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Impact of building materials on indoor air quality

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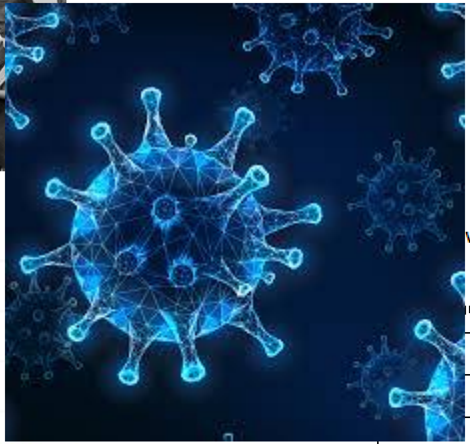
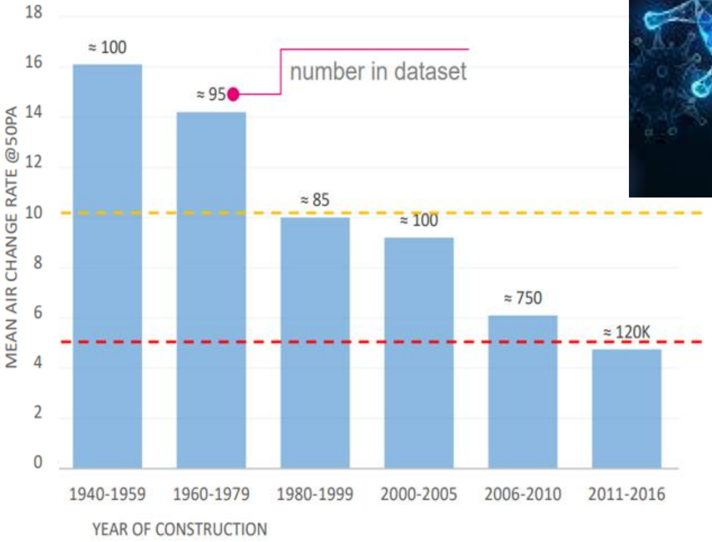
Acknowledgements: Alfred P. Sloan Foundation, EU CAPACITIE project

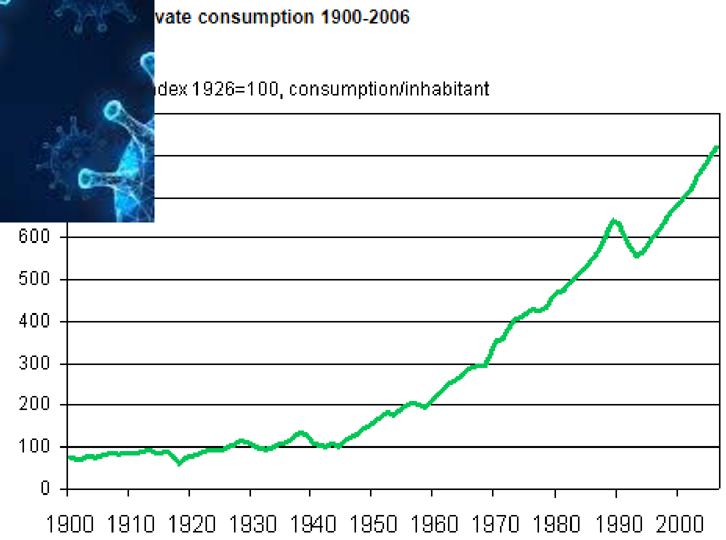
Overview

- Why study indoor air quality (now)?
- Sources of indoor air pollution
- Insight from modelling studies: focus on internal surfaces
- Traditional versus ‘green’ building materials
- Summarising remarks

Why study indoor air pollution now?



