Silver Nanoparticle Tracing Using Stable Isotope Labelling and Multiple Collector ICP MS (MC-ICP-MS)

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Abstract

Silver nanoparticles (AgNPs) have found widespread use in consumer products due to their antimicrobial properties. However, there is much uncertainty concerning their effects and longterm implications when they enter natural systems, which has prompted investigations into their environmental behaviour.
Predicted concentrations of engineered AgNPs are similar to natural background levels of Ag. Conventionally, AgNPs are detected by concentration measurements, which requires that NP addition generates a clear increase in elemental concentration above often variable background levels. To fulfil this condition, it is necessary to dose AgNPs at levels far higher than the predicted increase caused by engineered NPs (e.g. $< 1\%$ for soils).

Analytical limitations of conventional NP tracing methods can be overcome by stable isotope labelling. NPs are hereby synthesised from a single artificially enriched isotope to create an isotopically distinct nanomaterial. By measuring changes in a diagnostic isotope ratio, the enriched material can be detected and quantified with a sensitivity and precision that far surpasses concentration measurements.

Both naturally occurring stable isotopes of silver, 107Ag and 109Ag, are commercially available at enrichments of $> 99\%$. The 107Ag/109Ag ratio can be routinely determined with a precision of $\pm 0.05\%$ (2sd) using MC-ICP-MS. This allows detection of labelled AgNPs even when they contribute $< 0.03\%$ to the total Ag concentration of a sample.
Analyses by MC-ICP-MS requires pure elemental solutions and suitable methods for the separation of silver from natural samples are therefore needed. Our optimised separation approach provides sufficiently purified Ag at recoveries of $> 90\%$ and with procedural blanks of $\leq$10 pg. No Ag isotope fractionation was observed and natural isotope ratios were recovered relative to a pure Ag solution for several biological, soil and water samples. As such, the method allows utilisation of the unparalleled precision of MC-ICP-MS, whilst facilitating the high sample throughput required for the evaluation of environmental exposures.

Keywords: Silver nanoparticles, nanoparticles, stable isotope tracing, fate, transport, behaviour, environmental effects

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