INTERIORS: A new Indoor Air Quality Research Testing Facility at the University of York

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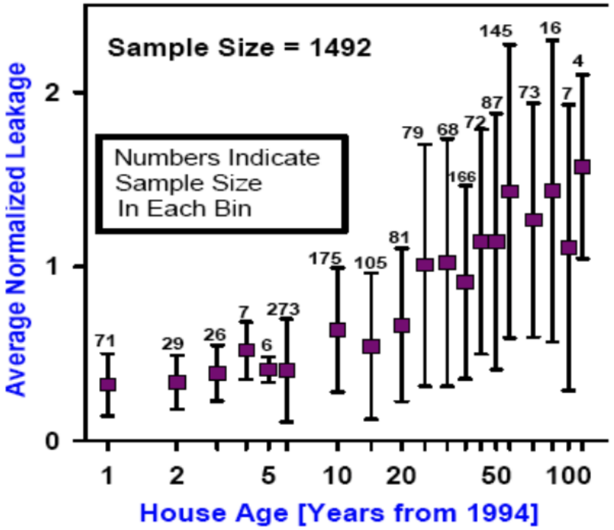
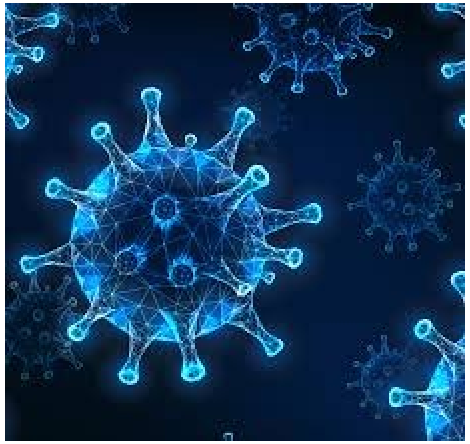
Overview

- Why is indoor air pollution important?
- How can building materials affect indoor air quality?
- The new INTERIORS facility: an introduction.
- Summary

Why is indoor air pollution important?





http://www.dailymail.co.uk/news/article-2104579/The-magic-1950s-suburbia-socks-darned-baths-shared-kids-roamed-wild.html; http://home.bt.com/tech-gadgets/internet/online-gaming-for-kids-advice-for-parents-how-to-protect-your-child-11364060707336; https://publications.lib.chalmers.se/records/fulltext/139940.pdf ; https://sdm-partners.com/en/news/architects-obliged-to-design-only-energy-efficient-housing/; https://teachingenglishinportugal.wordpress.com/2009/04/30/environment-cartoons/#jp-carousel-56;

Sources of indoor pollution

Some direct emissions plus some chemical production from these emissions…..

Courtesy of Toby Carter, University of York

Health Implications

“*Air pollution is one of the greatest environmental risks to health. By reducing air pollution levels, countries can reduce the burden of disease from stroke, heart disease, lung cancer, and both chronic and acute respiratory diseases, including asthma*” World Health Organisation.

https://ncas.ac.uk/our-science/air-pollution/

How do building material emissions affect IAQ?