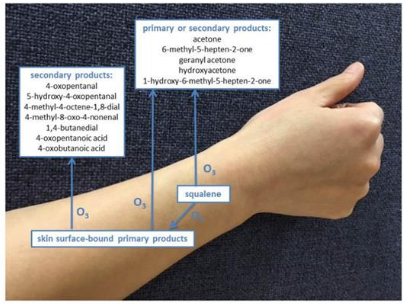




Source: Hjerppe, Riitta (1988); Statistics Finland, National accounts

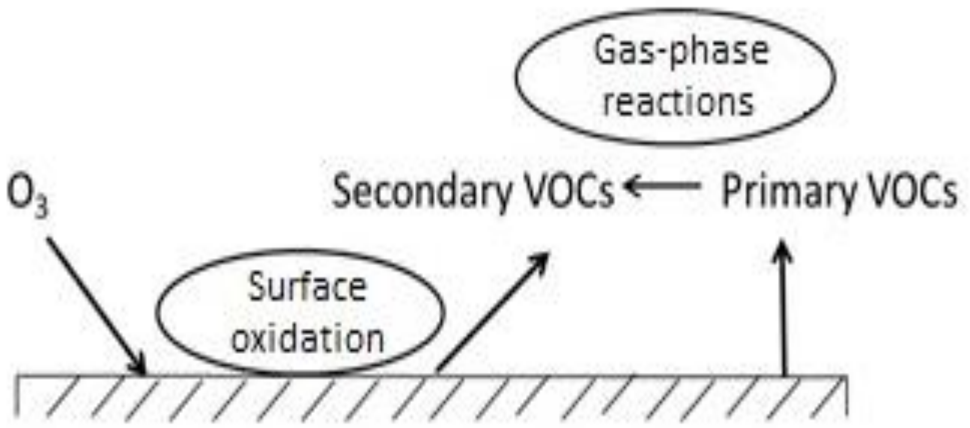
http://www.dailymail.co.uk/news/article-2104579/The-magic-1950s-suburbia-socks-darned-baths-shared-kids-roamed-wild.html
http://home.bt.com/tech-gadgets/internet/online-gaming-for-kids-advice-for-parents-how-to-protect-your-child-11364060707336
https://www.property-care.org/wp-content/uploads/2017/05/Ian-Mawditt-presentation-PCA-Conference-4th-May-2017.pdf; https://www.stat.fi/tup/suomi90/heinakuu_en.html

Sources of indoor air pollution



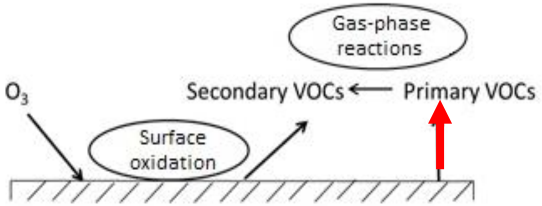
Some direct emissions plus some **chemical production** from these emissions…..

Emissions from surfaces

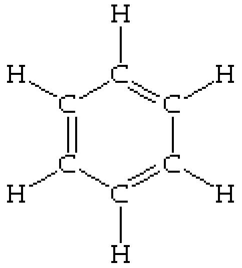
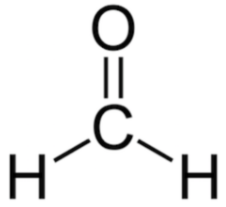
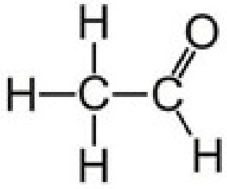
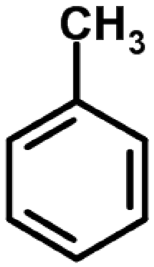
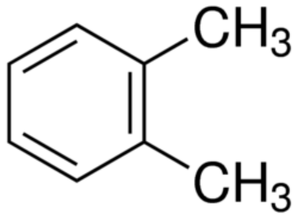


- Primary VOC emissions (different gases and surfaces)
- Primary VOC emissions can react with other air pollutants to form secondary VOCs
- Secondary VOC emissions can follow deposition of ozone (and other gases) on surfaces

Emissions from building materials



- Building materials (BMs) major contributors to sources of VOCs indoors
- In particular, benzene, formaldehyde, acetaldehyde, toluene and xylenes should be considered as priority pollutants owing to health effects

