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Targeted Mechanisms of Action of Metal-Based Nanoparticles on Gram-Positive Bacteria Cell Envelopes

Oliwia Metryka[1], Daniel Wasilkowski[2], Agnieszka Mrozik[2]
[1]Doctoral School, University of Silesia, Bankowa 14, 40-032 Katowice, Poland
oliwia.metryka@us.edu.pl
[2]Institute of Biology, Biotechnology and Environmental Protection, Faculty of Natural Sciences, University of Silesia, Jagiellońska 28, 40-032 Katowice, Poland
daniel.wasilkowski@us.edu.pl; agnieszka.mrozik@us.edu.pl

Extended Abstract

Over the last few decades, nanotechnology has become one of the leading and most promising scientific discoveries, offering extraordinary progress in the research, production, and practical application of nanomaterials. The global nanotechnology is undeniably dominated by metal-based nanoparticles (NPs). The exponential growth in the production and applications of NPs is related to their distinctive and valuable properties, distinguishing them from their larger-scale counterparts. A unique feature of inorganic NPs is their antimicrobial activity, consisting of a multi-faceted, pleiotropic, and non-specific mode of action on various biomolecules and metabolic processes. Due to the rise in the production of NPs, large amounts of NPs are released uncontrollably and accumulated in the natural environment, posing an inevitable threat to microorganisms and other living organisms. Although the number of studies on the synthesis and use of NPs is growing dynamically, reports on the impact of NPs on the functionality of microorganisms (especially non-target microorganisms) are still insufficient [1,2]. In particular, little is known about the interaction of NPs with the bacterial cell wall and cytoplasmic membrane. These mechanisms require further and in-depth elucidation because direct and indirect interactions of NPs with the bacterial outer layers can lead to permanent damage to protective barriers, destabilisation of membrane potential, structural changes, increased membrane permeability and lipid peroxidation, disruption of transport activity, uncoupling of oxidative phosphorylation, leakage of intracellular contents and disturbances in the respiratory metabolism [2-4].

This research aimed to explore and understand the action of metal-based NPs including Ag-NPs (cat. no. 576832, Sigma-Aldrich, <100 nm), Cu-NPs (cat. no. 774081, Sigma-Aldrich, 25 nm), ZnO-NPs (cat. no. 677450, Sigma-Aldrich, <50 nm) and TiO_2-NPs (cat. no. US1019F, US Research, 20 nm) on the structure and properties of Gram-positive *Bacillus cereus* (ATCC® 11778™) and *Staphylococcus epidermidis* (ATCC® 12228™) outer layers. The performed analyses concerned the assessment of cell membrane permeability, determination of cytoplasmic leakage, cellular ATP levels and ATPase activity, changes in the fatty acid profiling and the distribution and specific interactions of NPs with the surface of bacterial cells [4].

The results confirmed the differentiated effects of inorganic NPs on the metabolic processes and structure of tested bacteria, depending on their concentration and type of NPs. Undeniably, NPs caused significant changes in the permeability of the bacterial cell membrane, which were correlated with alternations in the leakage of intracellular contents together with the cellular ATP concentrations. Consequently, NPs induced considerable modifications in the composition and percentages of the analysed fatty acids, especially within the cyclopropane fatty acid abundances. Furthermore, it was established that *B. cereus* was more resistant to the NPs toxic activity than *S. epidermidis*. The multi-directional analysis indisputably contributed to a thorough comprehension of NPs biological activity toward microorganisms and provided insight into their distinguished interactions with bacterial outer layers [4]. The collected dataset fills a gap in the literature regarding NPs toxicity and complex molecular action on microbial cells and constitutes a valuable contribution to future research.

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