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ORIGINAL ARTICLE

Spermiotoxicity of nickel nanoparticles in the marine invertebrate *Ciona intestinalis* (ascidians)

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Abstract

Nickel nanoparticles (Ni NPs) are increasingly used in modern industries as catalysts, sensors, and in electronic applications. Due to this large use, their inputs into marine environment have significantly increased; however, the potential ecotoxicological effects in marine environment have so far received little attention. In particular, little is known on the impact of NPs on gamete quality of marine organisms and on the consequences on fertility potential. The present study examines, for the first time, the impact of Ni NPs exposure on sperm quality of the marine invertebrate *Ciona intestinalis* (ascidian). Several parameters related with sperm status such as plasma membrane lipid peroxidation, mitochondrial membrane potential (MMP), intracellular pH, DNA integrity, and fertilizing ability were assessed as toxicity end points after exposure to different Ni NPs concentrations. Ni NPs generate oxidative stress that in turn induces lipid peroxidation and DNA fragmentation, and alters MMP and sperm morphology. Furthermore, sperm exposure to Ni NPs affects their fertilizing ability and causes developmental anomalies in the offspring. All together, these results reveal a spermiotoxicity of Ni NPs in ascidians suggesting that the application of these NPs should be carefully assessed as to their potential toxic effects on the health of marine organisms that, in turn, may influence the ecological system. This study shows that ascidian sperm represent a suitable and sensitive tool for the investigation of the toxicity of NPs entered into marine environment, for defining the mechanisms of toxic action and for the environmental monitoring purpose.

Keywords

Ascidians, environmental risk, nickel nanoparticles, sperm quality, toxicity assay

History

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Introduction

Over the past decades, the introduction of a series of anthropogenic factors in the marine environment resulted in serious ecotoxicological impacts on the biota (Matranga & Corsi, 2012). It has been well documented that marine pollution, due to xenobiotic compounds, causes reproductive disorders in marine organisms that may affect the offspring development up to threatening species continuance. In particular, a toxic impact of various antifouling agents (Bellas et al., 2013) and metals as copper (O'Brien & Keough, 2014) was shown to pose at risk marine invertebrate embryos and larvae and marine biodiversity (Mieszkowska et al., 2014). Among the marine pollutants, a relevant role is played by nanoparticles (NPs) resulting from the large-scale applications of nanotechnologies and the rapid growth of nano-industry. Recent studies showed that NPs of silver, copper oxide, and zinc oxide severely affect a wide range of organisms from algae to mammalian cell lines (Bondarenko et al., 2013). NPs are nanomaterials characterized by small size (ranging from 1 to 100 nm) and peculiar physical–chemical and mechanical properties. Due to these features, they are employed in hundreds of commercial products, from photovoltaic cells to pharmaceutical and biomedical applications (Weissig et al., 2014). These, in particular, use the ability of NPs to adhere to the cell plasma membrane and/or enter the cells by endocytosis or transport systems to elicit their therapeutic effects. Based on this principle, NPs released into the environment following discharge of products may affect physiological processes of the living organisms representatives of various trophic levels, including bacteria, plants, and multicellular aquatic/terrestrial (Maurer-Jones et al., 2013).

Metallic NPs, including nickel nanoparticles (Ni NPs), are among the most widely employed types of nanomaterials. The increased use of Ni NPs in modern industry, as catalysts and sensors, and in electronic applications, is creating a concern due to the potential risk associated with the toxicity that they may exert once released in the environment. Recent studies have shown a variety of effects of Ni NPs in biological systems. Whereas evidences of a positive cytotoxic impact on mice and human cancer cell lines were provided suggesting possible clinical applications in anticancer therapies (Guo et al., 2008), other showed a carcinogenic potential (Zhao et al., 2009), genotoxic and mutagenic activities (Kasprzak et al., 2003) and

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