibility to degradation of polymers depends on their physicochemical properties, the length of the polymer chain, and their composition. Long-chain polymers containing only carbon, such as polyethylene and polypropylene, are more resistant to degradation, while in the case of polyurethane and polyethylene terephthalate, the presence of heteroatoms in the chain, e.g. oxygen, causes greater susceptibility to biodegradation. The appearance of polymer waste in the natural environment caused many microorganisms to develop the ability to use plastics as a source of carbon and energy. The evolution of the metabolic systems of cells, which allows obtaining nutrients from polymers, somehow adapts microbes to live in the era of synthetic materials. Microorganisms equipped with the ability to degrade plastic have been characterized in many scientific studies (Tab. 2).

The biodegradation of plastics is a complex process that depends on several factors: substrate availability, surface characteristics, morphology, and molecular weight. The first stage of biodegradation is the deposition of microorganisms on the surface of the

polymer, which is largely influenced by the hydrophobicity / hydrophilicity of the material. Microorganisms then produce specific extracellular enzymes that break down the main polymer chain into smaller fragments - dimers and monomers. Then the polymer molecules are transported inside the cell and the final products of polymer decomposition are water, CO_2, and biomass.

Plastics are characterized by high durability and resistance to biodegradation, therefore pre-aging or pre-treatment of synthetic materials is often necessary. The purpose of these treatments is to modify the surface, which increases susceptibility to the action of enzymes secreted by microorganisms. The most commonly used pre-treatment techniques are UV, gamma, high temperature, and nitric acid treatment. These techniques either reduce hydrophobicity or introduce more biodegradable groups on the surface of the polymer.

Describing the process of biodegradation of plastics is a technical challenge because it is a long-term process and difficult to study. The most commonly used methods of assessing the biodegradation of a polymer are the examination of the amount of mass lost by polymers, the examination of hydrophobicity and surface changes by imaging techniques such as SEM, and the chemical composition of polymers using Fourier transform infrared spectroscopy.

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