- For instance, paint typically contains hydrocarbons at typically 5-8% of mix including 2-butoxyethanol, butan-1-ol, xylenes, trimethylbenzene and toluene

Complex chemistry (toluene)

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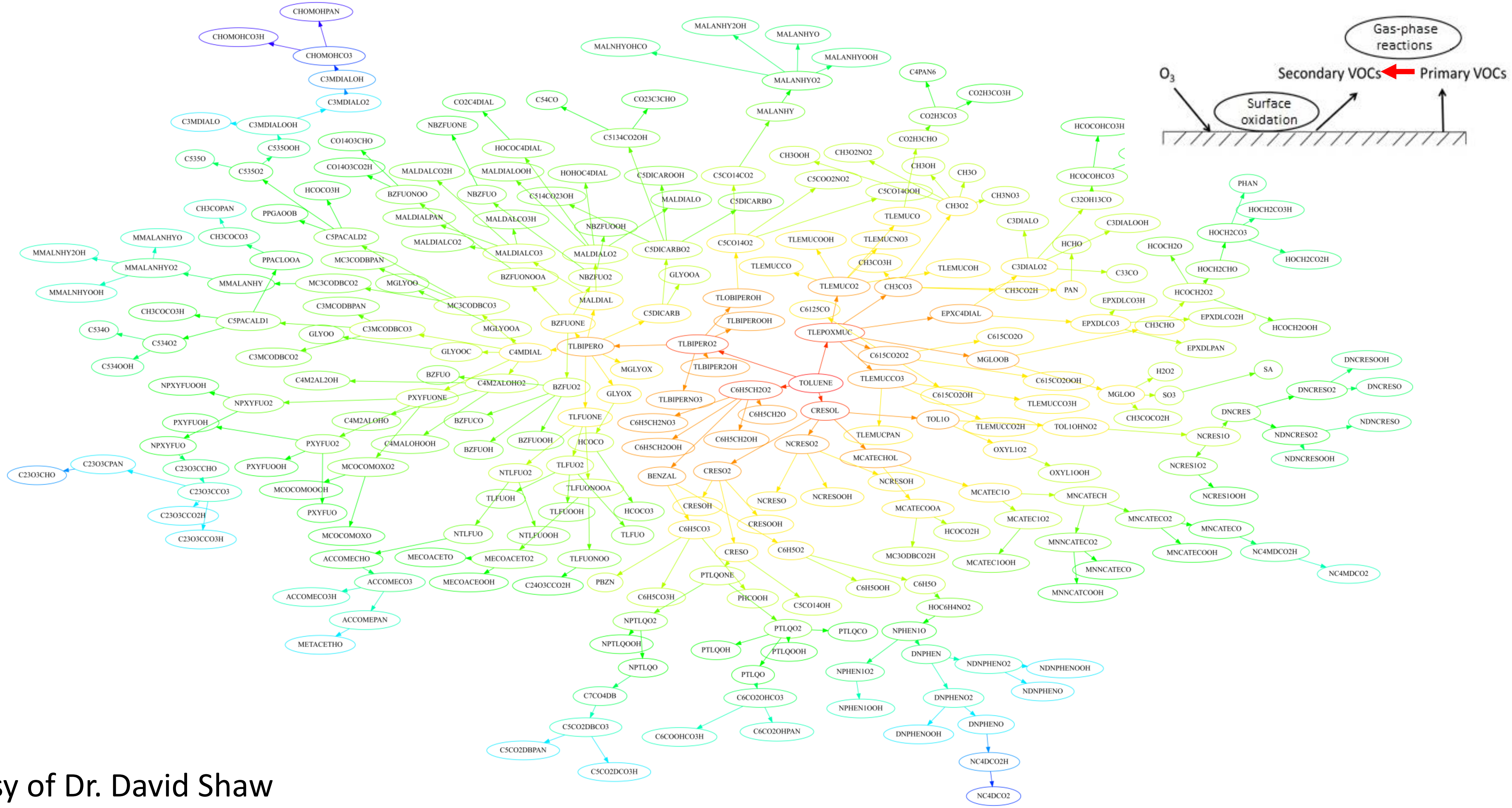

