Supplementary Materials

Problem Formulation

The mass and momentum conservation equations for a three-dimensional, isothermal, transient laminar multiphase flow field can be written as follows [52], [53]:

$$\frac{\partial \rho}{\partial t} + \nabla.(\rho \mathbf{v}) = 0 \qquad \textit{Continuity,} \tag{1}$$

$$\frac{\partial}{\partial t}(\rho \mathbf{v}) + \nabla.(\rho \mathbf{v}\mathbf{v}) = -\nabla \mathrm{p} + \mu \nabla^2 \mathbf{v} + \rho \mathbf{g} + \mathbf{F} \qquad \textit{Momentum.} \tag{2}$$

In these equations, t, $\mathbf{v}$, p, and $\mathbf{g}$ are time, velocity vector, pressure, and gravitational acceleration, respectively. ρ, μ, and $\mathbf{F}$ are the apparent density, viscosity, and surface tension force per unit volume, respectively. We utilize the continuum surface force (CSF) approach proposed by Brackbill et al. [54] to implement the surface tension. In this method, the surface tension effect is treated as a source term in the Navier-Stokes equations. This approach considers surface tension as a continuous, three-dimensional source across the interface, instead of a boundary condition at this location. The two-phase version of this model can be written as follows [54]:

$$\mathbf{F} = \sigma \frac{\rho k \nabla \alpha_l}{\frac{1}{2}(\rho_l + \rho_a)}, \tag{3}$$

where the volume fraction of the liquid water phase is shown by α_l. k is the interface curvature, which is related to the unit normal as follows:

$$k = -(\nabla.\mathbf{n}) \; where \; \mathbf{n} = \frac{\nabla \alpha_l}{|\nabla \alpha_l|}. \tag{4}$$

It can be shown that for constant surface tension and perpendicular to the interface, the source term is equal to the pressure difference across the interface ($p_2 - p_1$). The pressure difference can be related to surface tension and surface curvature measured in orthogonal directions, R_1 and R_2 as follows [54]:

$$p_2 - p_1 = \sigma \left(\frac{1}{R_1} + \frac{1}{R_2}\right). \tag{5}$$

Droplet contact behavior with the surface is also predicted by the adhesion model developed by Brackbill et al. [54]. In this strategy, instead of applying boundary conditions at the wall, the droplet contact angle dictates the droplet shape adjacent to the wall. Indeed, this dynamic boundary condition can take care of adjusting the droplet surface curvature near the surface. If θ_w is the contact angle at the wall, the instantaneous droplet surface normal vector near the wall is represented as follows [54]:

$$\mathbf{n} = \mathbf{n}_t \, cos\theta_w + \mathbf{n}_w \, sin\theta_w, \tag{6}$$

where $\mathbf{n}_w$ and $\mathbf{n}_t$ are the unit vectors normal and tangential to the wall, respectively. In this method, the contact angle is combined with the normal surface at one computational cell away from the wall to specify the dynamic local surface curvature on the wall [54]. The adjusted curvature is used to calibrate the body force term in Navier-Stokes equations [54]. To estimate the contact angle, the measured contact angles for some surfaces are listed Table 1S. In this study, the gravitational force is disregarded since it is negligible with respect to inertial forces. The volume fraction of the liquid water phase (α_l) determines fluid variables in each computational cell, which could be either one of the phases or a mixture of them. For example, a simple rule of mixtures is used to compute the effective density and viscosity in each cell [52], [53]:

$$\rho = \alpha_l \rho_l + (1 - \alpha_l)\rho_a, \tag{7}$$

$$\mu = \alpha_l \mu_l + (1 - \alpha_l)\mu_a, \tag{8}$$

where ρ_l and ρ_a stand for water density and air density, respectively. Similarly, water and air viscosity are represented by μ_l and μ_a, respectively. To capture the air-liquid interface, the liquid volume fraction continuity equation is solved [54]:

$$\frac{\partial}{\partial t}(\alpha_l) + \nabla.(\alpha_l \mathbf{v}) = 0, \qquad with\ \alpha_a = 1 - \alpha_l. \tag{9}$$

The described approach has been successfully used in modeling of flow with three-phrase contact line along with experimental and numerical validation [55]–[57].

Table 1S: Contact angle of droplet on various surfaces

Surface	Contact Angle
Glass [47], [48], [58], [59]	5º-15º, 29º
Wood [47], [48], [60]	62º-74º
Stainless steel [48][47], [61]	32º
Cotton [47], [48], [62]	41º-62º
Smartphone screen [47], [48], [63]	74º-94º
N95 mask [47], [48], [64]	97º-99º
PVC-coated surface [47], [48], [65]	80º-84º