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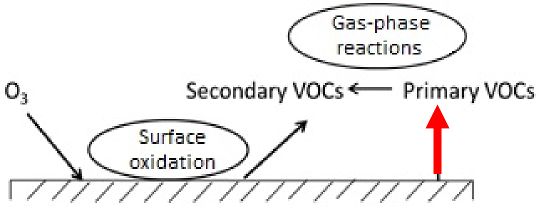
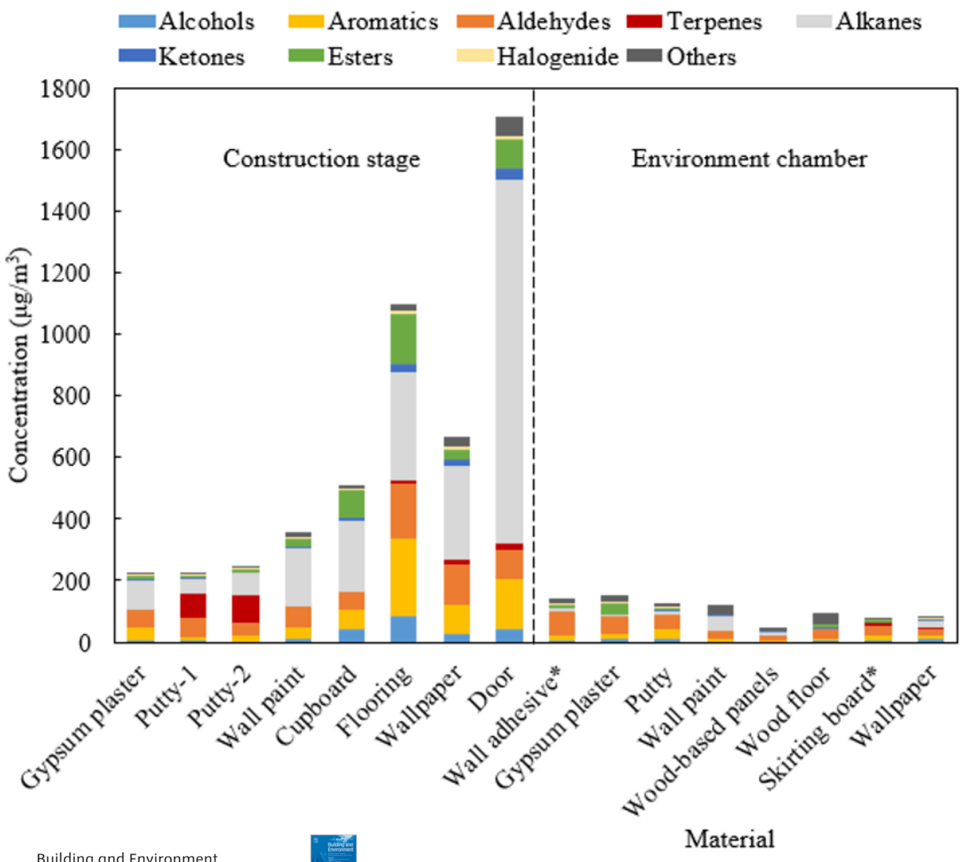
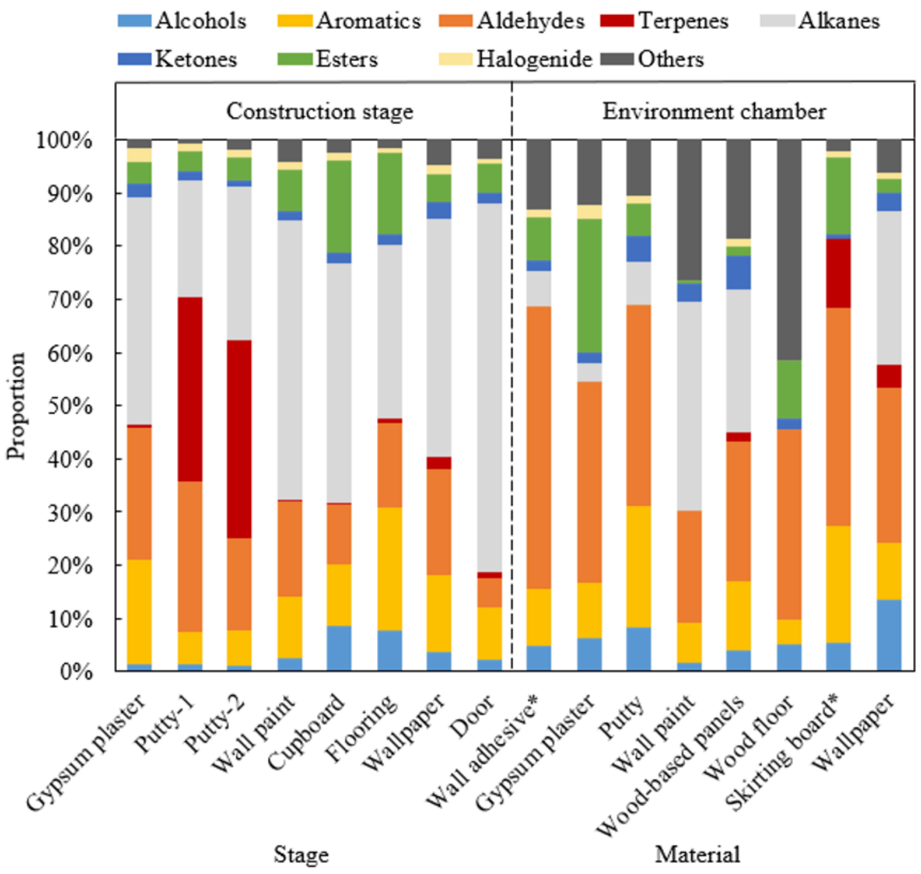
Courtesy of Toby Carter, University of York

- Primary VOC emissions
- Primary VOC emissions can react with other air pollutants to form secondary VOCs
- Secondary VOC emissions follow deposition of ozone (and other gases) onto surfaces

Emissions from building materials





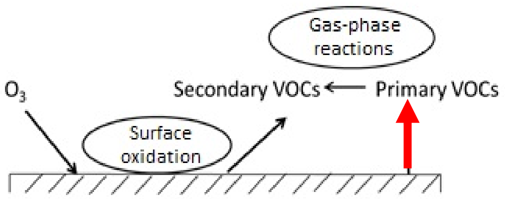


Building and Environment
Volume 252, 15 March 2024, 111257

Volatile organic compounds and odor emissions characteristics of building materials and comparisons with the on-site measurements during interior construction stages

Shan Guo, Weihui Liang

- Aldehydes main emission in the chamber
- Wet materials contributed most in first 24 h
- Wooden floor was the biggest emitter after 720 h



What about green building materials?

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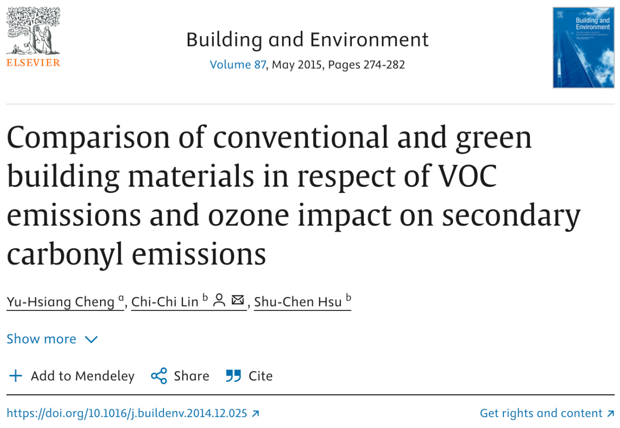

ELSEVIER
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Comparison of conventional and green building materials in respect of VOC emissions and ozone impact on secondary carbonyl emissions

Yu-Hsiang Cheng [a], Chi-Chi Lin [b], Shu-Chen Hsu [b]

