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# A new dual isotope approach to investigate the effects of ageing on ZnO nanoparticles in soils at field relevant concentrations

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## Abstract

The detection and quantification of engineered nanoparticles (NPs) at realistic field concentrations within complex natural samples is problematic using traditional methods and this has prompted the development of novel analytical approaches. One such technique applies artificially enriched stable isotopes to create and hence label NPs.

Here we present data from the first study to use two enriched stable isotopes of Zn within a single exposure. Results were obtained for exposures of the earthworm *Eisenia andrei* to both ZnO NPs and soluble ZnCl<sub>2</sub> in the same soil. The two Zn forms were labeled with Zn enriched to 99% in <sup>68</sup>Zn (to produce <sup>68</sup>ZnO NPs) and <sup>64</sup>Zn (to produce <sup>64</sup>ZnCl<sub>2</sub>), relative to natural abundances of 19% and 48%, respectively. Isotopic analysis using multiple collector ICP-MS allowed the simultaneous measurement of the diagnostic <sup>68</sup>Zn/<sup>66</sup>Zn, <sup>64</sup>Zn/<sup>66</sup>Zn and <sup>68</sup>Zn/<sup>64</sup>Zn ratios to a precision of better than 0.04% (2sd). This enabled detection of isotopically enriched <sup>68</sup>Zn and <sup>64</sup>Zn when they contributed as little as 0.008% and 0.02% to the total Zn concentration, respectively.

Aliquots of the standard test soil Lufa 2.2 were dosed with both <sup>68</sup>ZnO NPs and soluble <sup>64</sup>ZnCl<sub>2</sub> to Zn concentrations of 5 mg kg<sup>-1</sup> and between 0 and 95 mg kg<sup>-1</sup> of soluble ‘natural’ Zn were added. Zero, 1, 3, 6, and 12 months after dosing, earthworms were introduced to the soils for a 72-hour exposure. Subsequent analyses of soil, pore water and earthworms revealed essentially identical ratios of enriched <sup>68</sup>Zn to enriched <sup>64</sup>Zn for all sample types and exposure periods. This implies that the environmental behavior of ZnO NPs, when introduced at environmentally relevant levels, is indistinguishable from soluble Zn, regardless of the soil residence time of the ZnO NPs or the ratio of ZnO NPs to soluble Zn in the soil.

**Keywords:** nanoparticles, zinc, soil, isotopes, isotope labeling

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