Courtesy of Dr. David Shaw

Ozone deposition onto surfaces

Received: 17 January 2017 | Accepted: 12 March 2017
DOI: 10.1111/ina.12381

ORIGINAL ARTICLE WILEY

Impact of surface ozone interactions on indoor air chemistry: A modeling study

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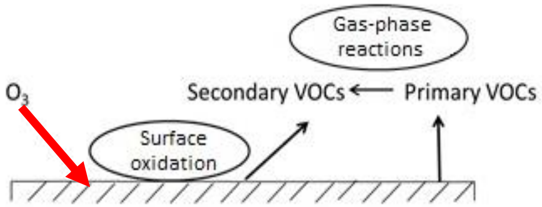
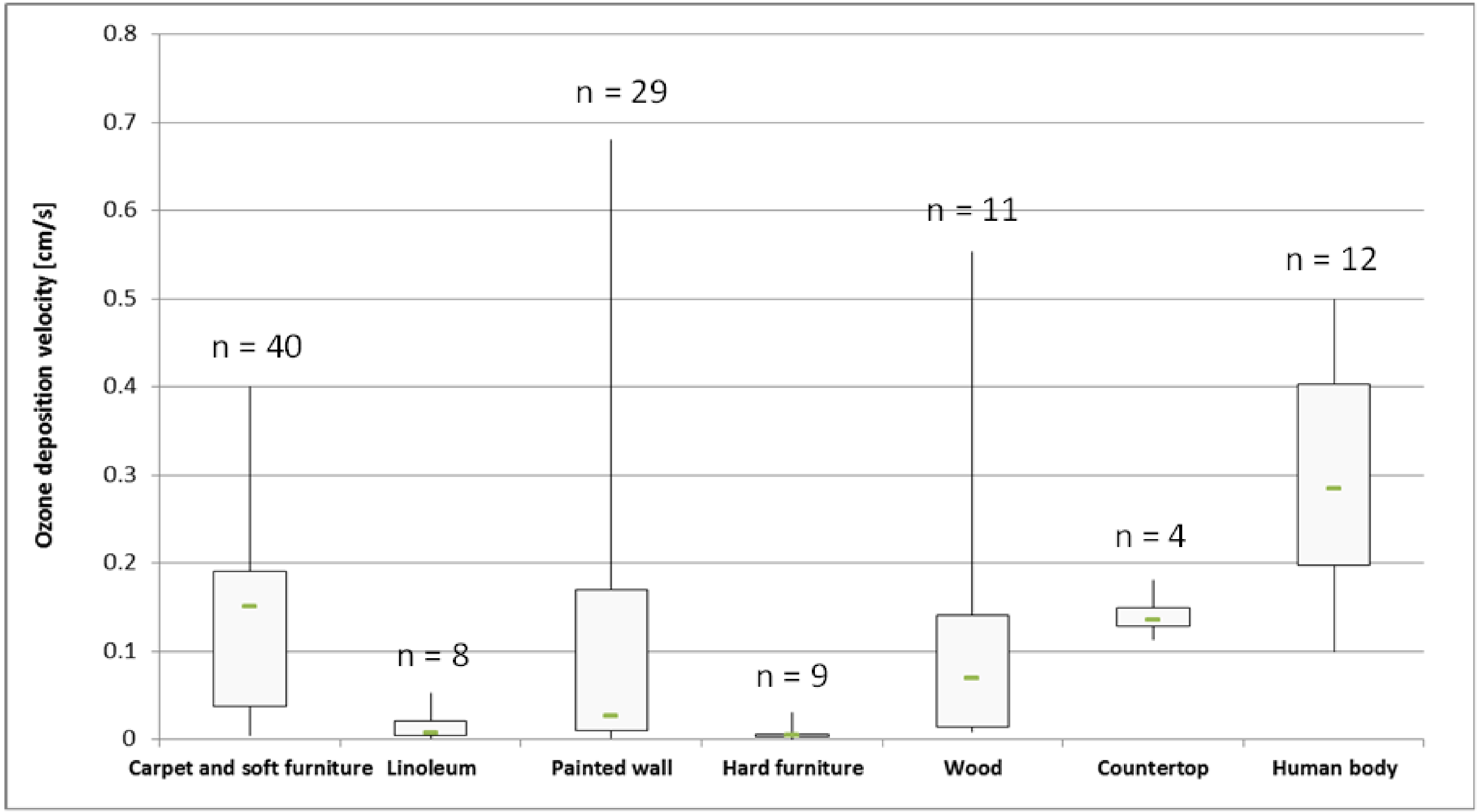
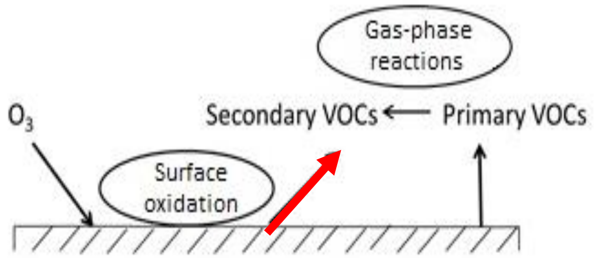