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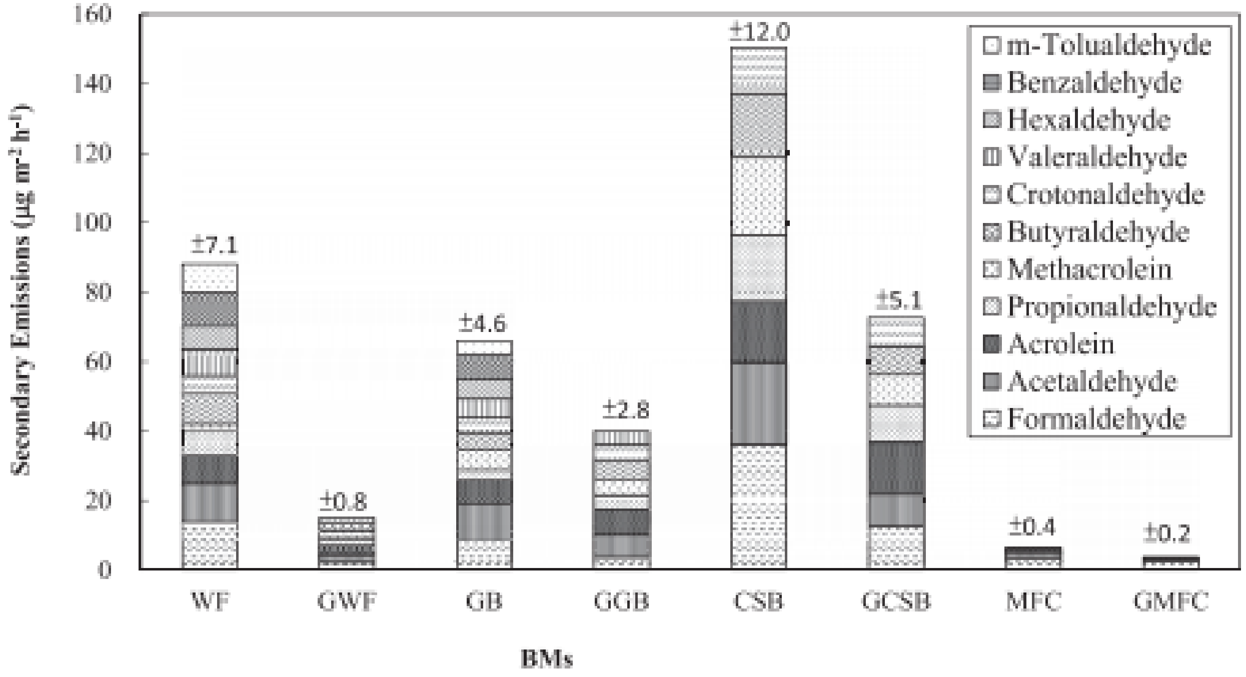
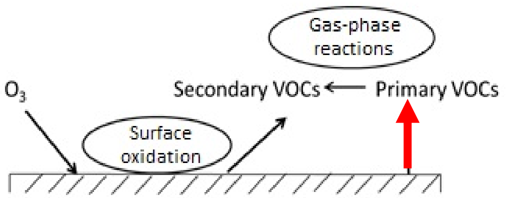


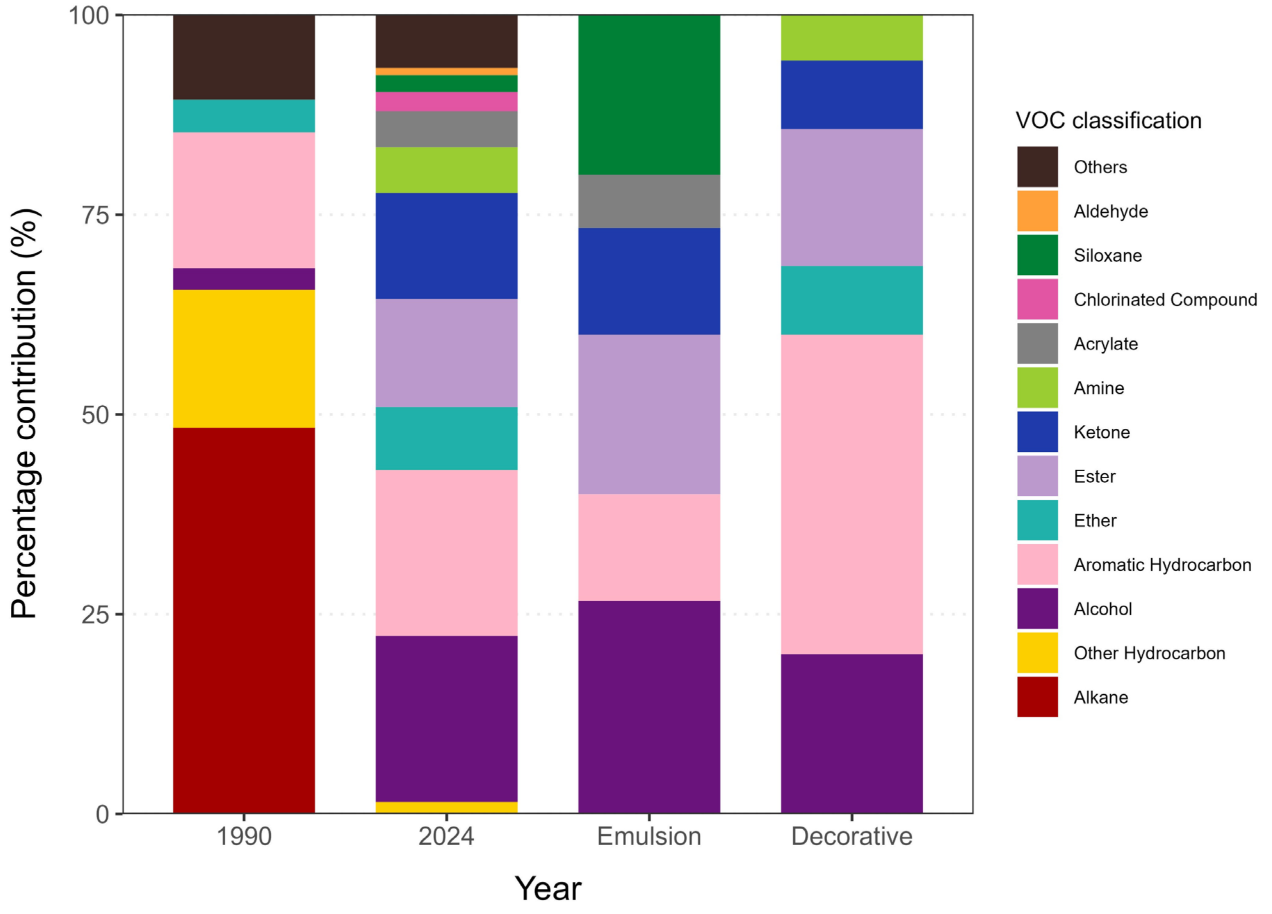
Fig. 10. Secondary carbonyl emissions from BMs. "±"above each column is the larger of propagated instrument error or standard error of the sum secondary emissions of each detected carbonyl.

