

Indoor air chemistry

David Shaw – 04/05/2020



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Background: BSc Physics with Astrophysics
MSc Fusion Energy
PhD Plasma Physics



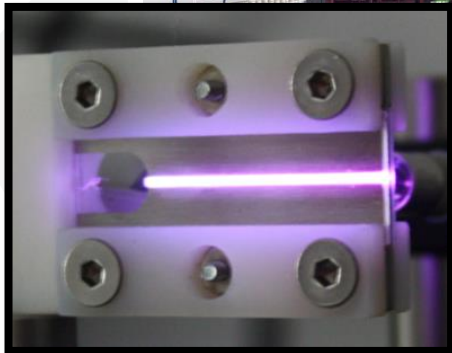
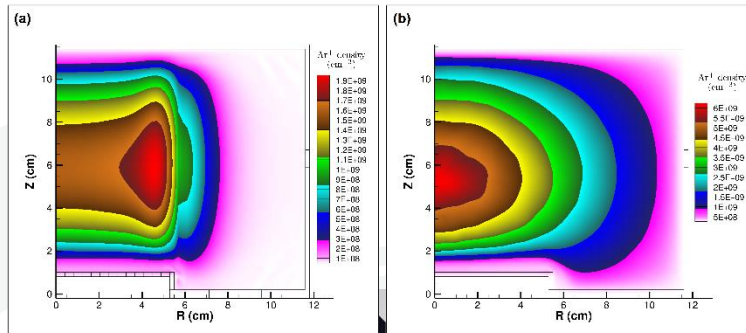
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Prof Nic Carslaw
Dr Magda Kruza
Dr Freja Oesterstroem
Zixu Wang



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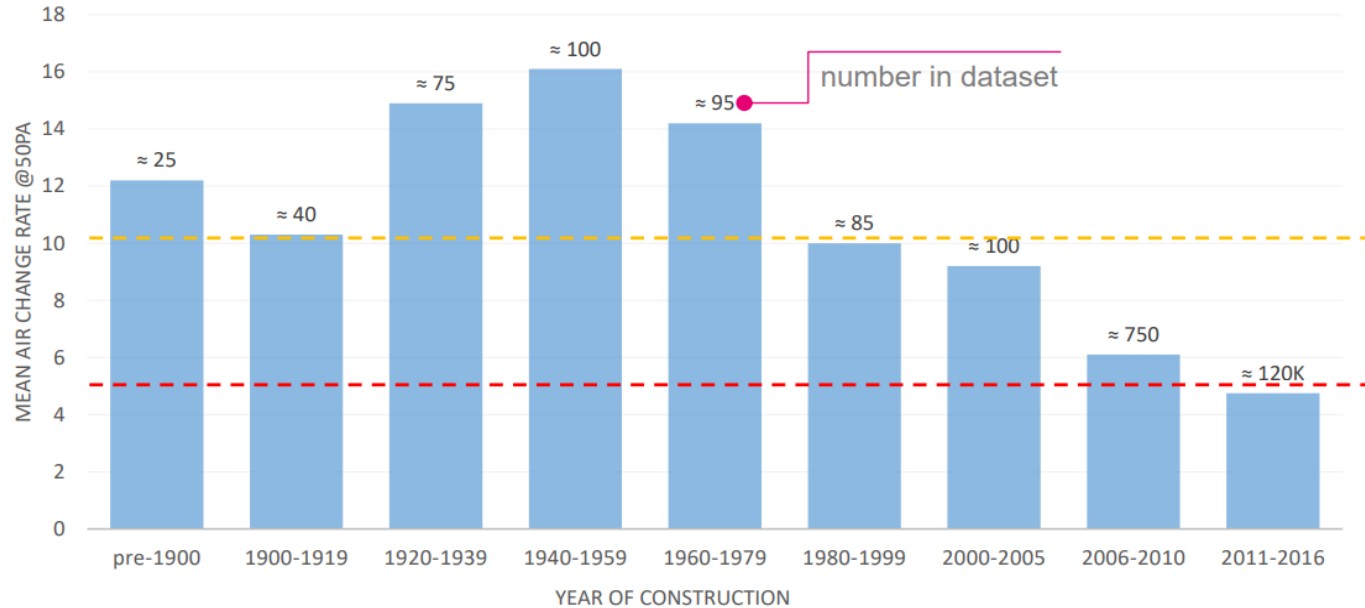
Why study indoor air?



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Why now?

