High-throughput Analysis of Eco-toxicity of Nano-TiO_2 to Model Bacteria under Simulated Environmental Conditions

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Introduction

Nano-TiO_2 (n-TiO_2) is among the most common engineered nanomaterials (ENM) and is applied in a diverse array of industrial and commercial products from sunscreens and disinfectants to catalysts. Due to its extensive applications and rapid growth of production, n-TiO_2 is inevitably released into natural environment, which has led to growing concerns on its potential environmental and health consequences. However, little is known about the effects of n-TiO_2 on bacteria under environmental conditions. In this study, we tested the toxicity of four types of commercialized n-TiO_2 to model bacteria *E. coli* and *B. subtilis* under simulated environmental conditions, with the help of the high-throughput screening technique.

Experimental design and results

Water collected from Lake Michigan was used as the solution matrix and a xenon arc lamp that provides simulated sunlight was used as the light source. Cell viability was evaluated with the BacLight Kit and reactive oxyten species (ROS) production was determined with carboxy-H_2DCFDA. Results confirmed a strong dependence of n-TiO_2 toxicity on the type of n-TiO_2 and illumination conditions. With broad spectrum illumination from the xenon arc lamp, Degussa P25 and two anatase exhibited significant toxicity to both bacteria while rutile caused no obvious toxicity. Under dark condition n-TiO_2 toxicity was almost negligible. Optic filters were used to assess the effects of light wavelength on n-TiO_2 toxicity. With exposure of Degussa P25 to light of above 400 nm, the viability of bacteria was similar to that under dark conditions, while exposure to light above 320nm produced cell mortality similar to that seen with broad spectrum illumination, indicating the importance of wavelengths between 320-400nm for n-TiO_2 toxicity. Suwannee River fulvic acid (SRFA) was used to assess the effects of natural organic matter (NOM) on n-TiO_2 toxicity. In contrast with the traditional assumption that NOM would enhance n-TiO_2 toxicity by reducing the size of n-TiO_2 aggregate, SRFA was found to decrease n-TiO_2 toxicity, probably due to its absorbance of light within UV region. Our study also suggests that photocatalytic activity of n-TiO_2, which is known to produce ROS, played an important role in bacterial inactivation. A correlation was observed between the decrease of bacterial viability and the increase of ROS production.

Significance

Environmental conditions determine the transport, fate and toxicity of n-TiO_2. Therefore, the simulated environmental conditions employed in our study makes our results more representative of the real scenario in the nature environment. Our study provides critical first steps in understanding the potential ecological effects of ENM.

Provenance, weathering and comminution ages of late Quaternary Weddell Sea sediments

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The location and geometric setting of the Weddell Sea, one of the large marginal seas of Antarctica, make it a sensitive recorder of the input of subglacial erosion products from Antarctica over glacial-interglacial time scales.

We present a study of Pb, Sr and Nd isotopic compositions, U-decay series, and trace element concentrations of siliciclastic sediments deposited over the last ~250 kyrs in the East and North Weddell Sea (EWS and NWS, respectively). Each sample was separated into three grain size fractions of carbonate free material (>20um, 20-2um, <2um).

Significant differences are observed between sediment compositions between both studied regions as well as between grain size fractions within each sample. Lead isotopic compositions show a clear distinction between both sites with $^{206}Pb/^{204}Pb$ ratios in the EWS and NWS ranging between 17.958-18.307 and 18.655-18.939, repsectively. The isotopic composition of Sr is generally similar in both sites, 0.7152-0.7231, except for <2um particles from the NWS that significantly higher values between 0.7256 and 0.7338. The latter also display the strongest ^{234}U-depletion with ($^{234}U/^{238}U$) ratios typically ranging between 0.766-0.850.

These observations imply that the clay fraction in the NWS originates from a distant region, most likely East Antarctica, and that it was exposed to more intense weathering relative to the coarser particles. Hence, secular variations in $^{87}Sr/^{86}Sr$ and ($^{234}U/^{238}U$) ratios provide a sensitive recorder of changes in the combined effect of the sediments comminution ages (i.e., their time of transport between source and sink) and the intensity of weathering processes they were exposed to. Additional acid leaching experiments provide quantitative constraints on the effects of chemical weathering compared to the preferential loss of ^{234}U through recoil and will be discussed in the context of determining the sediments' comminution ages, which are closely connected to the history of the Weddell Gyre and Antarctic glacial weathering processes.