Influence of Ambient Vapor Composition on the Stability and Breakup of Liquid Jets

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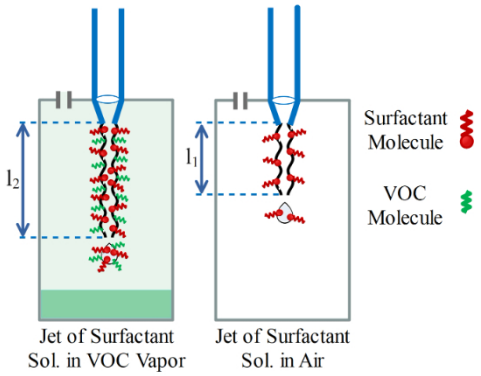
The stability and breakup of liquid-jets are crucial in both fundamental science and industrial applications, necessitating deeper understanding and precise process control. Although factors such as viscosity, surfactant presence, nozzle geometry, and flow rate have been extensively studied, the influence of ambient vapor composition remains largely unexplored. Building upon our previous studies on the impact of surrounding volatile organic compound (VOC) vapors on the surface tension of water and aqueous surfactant solutions, this study investigates how VOC-saturated atmospheres modulate liquid-jet behavior, particularly in surfactant-laden systems. Capillary pressure measurements were complemented by high-speed imaging to quantify jet stability and breakup. Our findings reveal that exposure of surfactant-laden liquid-jets to VOC vapors reduces capillary pressure, enhancing stability and extending continuous jet length. Barely soluble, non-polar VOCs such as pentane, heptane, and toluene influence the jet through co-adsorption at the liquid-air interface, while polar VOCs such as ethanol and acetone affect it through bulk absorption. We observe that pentane-saturated vapor has the strongest effect on a 4.1 mM Sodium Dodecyl Sulfate (SDS) solution jet, where the capillary pressure reduction is three times larger than that caused by surfactants alone, and the continuous jet length increases by 25 % compared to air. Analysis of characteristic timescales reveals that the diffusion timescales of both surfactants and VOCs are shorter than the timescale of jet instability. Notably, VOC adsorption occurs three orders of magnitude faster than surfactant adsorption, rapidly shaping interfacial dynamics. These findings introduce a novel method for modulating liquid-jet stability and breakup by altering the ambient vapor composition.

Keywords:
Jet breakup, Capillary pressure, Co-adsorption, Surfactant, VOC



Schematic illustrating the influence of VOC exposure on the stability of a surfactant-laden liquid jet.