2026 IDEC Special seminar

Gas-Surface-Microbe Interactions Shape Indoor Microbiomes

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Abstract

Indoor surfaces harbor diverse microbial communities, hosting bacteria originating from human occupants and environmental sources. Yet, despite our constant contact with these surfaces, the chemical factors regulating surface microbes remain poorly understood, particularly regarding the temporal interplay between gas-phase pollutants, deposited organic matter, and bacterial community dynamics. I will present results from our investigations, which integrate field sampling across 20 Hong Kong households with controlled chamber experiments, to show how routine activities and indoor air pollutants shape surface-associated bacterial communities through gas-surface-microbe interactions.

In our field investigations, routine oil-based cooking emerged as the primary driver of surface bacterial diversity and composition among 16 household and occupant-related factors examined. Cooking-derived organic compounds, particularly alkanes, deposited on surfaces and elevated total organic carbon concentrations. This increase in available carbon boosted bacterial abundance while simultaneously reducing community diversity. Network analyses revealed strong associations between these cooking-derived compounds and taxa within Proteobacteria and Firmicutes, suggesting selective pressures imposed by routine activities.

Cooking, however, is not just a source of nutrients. It also emits combustion byproducts like sulfur dioxide (SO_2), particularly from gas stoves or sulfur-containing fuels. This raises a question: can SO_2, at typical indoor levels, suppress the bacterial growth that cooking organics otherwise promote? To answer this, we conducted controlled laboratory chamber experiments to isolate and systematically probe the direct effects of SO_2 on surface-associated bacteria. Using Escherichia coli as a model organism, we demonstrated that indoor-relevant SO_2 concentrations (≤100 ppb) exhibit bactericidal activity, with efficacy strongly modulated by nutrient availability, relative humidity, and microbial density. Mechanistically, SO_2 on surfaces to form sulfate and control surface acidity, which selectively inactivate loosely adherent cells. In contrast, biofilms exhibit markedly greater resistance. To bridge these mechanistic findings to indoor ecologically relevant contexts, we collected microbial communities from real-world kitchens and exposed them to SO_2 under identical chamber conditions. At just 30 ppb, SO_2 consistently reduced bacterial abundance, lowered diversity, and reshaped community composition.

Together, these findings establish a continuous feedback loop: routine human activities release gases and particles that deposit onto indoor surfaces, altering their chemical landscape. These surface chemical changes then act as a key determinant, reshaping indoor microbial communities through both nutrient supplementation and selective inactivation.

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