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Probing indoor microbial VOC emissions with PTR-ToF-MS

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1 Introduction

Despite a number of microbial diversity measurements in residences (e.g. Adams et al. 2014), relatively little is known about their volatile metabolite emissions (Korpi et al. 2009), or how microbial activity varies at short time scales in culture or in healthy houses. Microbial "sniffing" experiments using a proton transfer reaction time-of-flight mass spectrometer (PTR-ToF-MS) were conducted to investigate the factors that control the abundance and diversity of volatile metabolite emissions from microbes in controlled laboratory cultures and in a residence, with the aim of better quantifying and understanding their activity.

2 Materials/Methods

Highly time (1 s) and mass (0.001 amu) resolved measurements of microbial volatile organic compounds (mVOCs) were measured by PTR-ToF-MS in the laboratory using microbial incubation chambers and subsequently in a residence. Microbial community composition analysis of surfaces and aerosols further complemented these chemical and particle-based assays.

3 Results and Discussion

We found that bacteria and fungi emit hundreds of detectable volatile molecules and that emissions change rapidly with stage of growth, environmental conditions, microbial taxa and substrate (culture medium, versus painted or unpainted wallboard). Many of these mVOCs are general in that they were emitted from most or all of the cultures, while other mVOCs were specific to particular species of bacteria or fungi. Moving from specific microbial cultures and lab experiments to more open conditions in a residence, we conducted observational experiments to identify "hotspots" for microbial growth, bioaerosol generation, and microbial production of chemical volatile compounds. Observations revealed at least 100 VOCs that matched the mVOCs observed in cultures and had elevated indoor concentrations as compared to outdoor. The most abundant of these compounds, including acetic acid, methanol, ethanol, and acetone (which we observed to be general microbial tracers), were also observed in association with other indoor sources (e.g. during food preparation and cooking). Therefore, our microbial indoor source apportionment has focused on the main microbial source factors taking advantage of the previously determined mVOC emission fingerprints

that were more specific. Microbial VOC emissions were directly detected close to the waste bins (including a food-waste pail), near wet surfaces in the bathroom, and from stainless-steel coupons placed in the kitchen sink and shower stall for several weeks, so as to allow microbial biofilms to grow. Subsequent genomic analysis of the coupons and tiles revealed that the majority of microbes were food and skin associated. For example, an $C_8H_8O_2H^+$ ion consistent with phenyl acetate and/or methyl benzoate was one fairly abundant component of the chemically specific signature found from sniffing these biofilms. We also observed it as an emission from commensal skin bacteria. In the house (Figure 1), this ion was correlated with numerous other ions known to be mVOCs. It was most strongly correlated with the $C_7H_6O_2H^+$ ion consistent with benzoic acid (also a dermal mVOC) and with less abundant but clear detection of $C_9H_{16}O_2H^+$ corresponding to hydroxynonenal (HNE) and/or nonanoic lactone. HNE is known as a reactive secondary dermal lipid peroxidation product (Niki 2015). This cytotoxic hydroxyalkenal is also produced in dermal and plant cells from lipid peroxidation (Schneider et al. 2008) At high concentrations, it may exhibit antimicrobial activity (Burgassi et al. 2009). On the other hand, nonalactone is a flavour component of different foods and can be a signalling molecule in many bacteria (γ-nonalactone, GNL) and secondary metabolites of fungi (δ-nonalactone, DNL) (Schulz and Dickschat 2007, Beck et al. 2012). The microbial tracers associated with food and skin had temporal patterns aligned with human presence and temperature. Concentrations of these ions significantly decreased during vacant periods, but they were still observed with temporal patterns that suggest temperature dependent microbial activity on indoor surfaces, or possibly utilizing residues such as deposited skin flakes or food-related substrates such as fatty acids.

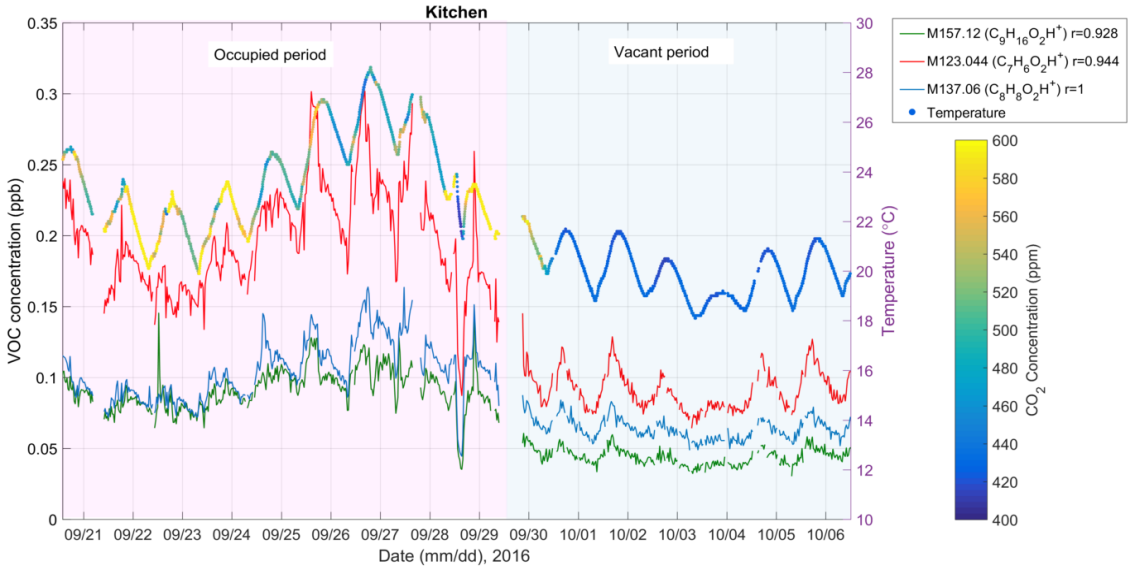

Figure 1: Example of presumed microbial metabolites (food and skin related) in a house.

4 Conclusions

Quantifying emission factors of microbial volatiles (including volatile metabolites) emitted from cultures isolated from residences allows for linking genomic analyses with volatiles and can be useful for tracking these chemical fingerprints in the indoor environment to detect microbial activity. Despite relatively low concentrations of highly specific mVOCs indoors, microbial signature ions point to microbial presence and activity on surfaces.

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