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NANOTECHNOLOGY AS A MEANS OF SOLVING ENVIRONMENTAL PROBLEMS

Leonchik E.D.

Belarusian State University of Informatics and Radioelectronics, Minsk, Republic of Belarus

Sokolova M. A. – Lecturer at the Department of Foreign Languages

Annotation: This article explores the promising applications of nanotechnology in addressing global environmental challenges, including climate change, water pollution, and plastic waste. By utilizing innovative materials such as carbonized rice husk and magnetic nanoparticles, nanotechnology offers effective solutions for capturing carbon dioxide and removing microplastics from water, contributing to a more sustainable future.

Keywords: nanotechnology, environmental remediation, nanocomposites, nanofiltration, magnetic nanoparticles, radioactive decontamination.

Introduction. Nanotechnology is a field of science and engineering that focuses on the creation and use of structures, devices, and systems by manipulating atoms and molecules at the nanoscale, or having one or more dimensions on the order of 100 nanometers (100 millionths of a millimeter) or less. By providing new and more effective ways to monitor, remove, and reduce emissions of environmental pollutants, nanotechnology can make a significant contribution to environmental protection and sustainable development. The creation of more efficient technologies can also help reduce resource and energy consumption [1].

Main part. Global environmental problems are ecological issues that extend beyond individual countries or regions, affecting the entire planet as a whole. These problems include, in particular, global warming and climate change, water pollution, and plastic pollution. Recently, there has been an increasing effort to address these issues using nanotechnology [2].

Global warming is a natural process of increasing the Earth's overall temperature. However, over the past century and a half, its rate has significantly accelerated due to technological progress and the widespread burning of fossil fuels, leading to a continuous rise in the concentration of greenhouse gases. Scientists attribute global warming and climate change to greenhouse gases. Many of these gases occur naturally, but human activity has caused their concentrations in the atmosphere to rise. Emissions of methane, carbon dioxide, nitrous oxide, and other gases influence the planet's temperature. Carbon dioxide has the greatest impact on the warming of the Earth, the concentration of which in the atmosphere has almost doubled by 2020 compared to pre-industrial levels. This problem can be addressed through nanocomposite materials. Nanocomposite materials are formed by incorporating nanoscale filler particles into a solid matrix. The properties of the final nanocomposite material depend on the nature of the interactions between the phases and the structure of the interfacial regions. This means that their properties can differ significantly from those of conventional materials. For example, they can be lighter, stronger, or more effective in interacting with gases. Carbon-based nanocomposite materials, such as carbonized rice husk and technical carbon black with magnetite, are becoming a promising solution for capturing carbon dioxide—one of the key challenges in combating global warming and climate change. These materials combine raw material availability, high efficiency, and environmental friendliness, making them an alternative to traditional methods that often involve high costs or toxicity [3].

Carbonized rice husk is an example of how agricultural waste can be transformed into a valuable resource. The process of obtaining it begins with pyrolysis, where the raw material is heated to 400–800°C in an oxygen-free environment. As a result, organic components decompose, forming a porous carbon structure with a high specific surface area. Additional activation with steam or chemical agents, such as potassium hydroxide, increases the surface area to 1000–2000 m^2/g, creating a network of micropores and mesopores. These pores play a key role in CO_2 adsorption: gas molecules are retained through physical interactions, such as van der Waals forces, and oxygencontaining groups on the material's surface (-COOH, -OH) can form weak chemical bonds with carbon dioxide [4].

Climate change causes disruptions in weather patterns, leads to extreme weather events, creates unpredictability in water supply, exacerbates water resource scarcity, and pollutes water sources. All of these factors contribute to a global environmental problem related to water. One way to address this issue is through the application of membrane technologies (nanofiltration and reverse osmosis). The main goal of membrane technologies is to separate components with the least energy expenditure. Modern membranes typically consist of several layers of different materials, each having its own structural organization at the nanoscale, which ensures a comprehensive set of technological characteristics for the membrane as a whole. The application of reverse osmosis membrane technologies for the purification of natural and wastewater has been ongoing for the past 40 years. In recent years, there has been increasing interest in nanofiltration as a method for preparing drinking water from surface water sources, due to the high efficiency of these membranes in retaining organic substances that cause water discoloration. Thanks to the «universality» of membranes in retaining organic substances of various natures and molecular weights, reverse osmosis and nanofiltration membranes are already widely used in processes for the post-treatment of municipal wastewater for reuse. Moreover, due to the different selectivity of membranes (retention efficiency) for monovalent and multivalent ions, as well as organic substances, processes for treating industrial wastewater utilize solution separation and recovery of various components from solutions. Finally, the development of nanofiltration membranes has made it possible to achieve deep multiple concentration of wastewater brines, effluents, and concentrates for further disposal [5].

Another global environmental problem is plastic pollution. The oceans, in particular, suffer significant consequences from pollution. In response to this issue, nanotechnology opens new horizons for combating contamination. One of the technologies involves magnetic nanoparticles. Researchers have developed magnetic nanoparticles as an innovative solution for cleaning the environment from microplastics. They are used for the effective removal of plastic particles from water due to their magnetic properties. Magnetic nanoparticles are functionalized with polydopamine, which provides strong adhesion to microplastic particles in water. After binding with plastic, the nanoparticles can be easily removed from the water using a magnetic field [6].

In Belarus, one of the ecological problems is radioactive contamination of the environment. The consequences of the Chernobyl disaster in 1986 had a significant impact on public health. One way to mitigate these effects is through the implementation of nanomaterials in the purification process. Nanosorbents possess a high surface area and sorption efficiency, allowing for a significant reduction in purification time and an increase in the removal of radionuclides.

Conclusion. The study revealed that nanotechnology holds significant potential for addressing global environmental challenges, such as climate change, water pollution, and plastic waste. Nanomaterials, including carbonized rice husk, have demonstrated effectiveness in capturing carbon dioxide, which could substantially contribute to reducing its atmospheric concentration.

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