WF = wooden floor
GB = gypsum board
CSB = calcium silicate board
MFC = mineral fibre ceiling

- In all cases, emissions (primary and secondary) from GBMs lower than from traditional
- Ozone deposition velocities onto GBMs also lower than for traditional materials
- Relatively few studies at the moment



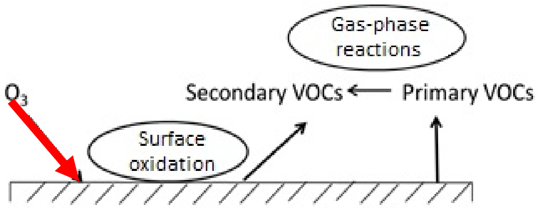
Paint emissions work at York



- Investigating paint formulations before and after EU Paints Directive (2004/42/EC)
- Modern decorative paints (water-based) phased out alkanes and moved towards oxygenated compounds for lower emissions and improved performance
- Far less likely to produce formaldehyde than before the Directive

Work led by Lidia Alfanti in the Department of Chemistry (& Ally Lewis, Sarah Moller, Dave Shaw and Andrew Rickard)

Ozone deposition onto surfaces



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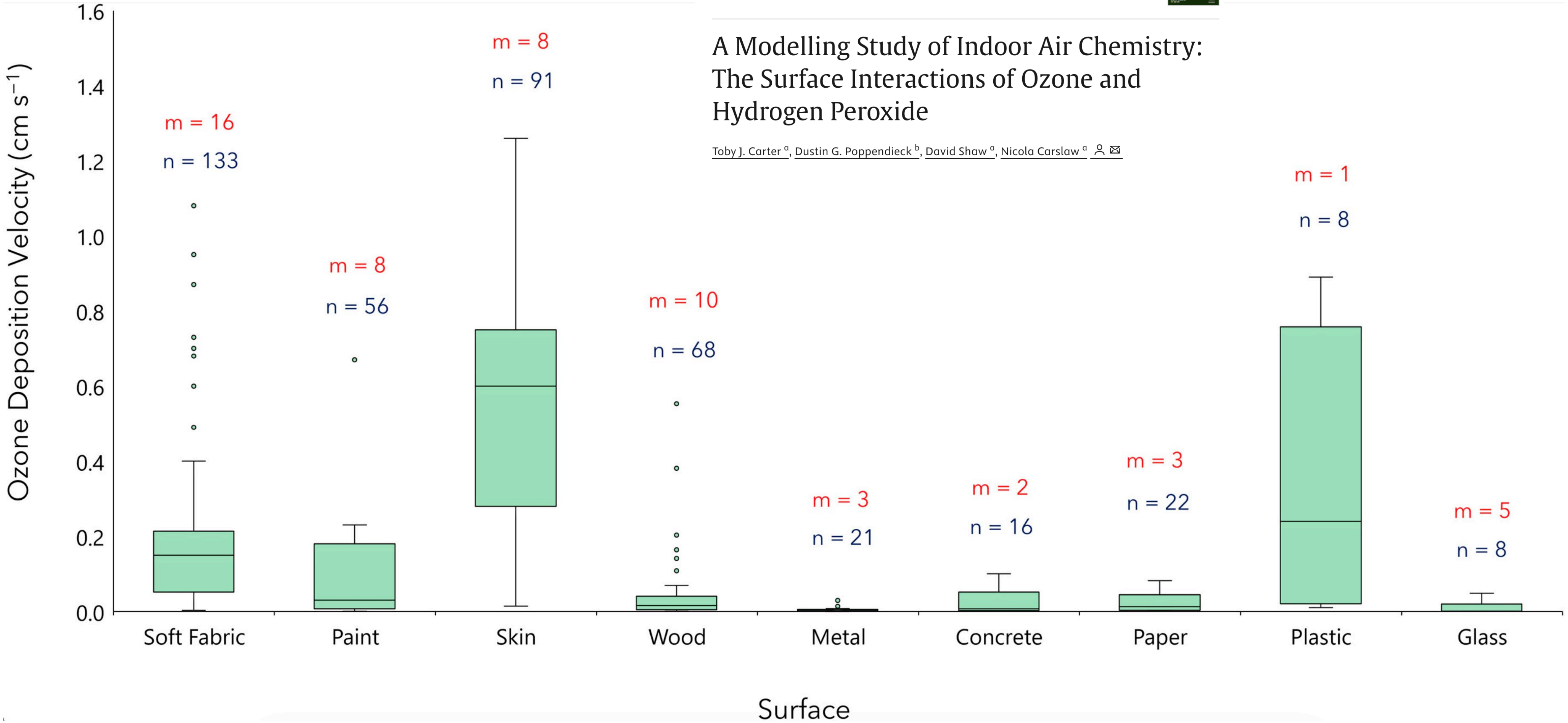
A Modelling Study of Indoor Air Chemistry: The Surface Interactions of Ozone and Hydrogen Peroxide

Toby J. Carter [a], Dustin G. Poppendieck [b], David Shaw [a], Nicola Carslaw [a]



Emissions from surfaces

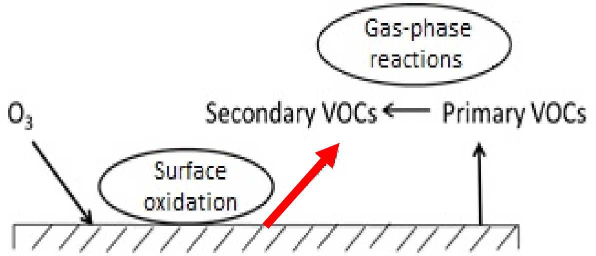


Table S1: Production yields for species as a result of ozone deposition onto soft fabric, painted (Wang and Morrison, 2010), skin (Weschler et al., 2007; Kruza and Carslaw, 2019), wooden (Cheng et al., 2015), metallic, concrete, paper (Poppendieck et al., 2007), and plastic (Coleman et al., 2008) surfaces. The surfaces without yields indicate the yield was below the limit of detection (LOD) or the species wasn't measured for that surface. The units are dimensionless.