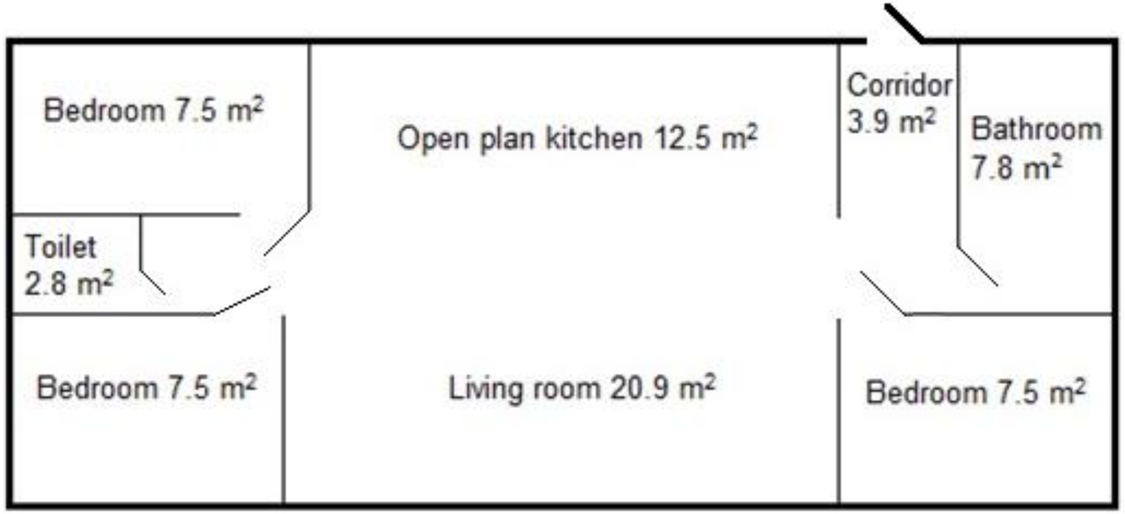
Ozone deposition velocity onto different indoor surfaces, considering minimum, 25% of data distribution, median value, 75% of data distribution and maximum value of ozone velocity deposition [cm/s]. ‘n’ symbol depicts number of measurements