Air permeability trends: house age



<https://www.property-care.org/wp-content/uploads/2017/05/lan-Mawditt-presentation-PCA-Conference-4th-May-2017.pdf>



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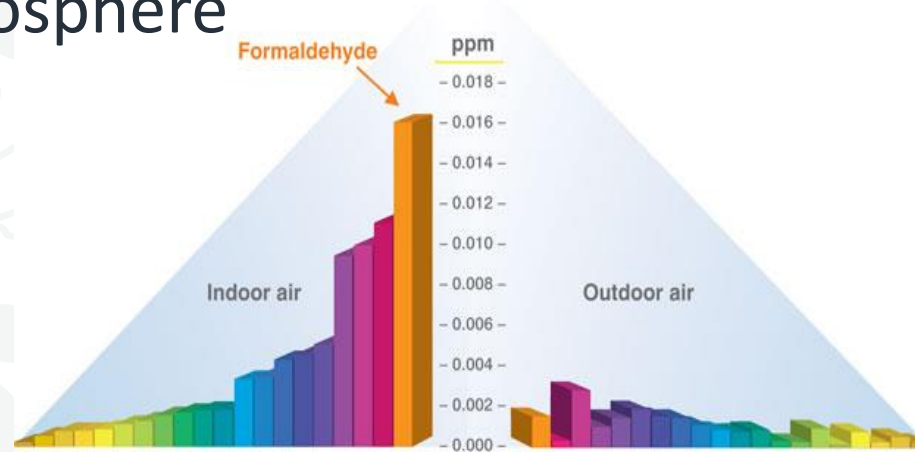


5

The indoor atmosphere



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Cooking

Particle numbers per cm³

Frying vegetables (500 g) – gas stove	1.4×10^5
Frying bacon (4 racers) – gas stove	5.9×10^5
Frying vegetables (500 g) – electric stove	0.11×10^5
Frying bacon (4 racers) – electric stove	1.6×10^5
Bake cake – gas oven	0.9×10^5
Bake cake – electric oven	0.3×10^5
Roast meat and potatoes – gas oven	1.2×10^5
Roast meat and potatoes – electric oven	0.2×10^5
Toast – gas grill	1.4×10^5
Toast – electric grill	1.4×10^5



- Cooking with gas generally leads to higher emissions than cooking with electric
- Cooking meat generally gives higher emissions than cooking vegetables

Abdullahi et al., Atmospheric Environment 71 (2013) 260-294



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Cooking

Frying 50 g of chips in a gas stove at maximum power with:

Olive oil

Peanut Oil

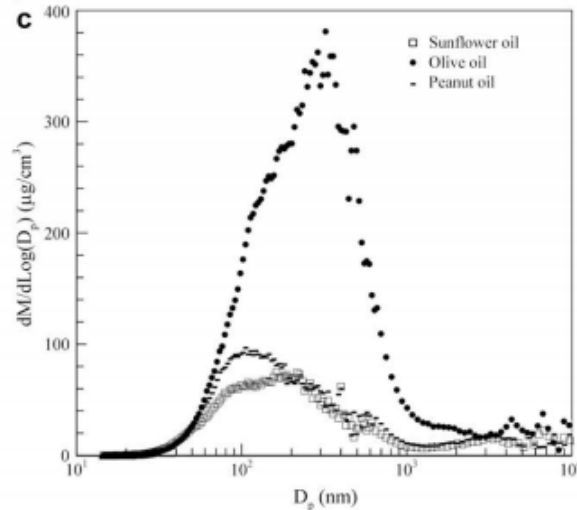
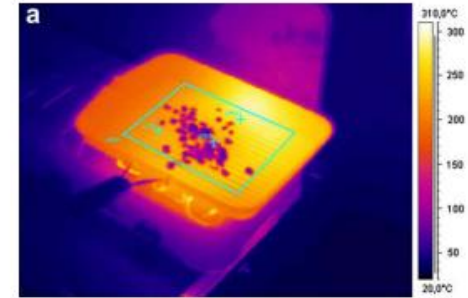
Sunflower Oil

Concentration
 $\mu\text{g}/\text{m}^3$

118

68

60



- Olive oil > Peanut oil > Sunflower oil
- Note that these concentrations are very much higher (x2-10) than those you would measure outdoors in most urban environments

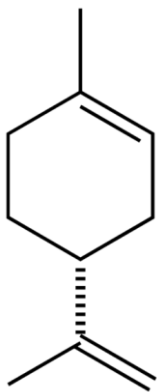


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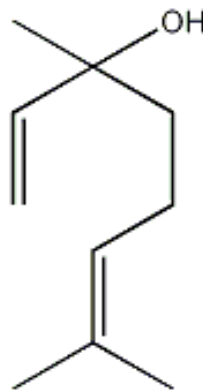
Cleaning - Terpenes



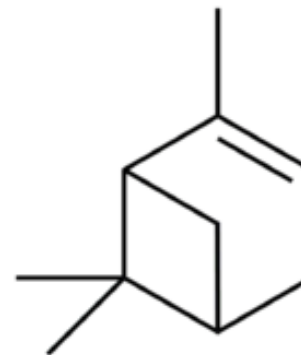
Limonene



Linalool



Pinene



Cleaning



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Limonene
reaction
pathways to
oxidation end
product, CO₂
and Water