	Production Yield (dimensionless)								
Species	Soft Fabrics	Paint	Skin	Wood	Metal	Concrete	Paper	Plastic	Glass
Formaldehyde	0.0335	-	-	0.7152	0.0007	0.0004	0.0004	0.0191	-
Acetaldehyde	0.0040	-	-	0.3908	0.0007	0.0005	0.0019	0.0127	-
Propanal	0.0050	-	-	0.1923	0.0002	0.0003	0.0002	-	-
Butanal	0.0035	-	-	0.1883	0.0001	0.0001	0.0002	0.0051	-
Pentanal	0.0058	-	-	0.1387	0.0001	0.0001	0.0003	0.0051	-
Hexanal	0.0200	-	-	0.1022	0.0002	0.0001	0.0010	0.0051	-
Heptanal	0.0064	-	-	-	-	-	2.481×10^{-5}	0.0051	-
Octanal	0.0061	0.0100	-	-	1.721×10^{-6}	-	1.944×10^{-5}	0.0051	-
Nonanal	0.0483	0.1333	0.0180	-	-	-	1.294×10^{-5}	0.0331	-
Decanal	0.0144	0.0433	0.0260	-	-	-	-	0.0255	-
2-Nonenal	0.0019	-	-	-	-	-	-	-	-
Acrolein	-	-	-	0.2268	-	-	-	-	-
Methacrolein	-	-	-	0.0398	-	-	-	-	-
Crotonaldehyde	-	-	-	0.1162	0.0001	1.136×10^{-5}	-	-	-
Benzaldehyde	-	-	-	0.1431	-	2.995×10^{-5}	0.0001	-	-
m-Tolualdehyde	-	-	-	0.1038	5.903×10^{-6}	-	1.092×10^{-5}	-	-
4-OPA	-	-	0.0260	-	-	-	-	-	-
Acetone	-	-	0.0049	-	-	0.0005	0.0013	0.0242	-
Formic Acid	-	-	0.0085	-	-	-	-	-	-
Acetic Acid	-	-	0.0065	-	-	-	-	-	-
Isopentanal	-	-	-	-	3.158×10^{-5}	1.445×10^{-5}	0.0002	-	-
2,5-DMBA	-	-	-	-	-	2.637×10^{-6}	-	-	-

- Some of the highest yields are for aldehydes from wooden surfaces
- Painted surfaces have relatively high yields (*), but few measurements
- Lots of gaps, lots of variability

Typical surfaces indoors

Environmental Science Processes & Impacts

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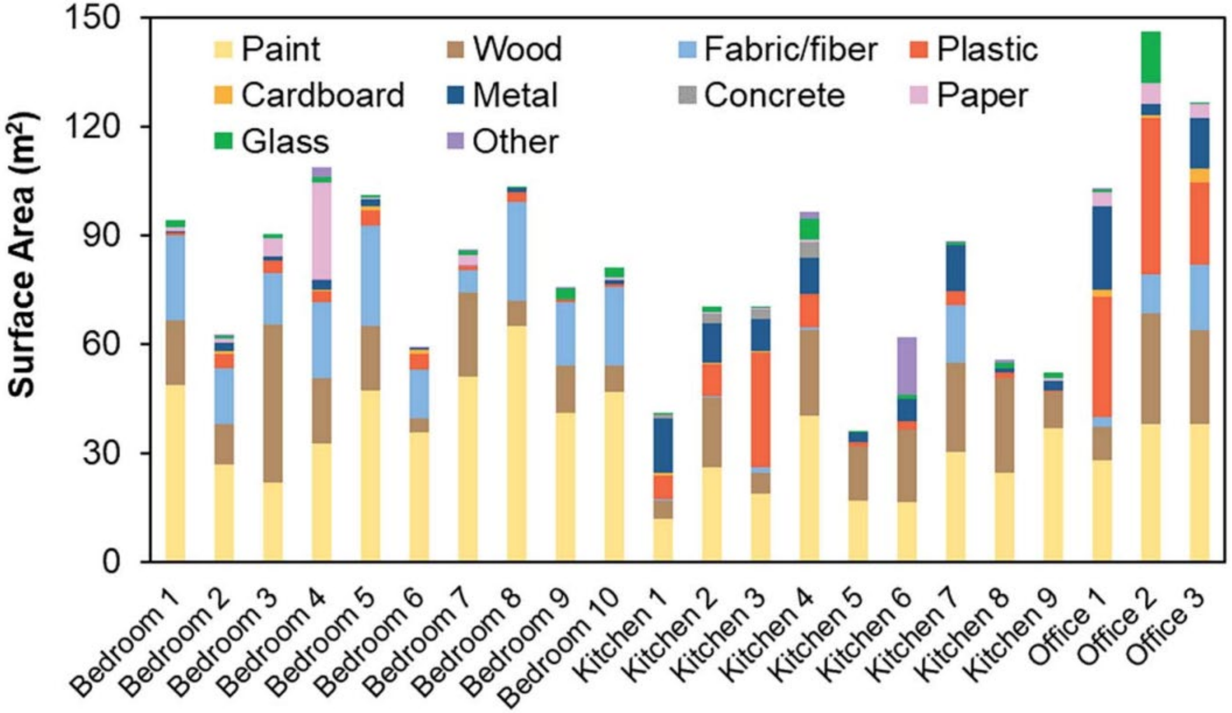
Cite this: *Environ. Sci.: Processes Impacts*, 2019, **21**, 1384

