Journal of Environmental Health and Sustainable Development

Using Nanozymes in the Removal of Persistent Organic Pollutants from Water Environments

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ARTICLE INFO

LETTER TO EDITOR

Article History:
Received: 18 May 2024
Accepted: 10 July 2024

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Citation: Pormazar SM. ***Using Nanozymes in the Removal of Persistent Organic Pollutants from Water Environments.*** J Environ Health Sustain Dev. 2024; 9(3): 2301-3.

Natural enzymes, with their distinct amino acid sequences, are large biocatalysts primarily composed of proteins. A few are made of catalytic nucleic acid molecules, playing a crucial role in metabolism and catabolism [1]. These enzymes have unique characteristics and high efficiency in various aspects of human life, including clinical diagnosis, environmental monitoring, and pollution treatment [2, 3]. However, natural enzymes have limitations such as performance in a narrow range of pH and temperature due to their high structural sensitivity, high cost, low stability and difficulty in storage [4, 5]. In addition, research has been done on synthetic enzymes with the structure and function of enzyme mimics. However, the higher activity of synthetic enzymes cannot meet the needs of industrial applications [6].

Advances in technology have led to the development of nanobiotechnology, which combines material science and biology to create novel nanomaterials capable of mimicking the activity of enzymes [7]. These nanomaterials, known as 'nanozymes', can catalyze reactions similar to natural enzymes in a physiologically relevant environment[8, 9]. However, their catalytic mechanism may differ from that of natural enzymes[10]. Nanozymes have significant advantages such as high stability, high catalytic activity, low cost, easy fabrication, greater reusability, and ease of modification[11, 12]. In addition, their unique nano-structural and physicochemical properties allow them to disperse effectively in aquatic systems and perform better in pollutant treatment. Furthermore, large-scale production can be cost-effective [3, 11].

One of the important aspects of this technology is that nanomaterials combine with a wide range of natural enzymes such as tyrosinases, glucose, proteins, spermine, phosphotriesterases, laccases, lignin peroxidase, soybean peroxidase, nitroreductases, reducing dehalogenases and quinone reductases in purifying pollutants [13-17]. Laccases and peroxidases are enzymes widely used in biological wastewater treatment to reduce oxidation of emerging hazardous pollutants such as phenols, bisphenols, herbicides, pesticides, textile dyes, pharmaceutical compounds, and others [2, 18].

Studies show that some of these nanozymes are used to break down specific pollutants and some others are multi-purpose [19]. Many nanozymes have both adsorption capacity and catalytic ability;

[DOI: 10.18502/jehsd.v9i3.16577]

however, they predominantly act as catalysts for degrading pollutants, with adsorption capacity serving as an auxiliary role in wastewater treatment[6]. Their catalytic mechanism involves converting several compounds through the oxidation of phenolic groups found in organic compounds. At the same time, they reduce molecular oxygen or hydrogen peroxide until it turns into water[2]. Additionally, some specially nanozymes have significant bactericidal activity [20]. The degradation of persistent organic pollutants, such as phenolic compounds, pharmaceutical compounds, dyes, pesticides, and organic phosphorus compounds, has seen significant progress through the use of nanozymes with catalytic activity[21-24]. Studies have demonstrated that composite nanoenzymes containing Fe_3O_4MNPs on carbon materials or MOFs exhibit higher catalytic efficiency compared to metal/metal oxide-based nanozymes[21]. The rate of degradation of nanoenzymes is influenced by several factors, including the composition and structural characteristics of nanozymes and pollutant compounds, the presence of other substances, and environmental variables such as pH and temperature[25].

Public concerns about environmental safety require the use of new and effective methods to reduce the toxicity of persistent pollutants. Nanozymes are a great solution to meet this need and improve the environment. Researchers are actively exploring and developing synthetic enzymes and nanozymes for environmental applications in water treatment. This would be highly relevant in treating complex contaminated media such as wastewater and leachates.

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