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RESEARCH ON ENVIRONMENTAL SAFETY OF ENGINEERED NANOMATERIALS

Abstract. Nanomaterials are now widely used in various industries due to their unique properties. However, this presence of nanomaterials in the environment raises possible serious toxicity problems for humans. The article considers the consolidation of new methods and results of impact assessment within this broad category of materials, future directions of research. Establishing consensus methods for characterizing each individual ENM is critical to use, pooling data to understand the risks associated with them, and developing useful occupational exposure limits. In this regard, the possibility of more radical alternative constitutions for social and technical security seems to be severely limited by the current ideology of innovation and the economic imperatives of a global knowledge-based capitalist economy.

Keywords: Nanotechnology, Nanoparticles, Human health, Nanomedicine, Nanotoxicity, Engineered nanomaterials, Physicochemical properties.

One of the current trends in the development of science and technology is the greening approach, which is declared in EU strategic documents and supported by the world community. The conservation of biological diversity, as a priority area for implementing the ideas of the European Green Deal, is particularly relevant to aquatic biocenosis. Harmful substances of anthropogenic origin enter water bodies and are included in the chains of interspecies interactions of aquatic organisms. The growing economic interest in nanotechnology and the industrial use of nanomaterials has exacerbated the possible risks of harmful effects of nanoparticles that directly and indirectly enter aquatic ecosystems [1]. Increasing the number and types of engineering nanomaterials and the areas of their use is crucial for the long-term development of society. There is no doubt that the benefits of nanotechnology far outweigh the potential adverse effects on the environment and human health. However, the responsible development of science and industry requires a careful approach to nanosafety research. In the scientific community, the discussion on the ecotoxicity of nanoscale structures has been initiated relatively recently [2] due to the rapid speed of development of technologies for the synthesis of new nanomaterials for industrial and biomedical purposes. The aim of this article was to find a responsible scientifically sound approach to the synthesis, study, and implementation of new nanomaterials used to protect ship surfaces and hydraulic structures from biofouling in accordance with current environmental trends in science and industry. The design of new nanomaterials for shipbuilding and ensuring the efficient operation of water structures meet the need to develop new protective coatings and paints. One of the causes of corrosion of ship bottoms and surfaces of hydraulic structures is biofouling of periphyton of aquatic organisms, which affects the safety and economic efficiency of navigation and increases energy costs. To solve this problem, biocidal paints are used, the environmental safety of which is constantly being studied and, accordingly, technical regulations are being revised.

The possibilities of nanotechnology allow for the creation of materials with unique properties. Analysis of literature sources indicates that to protect metal surfaces that are in constant contact with the aquatic environment, use fillers of nanooxide materials and antifouling agents are added to the coating [3]. Molecules or ions of biocides used to create protective composite nanomaterials can be released into the aquatic environment and prolong the antifouling effect of surfaces. Due to the possible bioaccumulation of nanoparticles, the issue of the environmental safety of such nanomaterials is a priority. It is known that the growth of microorganisms (bacteria and microscopic fungi) is inhibited on coatings with the addition of silver [4]. Silver nanoparticles are considered promising innovators for the development of nanocomposite antifouling coatings. The release of ions from silver nanoparticles has a destructive effect on microbial cells and biofilm formation [5]. Biofouling of surfaces in constant contact with the aquatic environment also begins with the formation of a mixed biofilm, the development of which can be inhibited by silver ions of nanoparticles of protective surfaces. The mechanisms of action of silver ions on microorganisms are associated with their action on the membrane structures of the cell and the activation of the formation of reactive oxygen species, which have a destructive effect [6].

In addition to nanosilver, popular fillers in protective antifouling coatings are nano-TiO_2, nano-SiO_2, nano-ZnO, nano-ZrO-TiO_2, carbon nanostructures (nanotubes and graphene), and others [7]. It has been shown that the impurity of titanium nano-dioxide in the nanocomposite significantly improves the antifouling properties and has an anti-corrosion effect on metal surfaces [8]. Nano-ZnO and nano-SiO_2, which are inexpensive and affordable, are often used to control biofouling [9, 10]. Insufficient solubility of metal oxides reduces their antifouling efficiency as fillers. Besides, structuring ZnO into nanotubes and fixing them on surfaces partially solves this problem. It is also known that ZnO nanotubes have less ecotoxicity [11]. The ecological toxicity of nanoparticles depends on the physicochemical parameters of nanoparticles (size, shape, the ratio of surface area to volume, agglomeration capacity, photostability, etc.) and the characteristics of the environment in which they fall [12]. The emergent properties of nanomaterials and the limited data on their concentrations in natural conditions are obstacles to predicting nanoparticles' behavior in the environment [13]. Therefore, the study of ecotoxicity involves the study of the effects of nanoparticles on living organisms in model systems. The number of works on modeling the concentrations and fate of nanoparticles in the environment is growing [14, 15]. For example, modeling of pollution of European rivers by nano-ZnO and nano-Ag allowed predicting long-term concentrations of these nanoparticles in water bodies.

When nanoparticles with an antifouling effect enter aquatic biocenosis, they come into contact with living organisms, are subject to biotransformation, bioaccumulation, and are included in trophic chains. Analysis of data obtained using crustaceans *Daphnia Magna* and fish *Danio rerio* suggests that contamination may potentiate the alteration of the microbiota of these living organisms. Changes in the microbiota of fish and other organisms affect their physiology, so it can have economic consequences for the fishing industry. The nanomaterials used to design antifouling surfaces contain components that inhibit the activity of biofilm-forming microorganisms. The use of bacteria and microscopic fungi is becoming increasingly popular in modeling the ecotoxic effects of nanoparticles. Studies of nanomaterials with antifouling effects prove the need to predict the environmental impact of their industrial use. From the viewpoint of the authors of this article, the first step in further detailed research of the properties of nanoparticles of applied value should be ecotoxicological studies. The existing arsenal of modern methods of analysis of biological reactions of microscopic organisms to pollution of aquatic biocenosis suggests that approaches to microbial ecotoxicology can quickly assess the impact of new materials and minimize experimental costs in the initial stages. The presence of toxic effects of nanoparticles requires risk assessment and the feasibility of further research in accordance with the ultimate goal. The growing number of engineered nanomaterials in the environment requires a more careful approach to the design of nanoparticles, considering their possible ecotoxic effects. Due to the emergent properties of nanoparticles, there are some difficulties in predicting their behavior in the environment. Modeling the environmental impact of synthesized engineering nanomaterials using microorganisms can be an economically feasible step in research.

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