Total surface area in indoor environments†

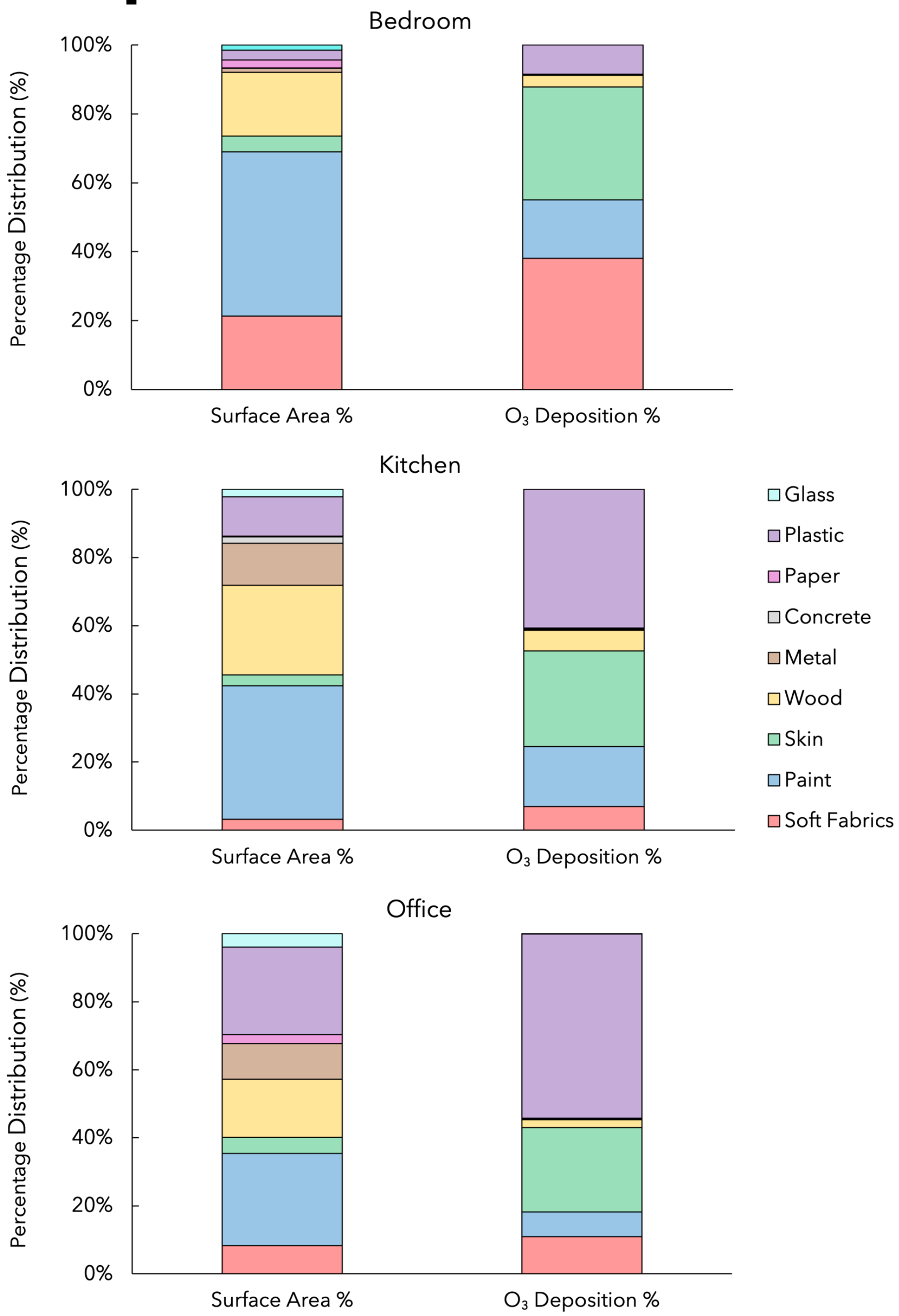
Archit Manuja,[a] Jenna Ritchie,[a] Khantil Buch,[a] Yaoxing Wu,[b] Clara M. A. Eichler,[a] John C. Little[a] and Linsey C. Marr *[a]

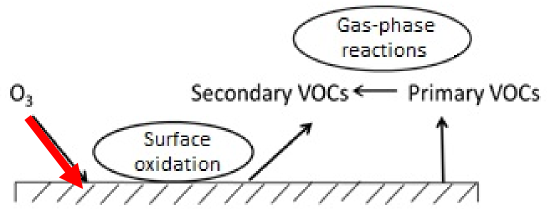


	Surface area (m^2)	
Room	S	S^*
Bedrooms	60 ± 11	86 ± 17
Kitchens	45 ± 15	64 ± 20
Offices	70 ± 15	125 ± 22
All	56 ± 16	82 ± 27

- S/V with contents ~ 3.0, 3.2 and 3.6 m^{-1} respectively with contents, compared to 2.0, 1.7 and 1.9 m^{-1} when empty.
- Painted surfaces accounted for 42% of total surface

Ozone deposition on internal surfaces





- Painted surfaces are biggest by SA, but ozone prefers to stick to other surfaces
- Plastic looks important, but relatively few measurements of deposition velocity (1 study)

