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The oxidative toxicity of Ag and ZnO nanoparticles towards the aquatic plant Spirodela punctuta and the role of testing media parameters

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Abstract

The toxicity effects of silver (nAg) and zinc oxide (nZnO) engineered nanoparticles (ENPs) on the duckweed Spirodela punctuta were studied to investigate the potential risks posed by these ENPs towards higher aquatic plants. The influence of media abiotic factors on the stability of the ENPs was also evaluated. Marked agglomeration of ENPs was observed after introduction into testing media whereby large particles settled out of suspension and accumulated at the bottom of testing vessels. The high ionic strength (IS) promoted agglomeration of ENPs because it reduced the inter-particle repulsion caused by a reduction in their surface charge. Low dissolution was observed for nAg, reaching only 0.015% at 1000 mg $L^{-}1$, whilst improved dissolution was observed for nZnO, only falling below analytical quantification at 0.1 mg $L^{-}1$ and lower. The quantification of free radicals namely, reactive oxygen and nitrogen species (ROS/RNS) and hydrogen peroxide (H2O2), indicated the induction of oxidative stress in plants exposed to the ENPs. A definite dose influence was observed for ROS/RNS volumes in plants exposed to nZnO for 14 days, a response not always observed. The total antioxidant capacity (TAC) and superoxide dismutase (SOD) activity in plants indicated varying degrees of oxidative toxicity caused by exposure to ENPs. This toxicity was driven mainly by particulates in plants exposed to nAg, whilst dissolved Zn2+ was the main driver for toxicity in plants exposed to nZnO. Our findings suggest that the toxicity of nAg and nZnO could be caused by both the particulates and ionic forms, as modified by media properties.