713 species in
1241 reactions



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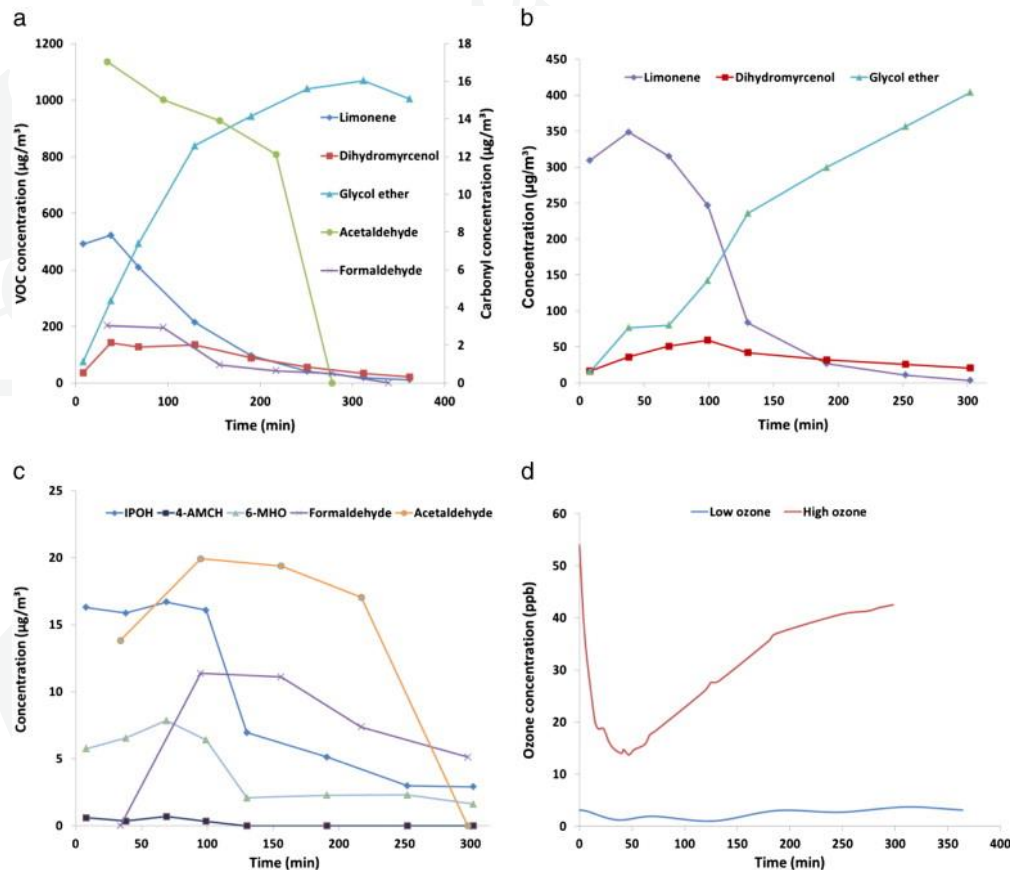
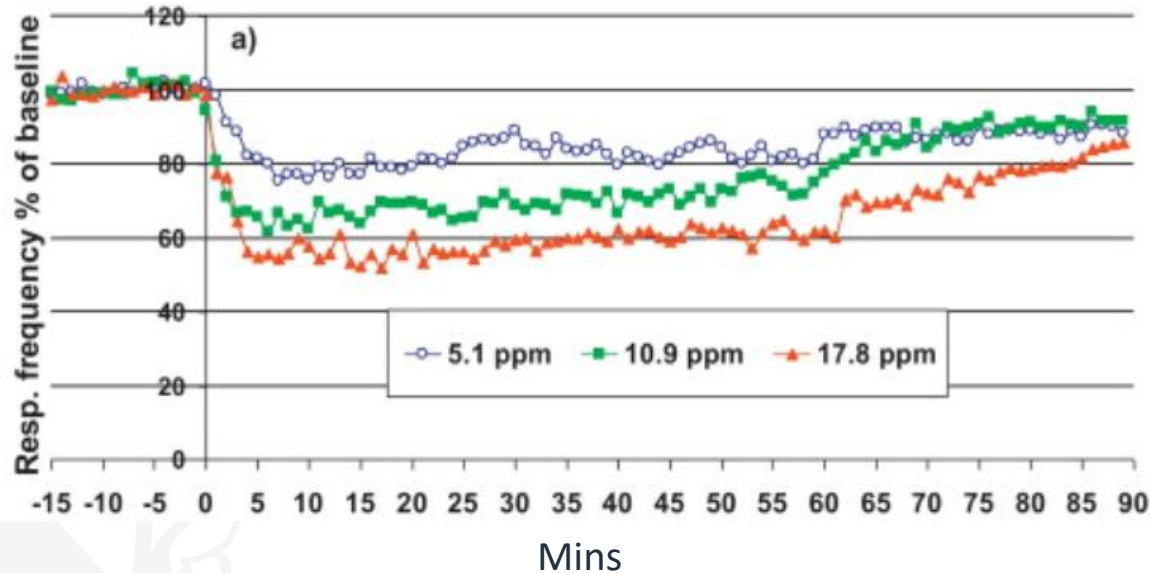


Fig. 1. Gas-phase concentrations of selected VOCs emitted from a kitchen cleaning agent and ozone-initiated reaction products.

- a) Low ozone test concentration (< 5 ppb).
- b) High ozone test concentration (55 ppb).
- c) Reaction products at high ozone test concentration.
- d) Ozone time profiles.





3-Isopropenyl-6-oxo-heptanal (IPOH) concentration
versus decrease of the respiratory frequency curve.

