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Colloidal matter in polar marine ecosystems: molecular complexity and transformation pathways.

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Unraveling the marine carbon cycle remains a central challenge in oceanography, as it determines the fate of atmospheric carbon fixed by primary producers. Traditionally conceptualized as a system governed by particulate (POM) and dissolved organic matter (DOM), this framework overlooks a highly dynamic intermediate fraction within the organic matter size continuum: colloidal organic matter (COM). This fraction is highly heterogeneous and polyfunctional, occupying a central transitional position between dissolved and particulate pools. Colloids can aggregate to form POM or disaggregate and contribute to the DOM pool, thereby actively mediating organic matter transformation and transfer across size fractions. In this study, we performed molecular characterization of COM collected along environmental pole-to-pole transects spanning from the Antarctica Pacific coastal zone to the Arctic ocean, including an Atlantic latitudinal gradient. Fatty-acid profiling differed between POM and COM. POM was consistent across regions, while COM varied regionally, uncovering molecular characteristics not seen in bulk POM. Colloids also represent a substantial fraction of the lipid pool: 21% of total fatty acids in Antarctica (3.7µg/L) and 10% in the Arctic (1.4 µg/L), and they contain valuable lipids such as polyunsaturated fatty acids (ω3 and ω6). These patterns suggest that environmental gradients, variations in primary production, and microbial processing shape COM composition. To improve the resolution of COM characterization, we developed a Pyrolysis-gas chromatography–mass spectrometry approach using standards reflecting high structural diversity, enabling precise detection of complex molecular mixtures. This approach allowed us to distinguish specific compositional pools within COM, providing a more detailed view of its molecular diversity. Our results highlight the importance of considering COM in these studies and provide a framework for exploring how this fraction responds to environmental changes.