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Inactivation of Airborne Viral Surrogates Using Essential-Oil Vapours: Implications for Indoor Air Quality and Exposure Risk Reduction

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Airborne viral aerosols constitute a major exposure pathway for respiratory infection in enclosed indoor environments, particularly in occupational and high-occupancy settings. While ventilation and filtration remain primary control measures, supplementary low-energy strategies that reduce airborne viral viability may enhance risk mitigation where infrastructure upgrades are limited. This study evaluates the efficacy of vapour-phase essential oils as a sustainable intervention for improving indoor air quality through viral aerosol inactivation. Vapours of patchouli (PEO) and frankincense (FEO) essential oils were tested against two viral surrogates representing different structural properties: MS2 (non-enveloped bacteriophage) and Phi11 (enveloped bacteriophage). Experiments were conducted in a sealed metallic chamber under controlled indoor-relevant conditions (25 °C, 55% relative humidity) using a battery-powered diffuser. Viral aerosols were exposed for up to 60 min, with inactivation assessed at 15-min intervals. Decay constants, log reductions, removal efficiencies, and clean air delivery rates (CADR) were calculated to facilitate comparison with established indoor air control metrics. For Phi11, frankincense oil showed the highest efficacy, achieving a decay constant of -2.04 min^{-1}, removal efficiency of 99% and CADR of 23m^3h^{-1} , significantly outperforming both the control (p = 0.0478) and PEO treatment (p = 0.0598). Patchouli oil achieved a decay constant of -0.90 min^{-1}, removal efficiency of 89% and CADR of 12 m^3h^{-1}, with significant improvement over control (p = 0.0202). For MS2, patchouli oil demonstrated superior performance, achieving a decay constant of -1.65 min^{-1}, removal efficiency of 97% and CADR of 21 m^3h^{-1}, with statistical significance compared to control (p = 0.0439) and FEO (p = 0.0401). Frankincense oil showed a decay constant of -1.20 $mint^{-1}$, removal efficiency 93%, and CADR of 15 m^3h^{-1}, also significantly better than control (p = 0.0475). These results support the potential role of essential-oil vapours as a chemistry-informed, low-energy supplementary strategy for reducing airborne viral exposure and improving indoor environmental health.