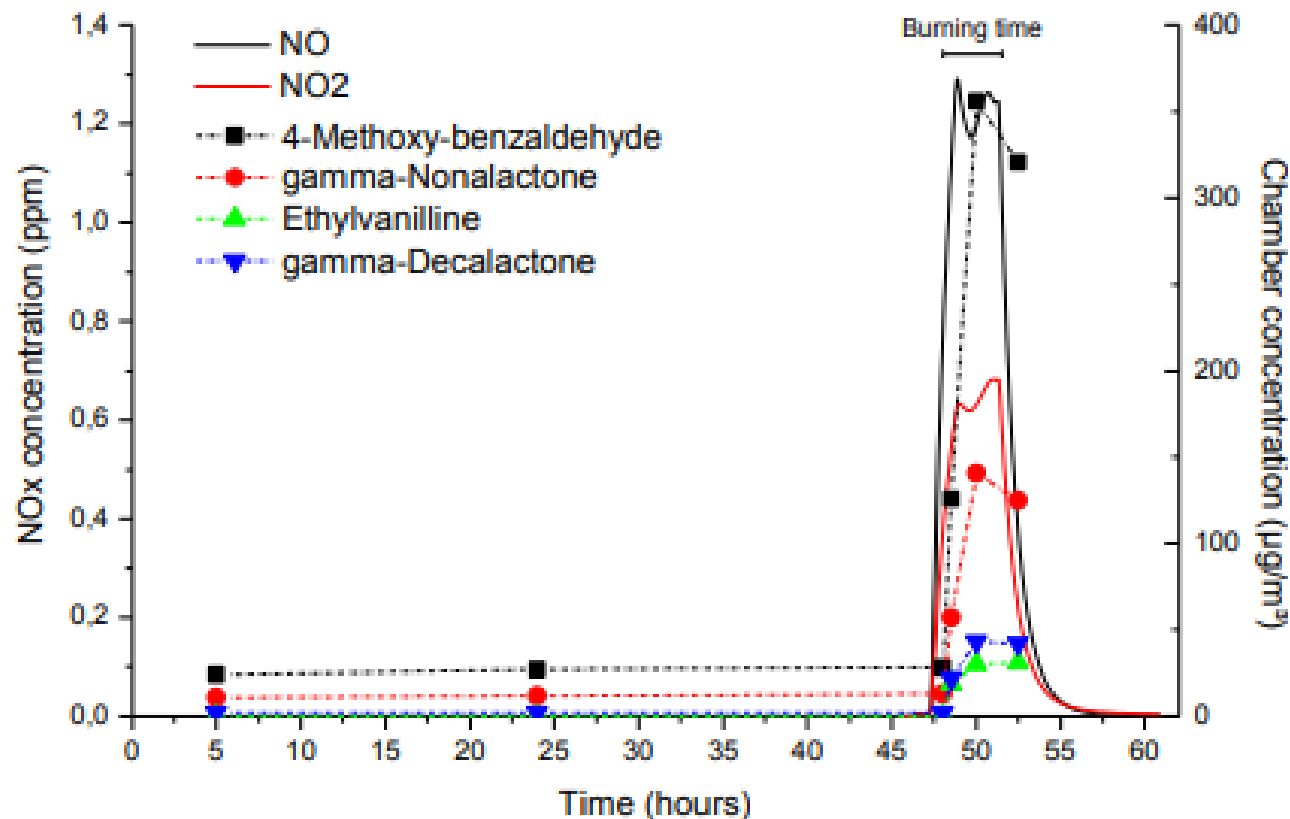


Scented candles



Global candles market was valued at US\$ 7.5 Billion in 2016 and is expected to reach US\$ 11.7 Billion by 2025 (5-6% growth per year)!!



