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Stickiness of extracellular polymeric substances on different surfaces via magnetic tweezers

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ABSTRACT

Organic particle dynamics in the surface ocean plays a critical part in the marine carbon cycle. Aggregation of marine organic particles drives their downward transport to support various marine organisms on their transit to the sediments. Extracellular polymeric substances (EPS) from various microbes are a major contributor to the oceanic organic particle pool. The stickiness of EPS is expected to play a determining role in the aggregation process of particles; however, stickiness parameters are usually indirectly estimated through data fitting without direct assessment. Here a magnetic tweezer method was developed to quantitatively assess the stickiness of three model EPS produced by: *Amphora* sp., (diatom), *Emiliania huxleyi (coccolithophore)*, and *Sagittula stellata* (bacteria), under different in vitro environmental conditions (salinity or EDTA complexed cations) and surface matrices (EPS-EPS and bare glass). Our results showed the stickiness of three microbial EPS decreasing for *S. stellata* > *E. huxleyi* > *Amphora* sp., in line with their decreasing protein-to-carbohydrate (P/C) ratios (related to their relative hydrophobicity). The data not only emphasize the importance of hydrophobicity on EPS stickiness, but also demonstrates that salinity and the nature of the substrate surface can influence the stickiness. Furthermore, we investigated stickiness between various types of EPS, and the observed selective stickiness of EPS between species may shed light on the interactions among heterogeneous marine microorganisms. Overall, this newly developed system provides a platform to assess the EPS stickiness to advance our understanding of the aggregation and sedimentation process of organic particles that are critical for the fate of organic carbon as well as for biofilm formation and microbial colonization of surfaces in the ocean.

1. Introduction

Particle dynamics is the major dominating factor in determining the fate and vertical transport of organic and inorganic materials from the surface to the deep ocean, strongly impacting the global carbon budget and elemental cycling (Burd and Jackson, 2009; He et al., 2016; Turner, 2015). Marine particle aggregation is ubiquitous in oceanic systems. Particle sizes ranging from nanometer (colloids) to micro-sized gel structures lead to the formation of larger aggregates with sizes of millimeters to centimeter that are also called 'marine snow' (Chin et al., 1998; Engel, 2000; Passow, 2002; Santschi, 2018; Shiu and Lee, 2017a; Shiu et al., 2018). The impacts of aggregated particles on the ecosystems are vast, for example, carbon and elemental export fluxes are driven by the aggregation and subsequent sinking of these organic-rich particles from the ocean's surface to the deep sea floor that directly mediate vertical fluxes of marine organic carbon and elements (Burd and Jackson, 2009; Verdugo et al., 2004). Organic aggregates can provide concentrated "hot-spots" of bioavailable nutrients for grazers within the 'microbial loop' (Verdugo, 2012). Some studies also have indicated that microgel formation is altering the scavenging of pollutants which in turn affects their bioavailability, and may act to regulate pollutant toxicity (Shiu and Lee, 2017b; Wei-Haas et al., 2014).

In general, the concentration, size, and stickiness of these particles can determine their physical and biogeochemical interactions with organisms and other particles and thus affecting sedimentation

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