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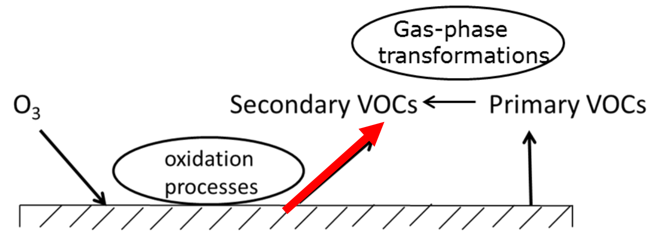
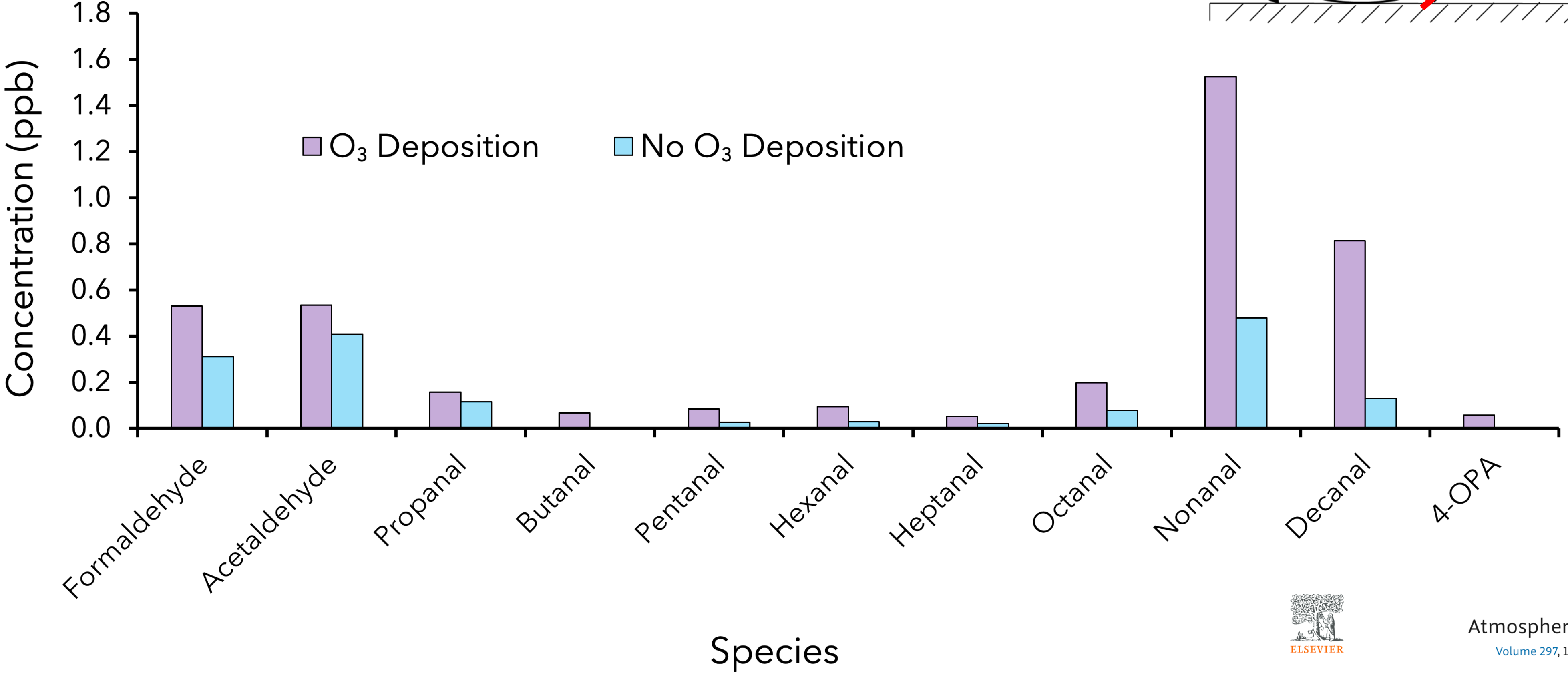
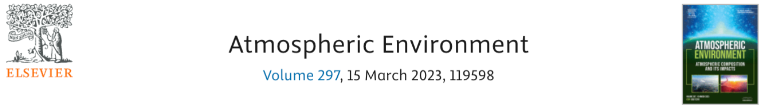
Emissions from surfaces (office)





- Formaldehyde, acetaldehyde from wooden surfaces
- Painted surfaces dominate nonanal emissions (*)
- Skin emissions from 3 people for decanal emissions



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INTERIORS: Interdisciplinary Facility for **I**nd**o**or Air Quality **Res**earch

The Wolfson Foundation

University of York

- Two three-bedroomed houses either side of an integrated air sampling laboratory: Passivhaus and standard
- Passivhaus is a proxy for Net Zero housing of the future
- Both houses are naturally ventilated, connected to mains water and electricity
- A custom-built gas sampling system enables air to be sampled from any room in each house, or outdoors.

Scientific Objectives

Unprecedented characterisation of IAQ under background and high concentration activities such as cleaning, and cooking

Quantification of the emissions from commonly-used building, furnishing and consumer products (including 'green') in a realistic setting over time

An understanding of the efficacy, lifetime and potential secondary impacts of consumer and material products used indoors

Characterisation of long-term emissions indoors, such as from materials as they age

Input to help models identify conditions where IAQ is likely to be harmful to human health, how this will change in the future and how we can improve product formulations generate fewer harmful pollutants

Identification of solutions to improve IAQ.