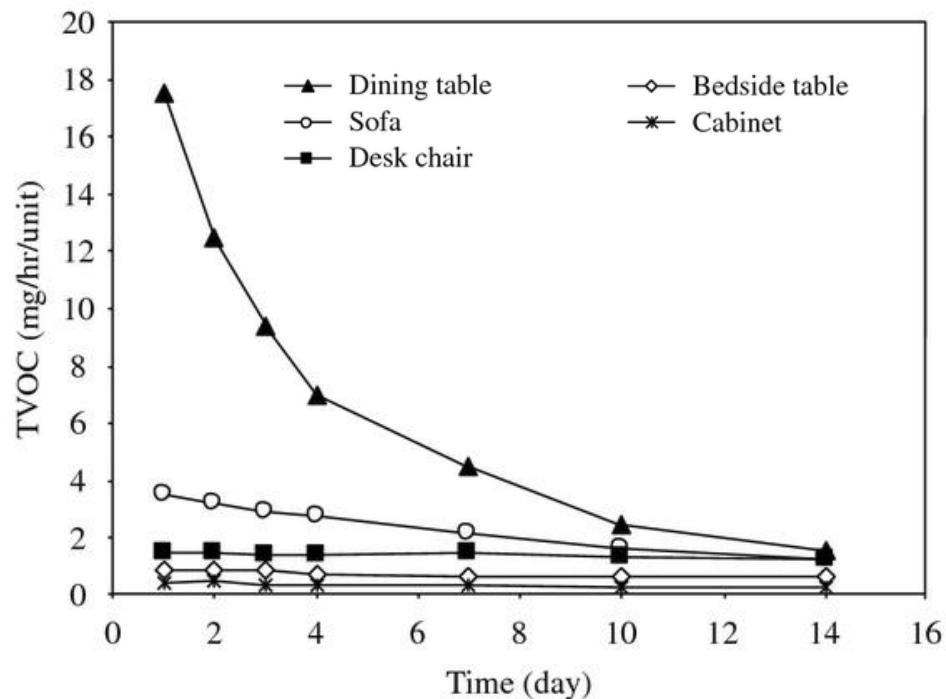


NO₂ levels similar to
central London
morning rush hour



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Surface emissions



<https://www.hindawi.com/journals/tswj/2011/650624/fig3/>



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Human emissions

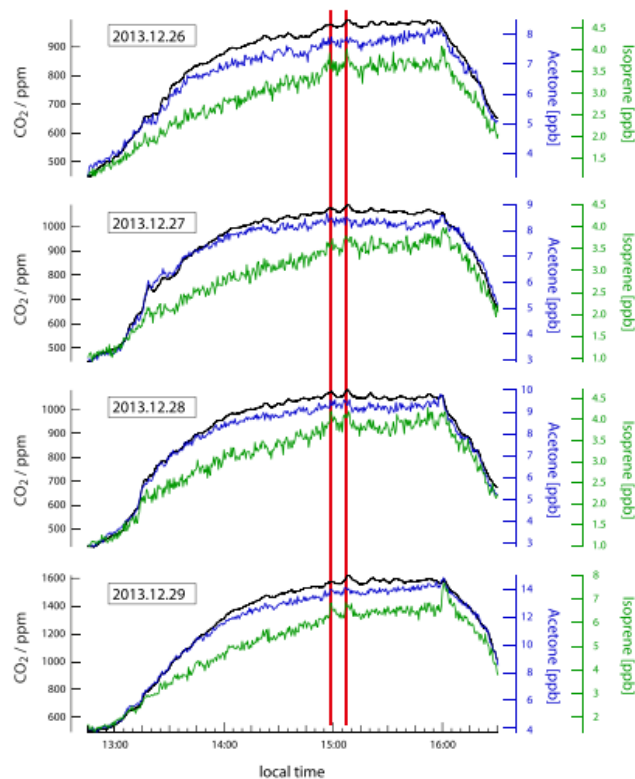
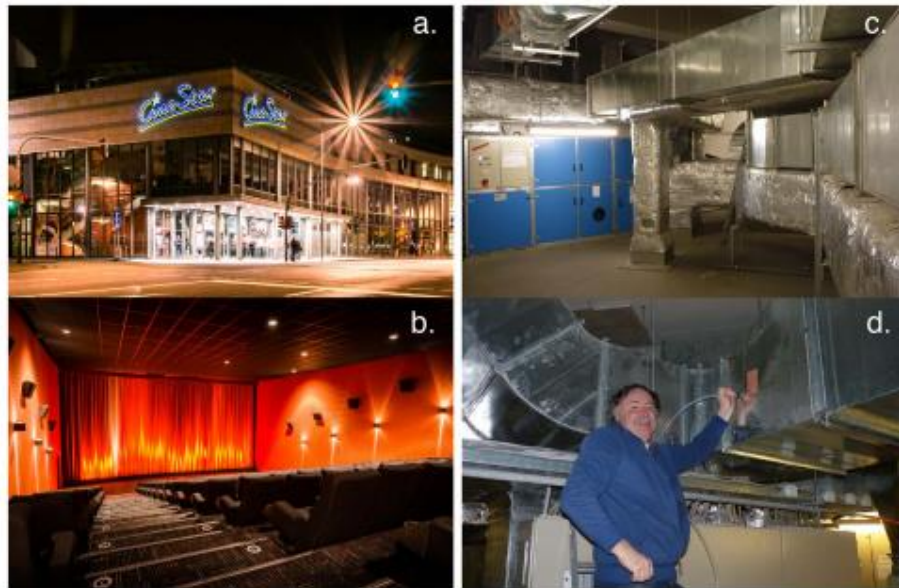


Figure 2. Measurements of CO_2 , isoprene and acetone taken during four separate screenings of "Hunger Games 2".

