

BIOLOGICAL DAMAGE OF SYNTHETIC POLYMER MATERIALS AND WAYS OF
PROTECTION AGAINST THEM

Adizova Nargiza Zamirovna

Associate Professor, Bukhara Institute of Engineering and Technology, Uzbekistan

Abstract: The article discusses the problems of biological damage and protection of synthetic polymer materials. The possibility of biodegradation of the main components of plastics is studied and substantiated. Methods of stabilizing polymers from biological damage processes are studied and the necessary proposals are made.

Keywords: biological damage, damage, plasticizer, synthetic polymers, damage, stabilization, components of polymer materials.

Synthetic polymeric materials are widely used in almost all areas of science and technology, in industry, construction, agriculture, etc. In addition to polymers, plastics contain fillers, plasticizers, dyes, stabilizers and other additives. In previous works, general issues of biological damage to various non-food products and their protection were considered.

Synthetic polymers are more resistant to damage by microorganisms than natural high-molecular compounds. The polymer chain of the macromolecule of synthetic high-molecular compounds is more resistant to direct absorption by bacteria or fungi. However, in some cases they are also damaged by microorganisms.

Polymers can also be damaged by insects and rodents. Biological damage to plastics by insects and rodents is manifested in direct mechanical damage to individual parts, protective coatings and packaging materials.

Damage to plastic packaging and subsequent settlement and reproduction of insects and rodents can occur in parts of devices and mechanisms that are difficult for humans to access, but can serve as a safe ecological niche for animals. The accumulation of animals and their metabolites in critical areas of electrical installations has repeatedly caused short circuits and other malfunctions.

Most often, damage is caused by fungi of the genera *Penicillium*, *Aspergillus*, *Chaetomium*, *Fusarium*, *Alternaria*, *Trichoderma*, *Rhizopus*, etc.

Mold fungi cause chemical (metabolites) and mechanical (contamination, growth of mycelial hyphae in the thickness of the material) damage to materials. The main chemical products of fungal metabolism, which damage synthetic polymeric materials by chemical damage (hydrolysis, oxidation, etc.) of polymer macromolecules or low molecular weight components (fillers, plasticizers, etc.), are extracellular enzymes and organic acids.

Microorganisms and metabolites, in addition to purely chemical degradation (damage) of polymeric materials, can also cause changes in their physicochemical and electrophysical properties as a result of swelling and cracking. The result of damage (deterioration) of the decorative and other external qualities of polymeric materials due to corrosion, fading and other external influences is the appearance of mold spots, which can lead to some degree of preservation of the functionality of the product.

The development of mold on the surface of the polymer contributes to the condensation of atmospheric water vapor, the accumulation of moisture, and this condition itself can have an undesirable effect on the change in the properties of the polymer material. As a result of the chemical interaction of the metabolic products of microorganisms with the auxiliary components of the polymer or synthetic material, some of the physicochemical properties of the material can change. Materials that are not resistant to fungi can have reduced strength, flexibility, dielectric properties, deteriorate electrical insulation properties, change the color of painted surfaces, etc.

Bacteria can cause less damage to plastics, but their impact can be very significant. In some cases, their presence is difficult to notice with the naked eye. Damage can also be assessed by the appearance of foreign odor, color, mucus, etc.

Bacteria of various genera and species (*Pseudomonas*, *Bacillus*, etc.) participate in the biodegradation of plastics.

Bacteria adapt to synthetic polymers and break down high-molecular compounds of different chemical composition into low-molecular fractions using various enzymes and metabolic products.

Biological degradation of plastics, like other materials, usually occurs simultaneously with their aging under the influence of external physical and chemical environmental factors (ultraviolet radiation, humidity, temperature changes, etc.). Both processes - biological damage and aging - complement and enhance each other.

Damage to plastics depends not only on the type and genus of microorganisms that act on them. The degree of damage to plastics is affected by the chemical structure of the polymer, its physical structure, molecular weight, molecular weight distribution of fractions, the presence and composition of plasticizers, fillers, stabilizers and other additives.

There is a certain relationship between the degree of biodegradability of a polymer and its chemical structure. Biological stability depends on the chemical nature of the polymer, its molecular weight and molecular structure.

The types of bonds that are inaccessible or difficult to access for microorganisms are $R-CH_3$; unsaturated valencies of the type $R-CH_2-R'$; $R=CH_2$; $R=CH-CH_3$, as well as the most sensitive to hydrolysis bonds in polymers such as acetal, amide, ether and carbonyl or carboxyl, are bond forms that are readily available for damage by microorganisms.

