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Microfluidic insight for the optimization of off-shore produced water treatment

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Oil exists in the forms of dissolved oil and dispersed oil in produced water, which can be hazardous to the environment. The dispersed oil are small droplets of oil suspended in the aqueous phase. They can have rather high stability and are difficult to remove. Production chemicals are routinely added during oil production to mitigate unwanted effects, e.g. pipeline corrosion, scale, bacteria and hydrogen sulfide. These chemicals may function as surface-active components, which significantly influence the phase behavior of oil-water mixtures, such as oil-in-water and water-in-oil emulsions. As a result, they may greatly affect the efficiency of produced water treatment.

The stability of an emulsion system is typically studied with bottle tests by mixing oil and water phases and let the system relax to equilibrium. However, it can take as long as months for a surfactant-oil-water (SOW) containing system to reach equilibrium. Moreover, bottle tests generally consume large amounts of chemicals. Microfluidics has proven to be a powerful tool for the investigation of oil droplet stability in different water phases in terms of droplet coalescence with precise control and manipulation of fluids at small temporal and spatial scale. It offers great advantages, e.g. direct visualization of individual microscopic events, high efficiency, small volume chemical consumption.

In this study, we perform bottle tests and microfluidic characterization of model SOW systems. The key parameters that determine the stability of a SOW system include effective alkane carbon number, i.e. the oiliness of the oil, temperature, salinity and the hydrophobic/hydrophilic nature of the surfactant. They are varied in terms of oil type, salinity and the species of surfactants used in the experiments. Three types of emulsions (Figure 1) were observed in the bottle tests at different compositions and salinities, i.e. oil-in-water (Type I), water-in-oil (Type II) and bicontinuous microemulsion (Type III). In order to reach the best separation efficiency, Type III emulsion should be produced. Microfluidic droplet coalescence experiments were performed with the same compositions as the bottle tests. We correlate microfluidic study with bottle tests to provide a fast characterization and an effective estimation for the optimization of separation conditions of oil and water for the produced water treatment.

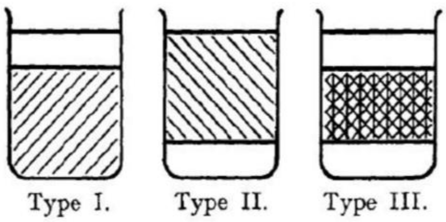

Figure 1. Three types of emulsions for a SOW system. Type I. oil-in-water emulsion; Type II. Water-in-oil emulsion; Type III. Bicontinuous microemulsion. Figure adapted from Salager et al. *Cosmetics* **2020**, 7, 57.