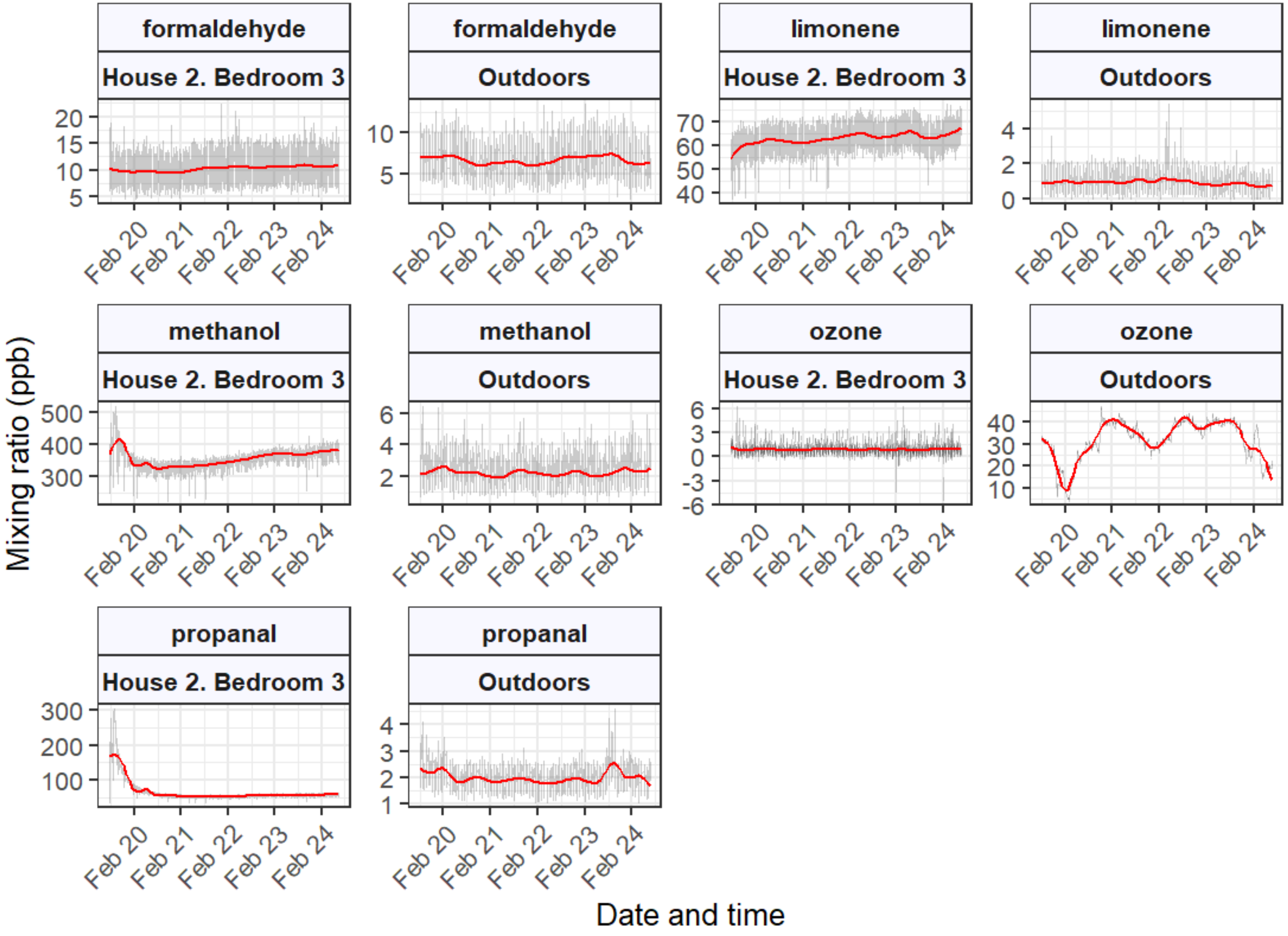
Instrumentation

Table 1: Instrumentation in INTERIORS facility.

Instrument	Species	Precision / detection limit 1σ	Time resolution / s	Notes
Located in integrated laboratory				
MIRO MGA8	HCHO, N_2O	0.5ppb, 0.1ppb	1s, 200s	
	HONO	2ppb, 0.4ppb	1s, 200s	
	CO_2	500ppb, 50ppb	1s, 200s	
	NH_3	0.1ppb, 0.02ppb	1s, 200s	
	H_2O	20ppm,2 ppm	1s, 200s	
	O_3	1ppb, 0.2ppb	1s, 200s	
	CO	0.4ppb, 0.1ppb	1s, 200s	
Los Gatos Research UGGA	CH_4	1.4ppb, 0.2ppb	1s, 100s	CO_2, H_2O: 300 ppb & 50 ppm respectively at 1s.
SIFT-MS (Voice200 Ultra, Syft Technologies)	~20 VOCs	10 - 100ppt	60s	VOCs: oxygenated, aromatic, alkanes, terpenes.
Teledyne T200UP NOx analyser	NO, NO_2	500ppt, 50ppt	10s, 600s	Precision: 0.5% >5 ppb
One instrument per house				
Palas AQ Guard	Coarse PM: 0.175–20 µm, 64 bins	$PM_{2.5}$ R^2 >0.98, PM_{10}>0.94 for EN 16450-certified Fidas® 200	1s	
Single instrument placed where needed				
TSI SMPS / water CPC, model 3938	Fine PM: 10–1000 nm,128 bins	Dynamic concn range up to 10^7 particles/cm^3	10s	
QUMA LOPAP	HONO	2 ppt	60s	
FIDAS 200	Outdoor PM	Measurement uncertainty $PM_{2.5}$ 9.7%, PM_{10} 7.5%	1s	Sample inlet on the laboratory roof.

- Also have GC-MS which can quantify ~100 VOCs

Preliminary paint experiments



Courtesy of Tom Warburton, Lidia Alfanti, University of York

Summary

- Many sources of VOCs from building materials indoors
- Surfaces are relatively more important indoors compared to outdoors
- Painted surfaces are often the biggest surface areas indoors and can have large impacts on IAQ
- Green BMs appear to have lower emissions than traditional BMs
  - What does green mean (sustainable versus low emission)?
- Need more information on:
  - Deposition rates to surfaces
  - Emission yields of chemicals from different surfaces
  - More studies on GBMs
- Also need more testing to be carried out in realistic environments

- INTERIORS will be available for experiments from autumn 2026
- Please contact nicola.carslaw@york.ac.uk for details