An important factor determining the resistance of a polymer to biodegradation is the size of its macromolecule. While monomers or oligomers can be easily damaged by microorganisms, polymers with high molecular weight are not easily attacked by microorganisms.

An equally important factor affecting biodegradation is the supramolecular structure of synthetic polymers. The compact arrangement of the structural units of crystalline polymers limits their swelling in water and at the same time prevents the penetration of enzymes into their structure. This limits the action of enzymes not only on the main carbon target of the polymer, but also on the biodegradable parts of the macromolecular chain.

The presence of defects in the macro and microstructure and molecular heterogeneity contribute to the biodegradation process.

The basis of plastics is polymer binders, which are polymer resins. According to the type of polymer resin, plastics are divided into thermosetting or thermoplastic (depending on the method of hardening the material during its production), as well as polyethylene, polyvinyl chloride, polyamide, etc. (depending on the chemical structure of the polymer).

A distinction is made between carbon-chain polymers, in which the main chain of the macromolecule is built only from carbon atoms (polyethylene, polypropylene, polyvinyl chloride, etc.), and heterochain polymers, in the main chain of which there are atoms of carbon, oxygen, nitrogen (polyamides, polyurethanes), etc.

Polymer resins have different biostability depending on the chemical structure of the macromolecule, the length of the polymer chain, the presence of side branches, etc. The general rule is that the resistance of polymers to microbiological damage increases with increasing chain length of the macromolecule. All other things being equal, linear carbon chain polymers are less biostable than branched or heterochain polymers.

The influence of chemical structure on the biostability of polymers has been demonstrated using polyurethane as an example. For this purpose, more than 100 samples were synthesized that did not contain impurities that promote the growth of microscopic fungi. It was found that polyurethanes

with a simple ether bond were more severely affected than polyurethanes with complex ether bonds. The presence of an ether bond facilitates the degradation and use of the polymer. It has also been found that compounds with a long carbon chain between the ether bonds are prone to degradation. The presence of three methyl groups located close to each other also increases the attack of polyurethanes by microscopic fungi.

For example, the microbiological resistance of polymer resins directly depends on the molecular weight of the polymer and decreases when low molecular weight fragments are present in the material. The same effect is observed when polymers are aged under the influence of light and heat. The transition from amorphous to crystalline polymer structure increases its biostability.

Among the polymer resins that increase resistance to damage by mold fungi are polyethylene, polypropylene, polystyrene, polyvinyl chloride (solid), polyamide and polyethylene terephthalate. Less resistant to fungi are polyvinyl acetate, polyvinyl alcohol, chlorosulfonated polyethylene, etc.

An important component of plastics is plasticizers, of which the most commonly used are esters of dicarboxylic and polycarboxylic aliphatic and aromatic acids. The plasticizer content can reach 30-50% of the plastic mass, therefore the biostability of the entire material largely depends on its biostability.

It has been established that the biostability of organic plasticizers depends on the length and spatial configuration of the carbon chain: the most stable are esters of orthophthalic acid, the least stable are derivatives of para-, meta-, iso- and terephthalic acids.

Ester-type plasticizers are hydrolyzed to bases and short-chain acids and are used by microorganisms, and this process can occur at relatively low relative humidity (50%) and a temperature of 20°C.

Using plasticizers and fillers as a food source, microorganisms accelerate the aging process of plastics.

When comparing the resistance of the most common plasticizers - esters of phthalic and adipic acids - to mold damage, it was found that esters of phthalic acid are more resistant than esters of aromatic acid - adipic acid - aliphatic dicarboxylic acid. Other aliphatic acid, fatty acid esters have low resistance to fungi.

An important component of plastics are fillers. Fillers are inert solids that are mainly included in the composition of polymeric materials to regulate mechanical properties and for other purposes. The introduction of a filler also reduces the cost of materials and plastic products, increases their strength, electrical and other properties.

Organic fillers (wood flour, cotton fiber, paper, etc.), which are nutrient substrates for microorganisms, reduce the resistance of polymer compositions to fungi, while inorganic fillers (asbestos, fiberglass, quartz powder, kaolin) increase biostability.

Currently, research is of interest in the development of compositions containing, in addition to a high-molecular basis, organic fillers, which are a nutrient medium for microorganisms. In addition to the destruction of the material associated with the damage of the filler by bacteria, an additional destructive effect is observed due to the structural properties of the filled polymer. It is known that the filler can accumulate in less ordered areas of the polymer. In addition, the packing density of macromolecules in the boundary layers of the polymer-filler system is approximately half the volume in the rest of the disordered phase of the polymer. Therefore, when the filler is destroyed by bacteria, it is easier for microorganisms to access the less biodegradable part of the polymer.

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