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A Novel Approach for Shipboard Enrichment of Marine Nanoparticles Followed by Rapid Detection by Dynamic Light Scattering

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Marine nanoparticles play a crucial role in biogeochemical cycles and metal-bearing nanoparticles serve as indicators of redox conditions in aquatic environments. They can trace redox and hydrothermal activity in extreme habitats. Besides, plastic nanoparticles contribute significantly to environmental pollution.

Detecting marine nanoparticles is challenging due to their low concentrations, requiring advanced techniques like single-particle ICP-MS (sp-ICP-MS) and electron microscopy (SEM, TEM), which are impractical for on-board use. Their high reactivity causes morphological and size changes, making in-situ or shipboard analyses essential for identifying nanoparticle-rich zones.

To address this, we have developed a novel shipboard methodology utilizing Amicon Stirred Cell filtration units, typically used for micro- and nanoscale biomaterials. Unlike conventional filtration, this method prevents particle accumulation on the filter surface, maintaining their liquid environment and minimizing chemical alterations. Filtration was performed using a 400 mL stirred cell with 0.1 µm PVDF membranes. We applied this method for the first time in the particle-rich redox transition zone of the Black Sea, concentrating ~4.5 L of seawater (pre-filtered through a 100 µm sieve) to 5–25 mL.

Additionally, nanoparticles were extracted from anoxic and suboxic sediments. For this, 10–20 mL of sediment from each core slice was mixed with an equal volume of 0.02 µm-filtered seawater, sonicated for 5 minutes, and centrifuged at 1500 rpm for 10 minutes. The supernatant was filtered through 0.45 µm and 1.0 µm syringe filters into separate aliquots for analysis. Dynamic Light Scattering (DLS) analysis was performed onboard on both water column and sediment samples.

These first results provided relative nanoparticle concentrations closely matching the theoretical estimates. We have also demonstrated the relative levels of nanoparticles across different depths in an aquatic redox transition for the first time. While further field studies are needed to refine size distribution analysis, the method demonstrated promising reproducibility in natural waters and offers potential for advancing in-situ and on-board nanoparticle research.