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Capturing the Evolution of the Oil-in-Water Emulsion Interface by Correlative Imaging

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Bilgewater formed from the shipboard is regarded as a major pollutant in the marine environment. Bilgewater exists in a stable oil-in-water (O/W) emulsion form. However, little is known about the O/W liquid-liquid (l-l) interface. Traditional bulk characterization approach is not capable of capturing the chemical changes at the O/W l-l interface [1]. Although surfactants are deemed essential in droplet formation, their roles in bilgewater stabilization are not fully revealed. Therefore, it is important to study the physical and chemical properties at the evolving O/W interface in emulsions to deepen the fundamental understanding and formulate solutions to treat pollutants.

We developed a transferrable microfluidic sample holder, system for analysis at the liquid vacuum interface (SALVI) and enabled in situ chemical imaging of liquids using scanning electron microscopy (SEM), time-of-flight secondary ion mass spectrometry (ToF-SIMS) [2]. One of the main advantages of using SALVI to study liquid is that the same sample can be analyzed using different instruments. We use in situ SEM to determine droplet size distribution (DSD), in situ SIMS to characterize the O/W interface, and optical microscopy to perform glossary survey of droplets prior to more in-depth in situ analysis. The NAVY bilge model was used in this work [1].

Our results show that the DSD does not change significantly without the addition of X-100 surfactants at static or rocking conditions. Both the oil components and the water clusters are shown to evolve over time at the O/W droplet interface by in situ liquid SIMS imaging. Of particular interest to droplet stabilization, the contribution of surfactants to the aged bilge droplets becomes more significant as the droplet size increases. The higher mass surfactant component does not appear on the droplet surface immediately while many lower mass surfactants are solvated inside the droplet. We have provided the first three-dimensional images of the evolving O/W interface based on in situ SIMS imaging and demonstrated that in situ surface chemical mapping is powerful to reveal the complex and dynamic l-l interface in the liquid state. Our observational insights suggest surfactants are important in mediating droplet growth and facilitating effective separation of bilgewater emulsion. The application of correlative imaging is not limited to bilgewater emulsions. It is anticipated that in situ correlative imaging will see more advanced and diverse usage in the near future [4].

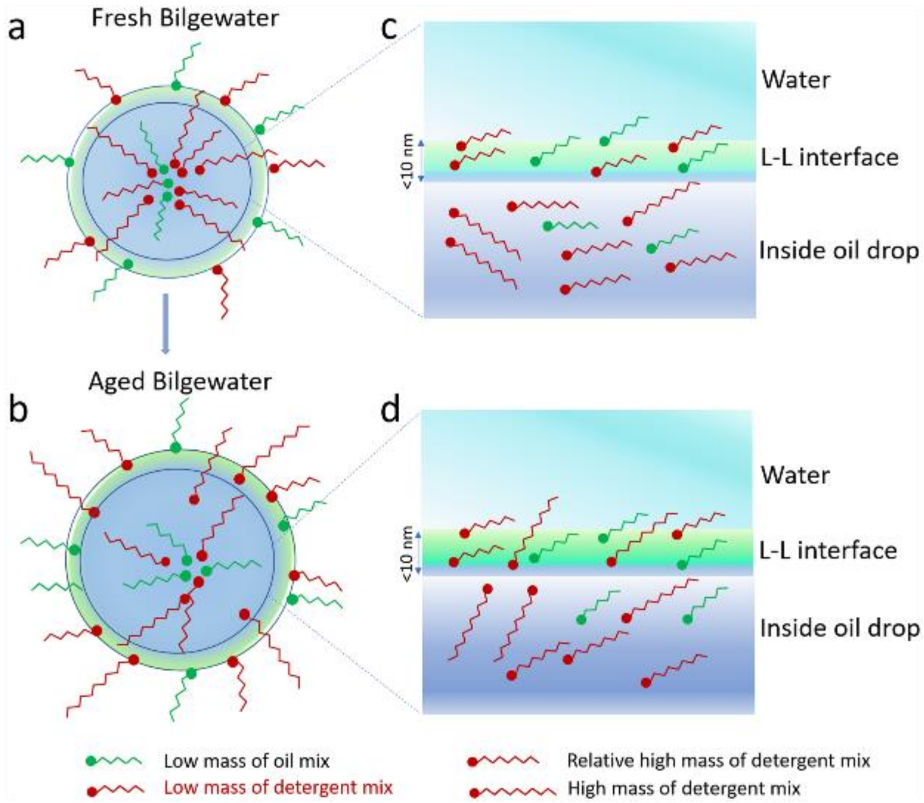

Figure 1. The schematic showing the evolution of the O/W interface in fresh and aged bilgewater.

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