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The comprehensive effects of aluminum oxide nanoparticles on the physiology of freshwater microalga *Scenedesmus obliquus* and it's phycoremediation performance for the removal of sulfacetamide

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ABSTRACT

Nanoparticles are inevitable byproducts of modern industry. However, the environmental impacts arising from industrial applications of nanoparticles are largely under-reported. This study evaluated the ecotoxicological effects of aluminum oxide nanoparticles (Al_2O_3NP) and its influence on sulfacetamide (SA) biodegradation by a freshwater microalga, *Scenedesmus obliquus*. Although Al_2O_3NP showed limited toxicity effect on *S. obliquus*, we observed the toxicity attenuation aspect of Al_2O_3NP in a mixture of sulfacetamide on microalgae. The addition of 100 mg L^{-1} of Al_2O_3NP and 1 mg L^{-1} of SA reduced total chlorophyll by 23.3% and carotenoids by 21.6% in microalgal compared to control. The gene expression study demonstrated that *ATPF0C, Lhcb1, HydA, and psbA* genes responsible for ATP synthesis and the photosynthetic system were significantly downregulated, while the *Tas* gene, which plays a major role in biodegradation of organic xenobiotic chemicals, was significantly upregulated at 1 and 100 mg L^{-1} of Al_2O_3NP. The *S. obliquus* removed 16.8% of SA at 15 mg L^{-1} in 14 days. However, the removal was slightly enhanced (18.8%) at same concentration of SA in the presence of 50 mg L^{-1} Al_2O_3NP. This result proves the stability of sulfacetamide biodegradation capacity of *S. obliquus* in the presence of Al_2O_3NP co-contamination. The metabolic analysis showed that SA was degraded into simpler byproducts such as sulfacarbamide, sulfaguanidine, sulfanilamide, 4-(methyl sulfonyl)aniline, and N-hydroxy-benzenamine which have lower ecotoxicity than SA, demonstrating that the ecotoxicity of sulfacetamide has significantly decreased after the microalgal degradation, suggesting the environmental feasibility of microalgae-mediated wastewater technology. This study provides a deeper understanding of the impact of nanoparticles such as Al_2O_3NP on aquatic ecosystems.

1. Introduction

Clean water is a vital resource for the sustainability of humankind. In recent times, the importance of securing safe water resources has been of great interest among researchers, stakeholders, and policy makers. Contamination of natural reservoirs by industrial processes and anthropogenic factors restricts access to clean and potable water. Furthermore, newly emerging pollutants in water represent potential environmental threats (Schwarzenbach et al., 2006). These emerging contaminants (ECs) include pharmaceutical compounds, disinfectants, pesticides, personal care products, fragrances, surfactants, microplastics, and nanoparticles (Geissen et al., 2015; Viancelli et al., 2017).

Aluminum oxide is one of the most widely used nanoparticles (NPs) for various industrial applications, such as cosmetic fillers, adsorbents,

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