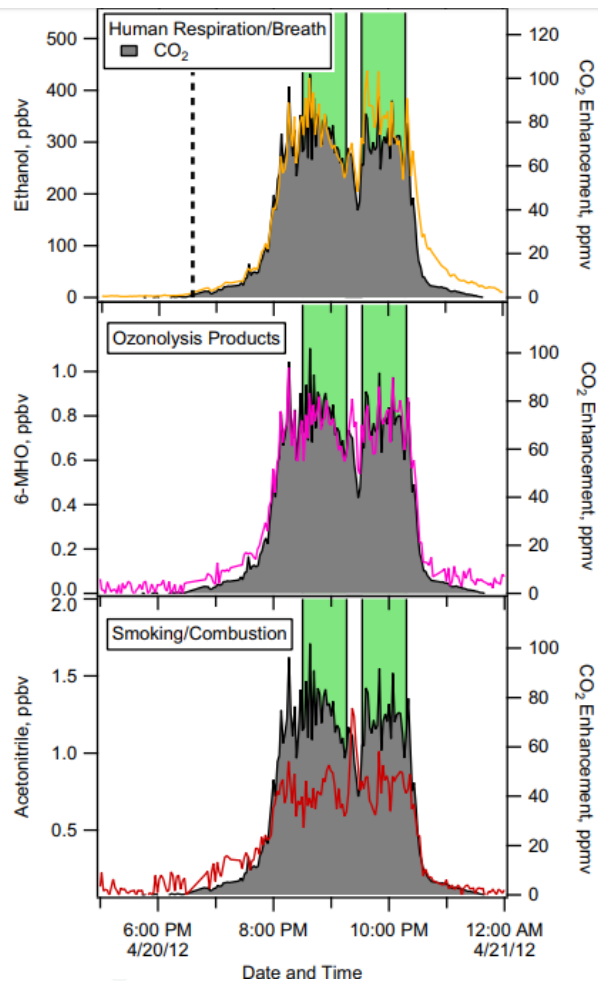


Nature Scientific Reports | 6:25464
| DOI: 10.1038/srep25464



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Human emissions



Atmospheric Environment 77 (2013) 1052-1059

The Indoor Detailed Chemical Model (INDCM)



$$\frac{dC_i}{dt} = -V_d \left(\frac{A_i}{V_i} \right) C_i + \lambda_r f C_o - \lambda_r C_i + \frac{Q_i}{V_i} + \sum_{j=1}^n R_{ij}$$

C_i = Concentration of species indoors

V_d = Deposition velocity

A_i = Surface area of the room

V_i = Volume of the room

λ_r = Indoor/outdoor exchange rate

f = Penetration factor

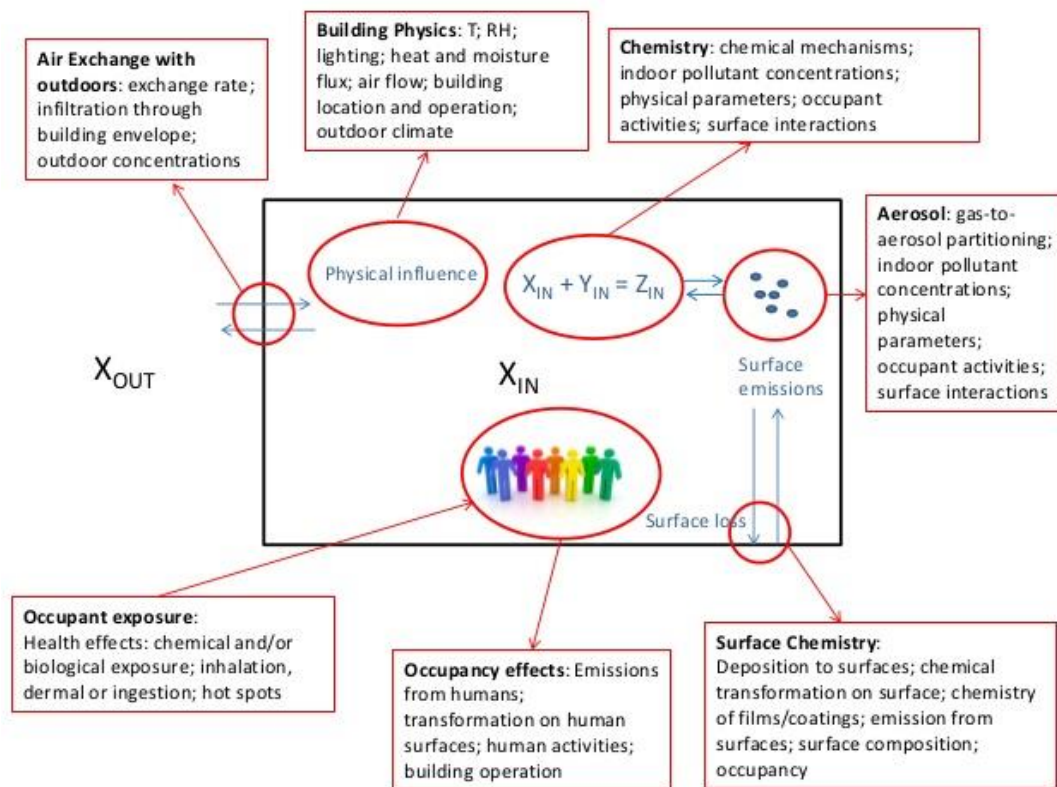
Q_i = Indoor emission rate

R_{ij} = Gas phase reaction between species i and j



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The Indoor Detailed Chemical Model (INDCM)



The Master Chemical Mechanism (MCM)

<http://mcm.leeds.ac.uk/MCM>

“The Master Chemical Mechanism (MCM) is a near-explicit chemical mechanism which describes the detailed gas-phase chemical processes involved in the tropospheric degradation of a series of primary emitted volatile organic compounds (VOCs). Currently, the degradation of methane and 142 non-methane VOCs is represented”