Emissions from surfaces: focus on aldehydes

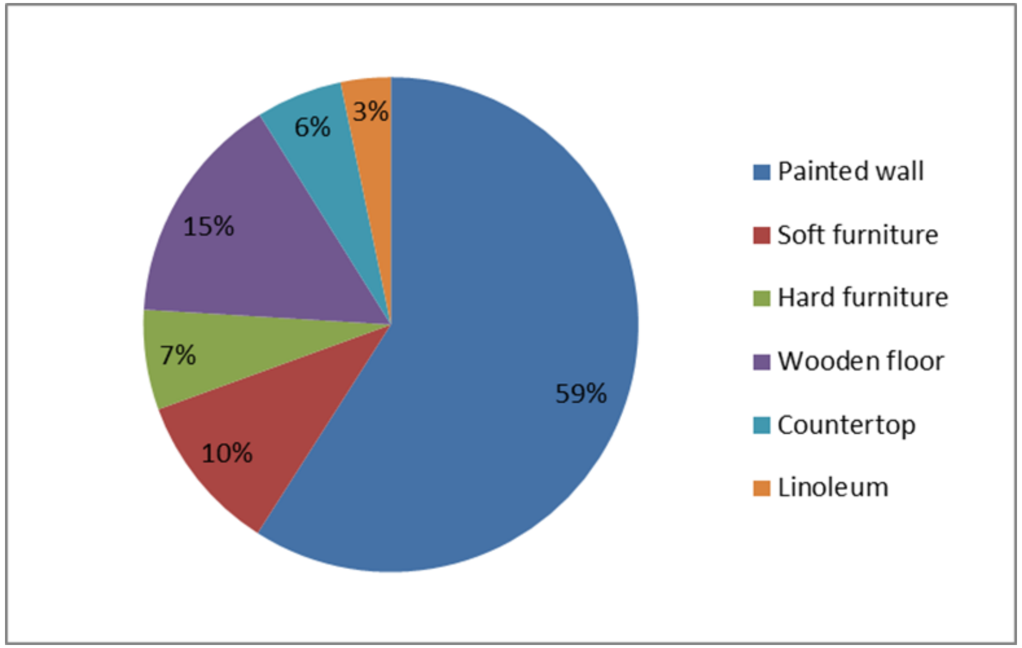
Surface type	Compound	No. of measurements (n)	Average age surface aldehyde yield (±SD)	New home surface aldehyde yield	Old home surface aldehyde yield
Carpet and soft furniture	Hexanal	16	0.03 (±0.03)	0.03	0.03
	Heptanal		0.01 (±0.01)	0.01	0.00
	Octanal		0.01 (±0.02)	0.01	0.01
	Nonanal		0.06 (±0.03)	0.08	0.04
	Decanal		0.03 (±0.03)	0.04	0.02
Painted wall	Octanal	3	0.01 (±0.02)	0.00	0.03
	Nonanal		0.13 (±0.18)	0.03	0.34
	Decanal		0.04 (±0.07)	0.01	0.12
Countertop	Hexanal	12	0.08 (±0.05)	0.09	0.06
	Heptanal		0.02 (±0.02)	0.03	0.02
	Octanal		0.01 (±0.01)	0.01	0.02
	Nonanal		0.26 (±0.15)	0.33	0.19
	Decanal		0.03 (±0.04)	0.04	0.03
Linoleum	Hexanal	7	0.07 (±0.06)	0.08	0.06
	Heptanal		0.01 (±0.01)	0.01	0.00
	Octanal		0.01 (±0.02)	0.02	0.01
	Nonanal		0.13 (±0.10)	0.20	0.04
	Decanal		0.03 (±0.04)	0.05	0.00



