THE DANGER BACKGROUND COLOR: THE LIGHTENED EFFECT OF ORGANIC COLORS ON THE WATER ECOSYSTEM

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Abstract. This article provides a comprehensive analysis of the latent effects of organic dyes on the aquatic ecosystem. The study highlights the sources of organic dyes entering the aquatic environment, their physicochemical properties, and the mechanisms of their ecotoxicological effects.

Keywords: organic dyes, aquatic ecosystem, ecotoxicology, bioaccumulation, biomagnification, azo dyes, water pollution, photosynthesis, environmental hazard, wastewater, sustainable pollutants.

Today, the rapid development of industry, especially in the textile, leather and footwear, paper and food industries, and the widespread use of organic dyes as coloring agents, are creating new types of environmental hazards for the environment, in particular for aquatic ecosystems. These substances, in large quantities, enter wastewater during production and processing processes and reach natural water bodies. Often, they are perceived only as a factor that changes the color of water in terms of appearance, but their effect is much deeper and more complex.

One of the main properties of organic dyes in the aquatic environment is their chemical stability and resistance to decomposition. This leads to their long-term persistence in water bodies and their involvement in various ecological processes. As a result, the physicochemical properties of water change, light transmission decreases, and photosynthesis is disrupted. In particular, the decrease in the activity of phytoplankton and aquatic plants affects the entire trophic chain.

Another important aspect of the problem is that organic dyes are often biologically active even at low concentrations, causing subtle but long-term harmful effects on living organisms. They can accumulate in aquatic organisms, be transferred to higher levels of the food chain, and ultimately pose a threat to human health. Scientific studies have shown that some dyes and their degradation products are mutagenic and carcinogenic.

In this regard, an in-depth study of the hidden effects of organic dyes on the aquatic ecosystem, an assessment of their ecological risk, and the development of effective cleaning methods are of great scientific and practical importance. This study aims to shed light on these issues, analyzing the distribution of organic dyes in the aquatic environment, their ecotoxicological properties, and hidden mechanisms of action.

The issue of the impact of organic dyes on the aquatic ecosystem is one of the scientific problems that has been actively studied in the fields of environmental chemistry and ecotoxicology in recent years. Studies in this area show that organic dyes are not only a polluting factor of the external environment, but also dangerous substances that affect complex biological and chemical processes.

In modern studies, organic dyes are considered as widespread micropollutants in the aquatic environment. In particular, A. Tkaczyk, K. Mitrowska, A. Posyniak emphasize that the presence of dyes in the aquatic ecosystem is explained by their high stability and resistance to biodegradation [1]. The authors note that dyes are detected in water, sediments and tissues of living organisms, justifying the fact that their ecological hazard is systemic in nature.

The ecological impact of industrial wastewater containing dyes has been extensively analyzed by Al-Tohamy et al., who found that the organic compounds contained in such waters inhibit photosynthesis, change the optical properties of water,

and have a toxic effect on aquatic organisms [2]. The authors also emphasize that some dyes and their degradation products have mutagenic and carcinogenic properties.

Studies by Liu et al., however, highlight the complex impact of dye wastewater on the ecosystem, showing a disruption of the oxygen balance in the aquatic environment, a decrease in the number of biologically active organisms, and a decrease in overall ecological stability [3]. This means that dyes affect not only individual organisms, but also the entire ecosystem.

Azo dyes are considered a separate hazardous class. Alzain and Alghamdi reported that these dyes form aromatic amines when decomposed and are highly toxic and carcinogenic [4]. At the same time, studies by Goswami and Sharma show that the biodegradation of azo dyes in aquatic environments is a complex process, and they indirectly harm the ecosystem by increasing the biological oxygen demand of water [5].

Among modern studies, the work of Bora and Dutta is of particular importance, which considered the global problems of paint pollution and technologies for their elimination [6]. The authors emphasize that long-term storage and accumulation of paints increase their hidden ecological risk.

Previous studies also play an important role in forming the scientific basis of this direction. Forgacs and co-authors analyzed the methods of cleaning synthetic paints from wastewater and showed that the cleaning process is difficult due to their complex chemical structure [7]. Robinson et al. evaluated the possibilities of decontamination of dyes using biological and physicochemical methods [8].

Fundamentally, the scientific works written by Zollinger and Hunger provide a thorough overview of the chemical structure, properties, and applications of organic dyes [9; 10]. These sources provide an important theoretical basis for understanding the stability and reactivity of dyes and their behavior in the ecological environment.

The literature analyzed above shows that organic dyes have a multifaceted and often hidden impact on aquatic ecosystems. They not only change the appearance of water, but also interfere with biological processes and disrupt ecosystem stability. Therefore, studying this problem on the basis of an integrated approach and developing effective solutions remains an urgent scientific task.

When organic dyes enter the aquatic ecosystem, their impact manifests itself in several directions at once. First of all, these substances change the physical properties of water: coloring components limit the passage of sunlight falling into the water layer. As a result, the photosynthesis process carried out by aquatic plants and phytoplankton slows down, which directly affects the energy base of the ecosystem. A decrease in the intensity of photosynthesis leads to a decrease in oxygen production, which reduces the amount of dissolved oxygen in the water, which creates unfavorable conditions for aquatic organisms [2; 3].

From a chemical point of view, most organic dyes have a complex aromatic structure, and their decomposition occurs very slowly. This causes them to persist in the aquatic environment for a long time. Such stability allows them to be considered as “persistent pollutants”. Studies show that some dyes are biologically active even at low concentrations, causing physiological and biochemical changes in aquatic organisms [1].

Another important property of organic dyes is their bioaccumulation property. Dyes that enter the aquatic environment are first absorbed by microorganisms and planktonic organisms, and then transferred through the food chain to organisms of higher trophic levels. In this way, the concentration of dyes increases from organism to organism, a process called biomagnification. As a result, even very small amounts of dyes present in water can reach dangerous levels in higher organisms, including fish and humans [1; 6].

Of particular concern are dyes belonging to the azo group, which, when decomposed under anaerobic conditions in the aquatic environment, form aromatic amines. These substances are highly toxic, and many studies have revealed their mutagenic and carcinogenic properties [4]. In addition, dyes also negatively affect the activity of microorganisms in water, which leads to disruption of natural self-cleaning processes [5].

When viewed at the ecosystem level, the impact of organic dyes is complex. They reduce biodiversity in water, cause the extinction of some sensitive species, and disrupt the ecological balance. These processes often occur slowly and imperceptibly, that is, at the initial stage, obvious negative signs may not be observed. Therefore, the impact of organic dyes is considered a “hidden danger”.

Various treatment methods have been developed to eliminate this problem. Although traditional physicochemical methods (coagulation, adsorption, oxidation) are effective to a certain extent, they have economic and ecological limitations. In recent years, biological treatment, in particular, the decomposition of dyes using microorganisms (bioremediation), is considered a promising direction [7; 8]. However, for the widespread introduction of these methods, their effectiveness and sustainability must be further studied.

Thus, the impact of organic dyes on the aquatic ecosystem is a multifaceted and complex process, which is formed as a result of the interaction of physical, chemical, and biological factors. Identifying and assessing their hidden mechanisms of action is important in ensuring environmental safety.

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