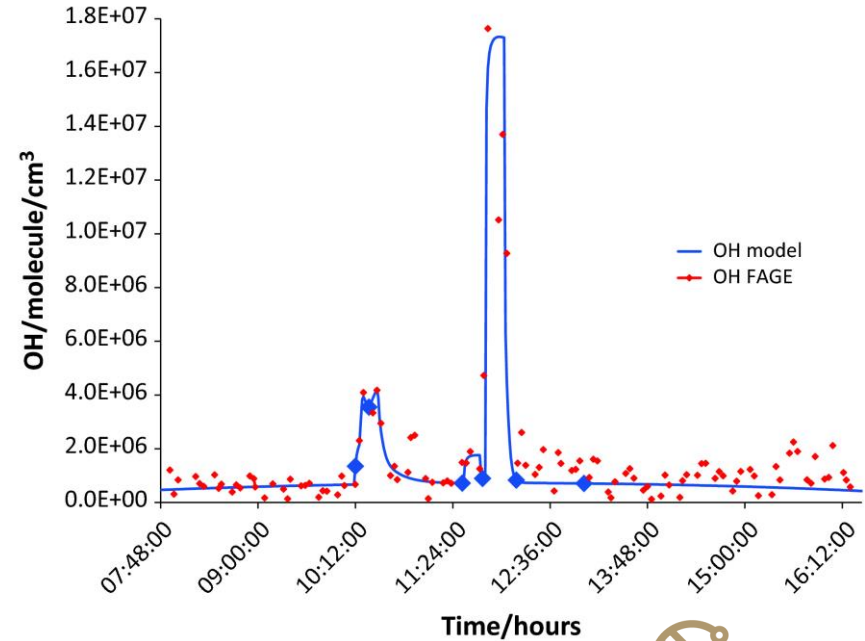
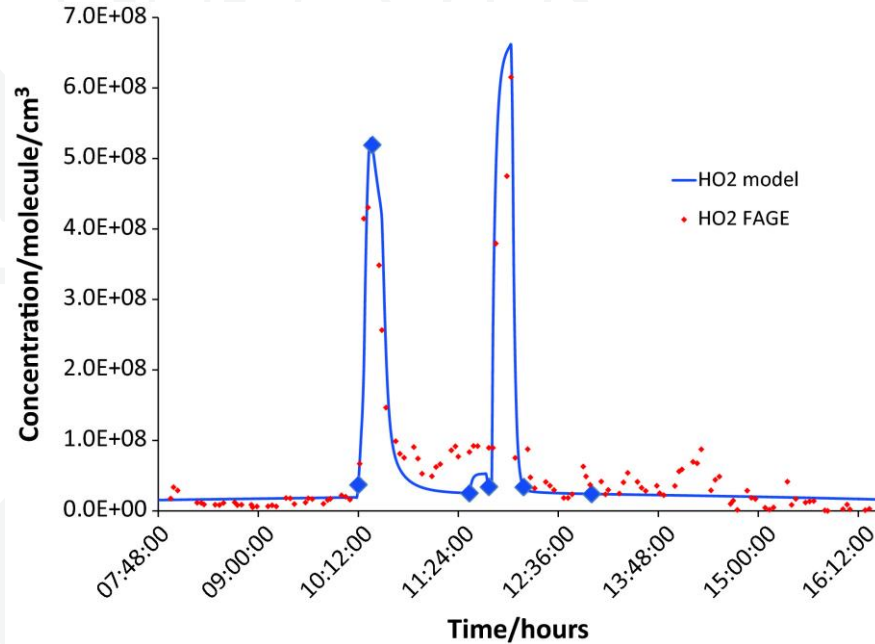
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Assumptions

- A single well mixed environment (1d box model)
- Irreversible deposition on surfaces, consistent with measurements and 10-100 times lower than measured outdoors
- Surface production for some measured species. Most notably HONO
- Photolysis is dealt with in distinct UV and visible bands. Constants have been determined from data in the recent IUPAC recommendation. They are attenuated for windows and then summed for each species
- Outdoor concentrations are average profiles of specific locations



