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Al_2O_3 Nano-Particles Impact on Pseudomonas Putida Gene Expression: Implications for Environmental Risk

Authors : Nina Doskocz, Katarzyna Affek, Magdalena Matczuk, Monika Załęska-Radziwiłł

Abstract : Wastewater treatment is a critical environmental issue, especially in the face of increasing urbanization and industrialization. One of the emerging issues related to wastewater is the presence of nanoparticles (NPs) - tiny particles with dimensions measured in nanometers. These nanoparticles are widely used in various industries, including medicine, electronics, and consumer products. With technological advances, NPs are increasingly finding their way into water and wastewater systems, posing new environmental challenges that require urgent research and regulation. Therefore, research on the impact of nanoparticles on wastewater treatment processes is critical to protect environmental health and ensure sustainable development in the face of advancing nanotechnology. Traditional ecotoxicological tests are often inadequate for routine analysis as they do not provide insight into the mechanisms of toxicity of these compounds. The development of (geno)toxicity biomarkers for nanoparticles will greatly aid in the rapid assessment and prediction of the effects of current and emerging nanomaterials on various organisms. However, despite growing interest in gene expression responses to nanoparticle-induced stress, the toxic mechanisms of action and defense responses against nanoparticle toxicity remain poorly understood. The aim of our research was to investigate the expression of several molecular biomarkers related to essential cellular functions - such as oxidative stress, xenobiotic detoxification, and mitochondrial electron transport - in Pseudomonas putida in response to Al_2O_3 nanoparticles found in wastewater, both before and after biological treatment, as well as in their native form. Real-time PCR (qPCR) was used to assess gene expression changes after 1 hour and 16 hours of exposure to Al_2O_3 NPs and wastewater containing these nanoparticles, both before and after biological treatment. In addition, gene expression measurements were performed on P. putida in the presence of bulk Al_2O_3 (pristine and in wastewater). The results showed increased expression of ahpC, katE and ctaD genes, indicating oxidative stress, increased detoxification capacity and impaired mitochondrial function. Both untreated and treated wastewater containing nanoparticles caused significant changes in gene expression, demonstrating the persistent bioactivity and potential toxicity of these nanoparticles. Nanoparticles exhibited greater reactivity and bioavailability compared to their bulk counterparts.

Keywords : nanoparticles, wastewater, gene expression, qPCR
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