Results

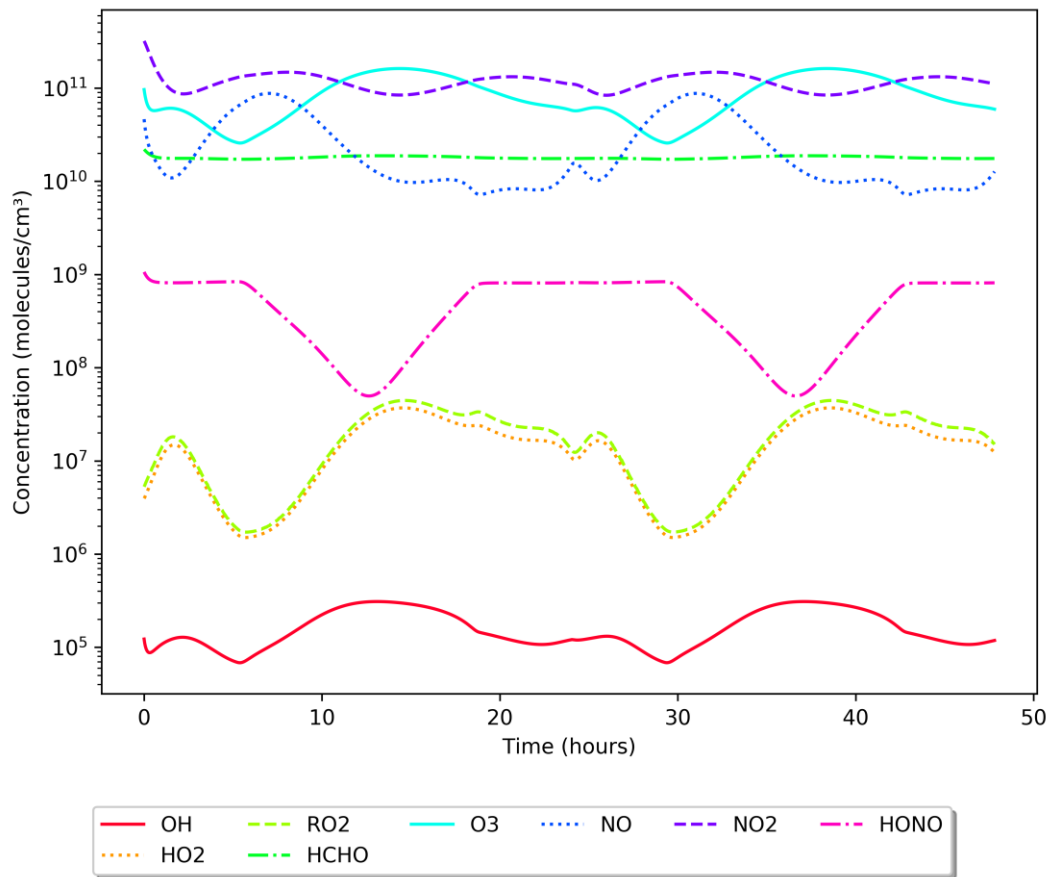


Fluorescence assay by gas expansion (FAGE) of cleaning followed by air cleaning device



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Python Output

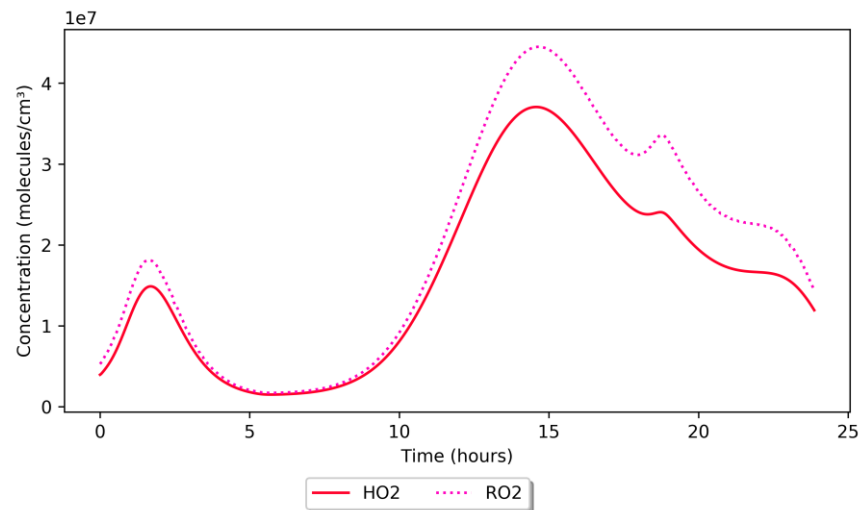
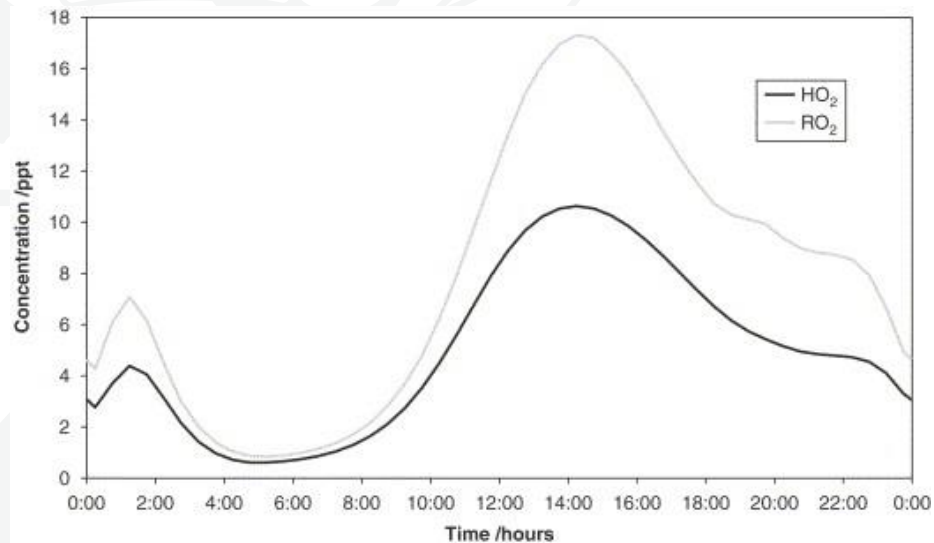


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Comparison



Thank you, any questions?



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