Typical surfaces indoors

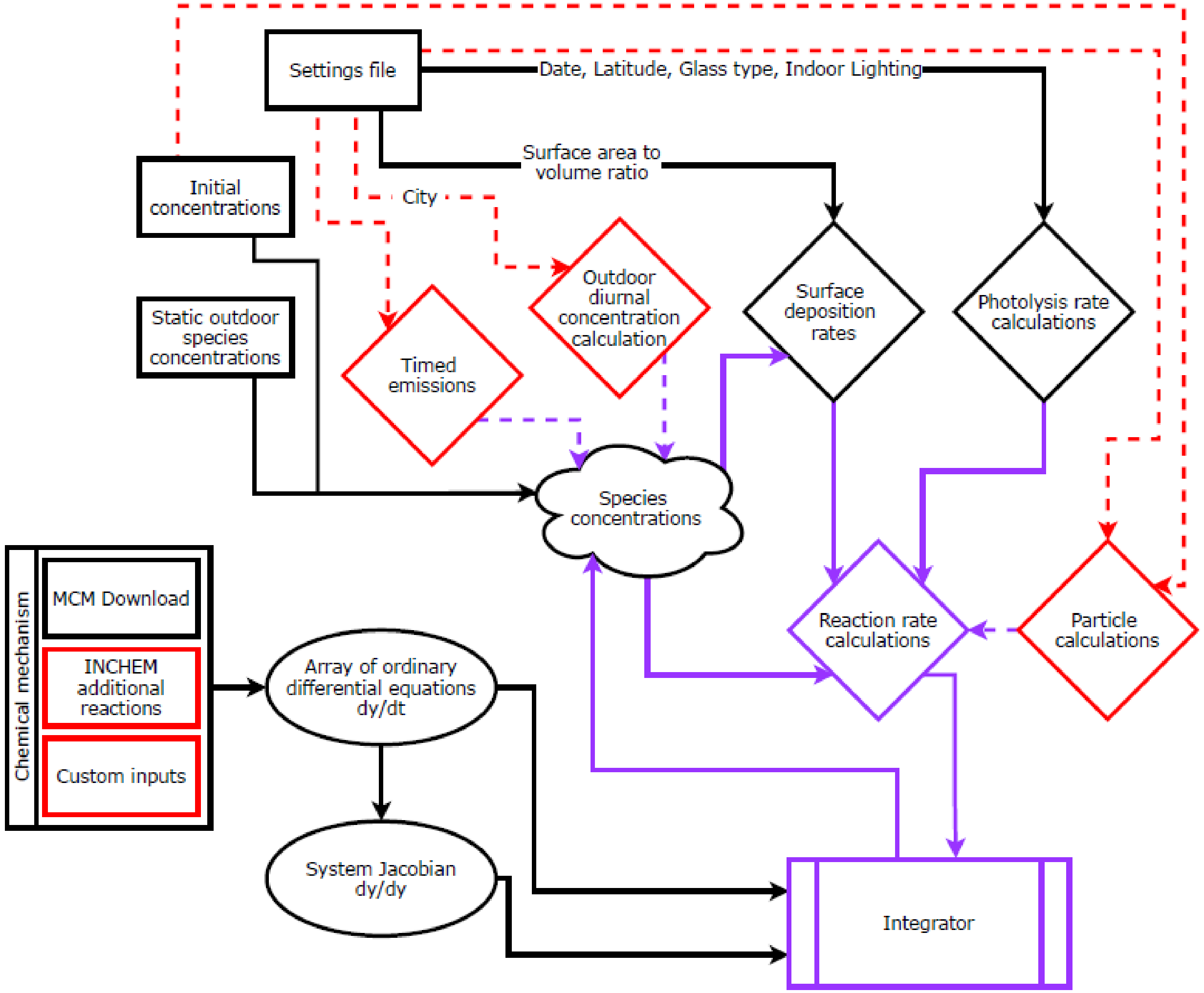


- Case study apartment floor plan: total unfurnished surface area of **70 m²** and a volume of 168 m³
- But including surfaces gives a total surface area for deposition of **337 m²**.



	Ozone outdoors [ppb]	NO_2 outdoors [ppb]	NO outdoors [ppb]	Ozone indoors [ppb]	NO_2 indoors [ppb]	NO indoors [ppb]
Milan 2003	88.8	29.1	14.5	67.0	9.3	0.1
Milan 2009	56.5	18.7	14.4	40.7	7.1	0.1
Seoul	34.4	25.0	9.2	24.9	7.6	0.2

INCHEM - Py

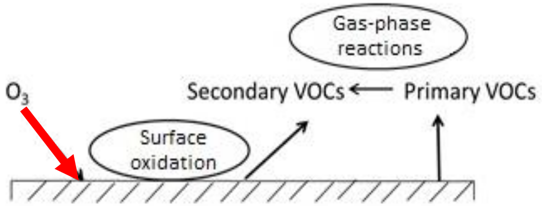


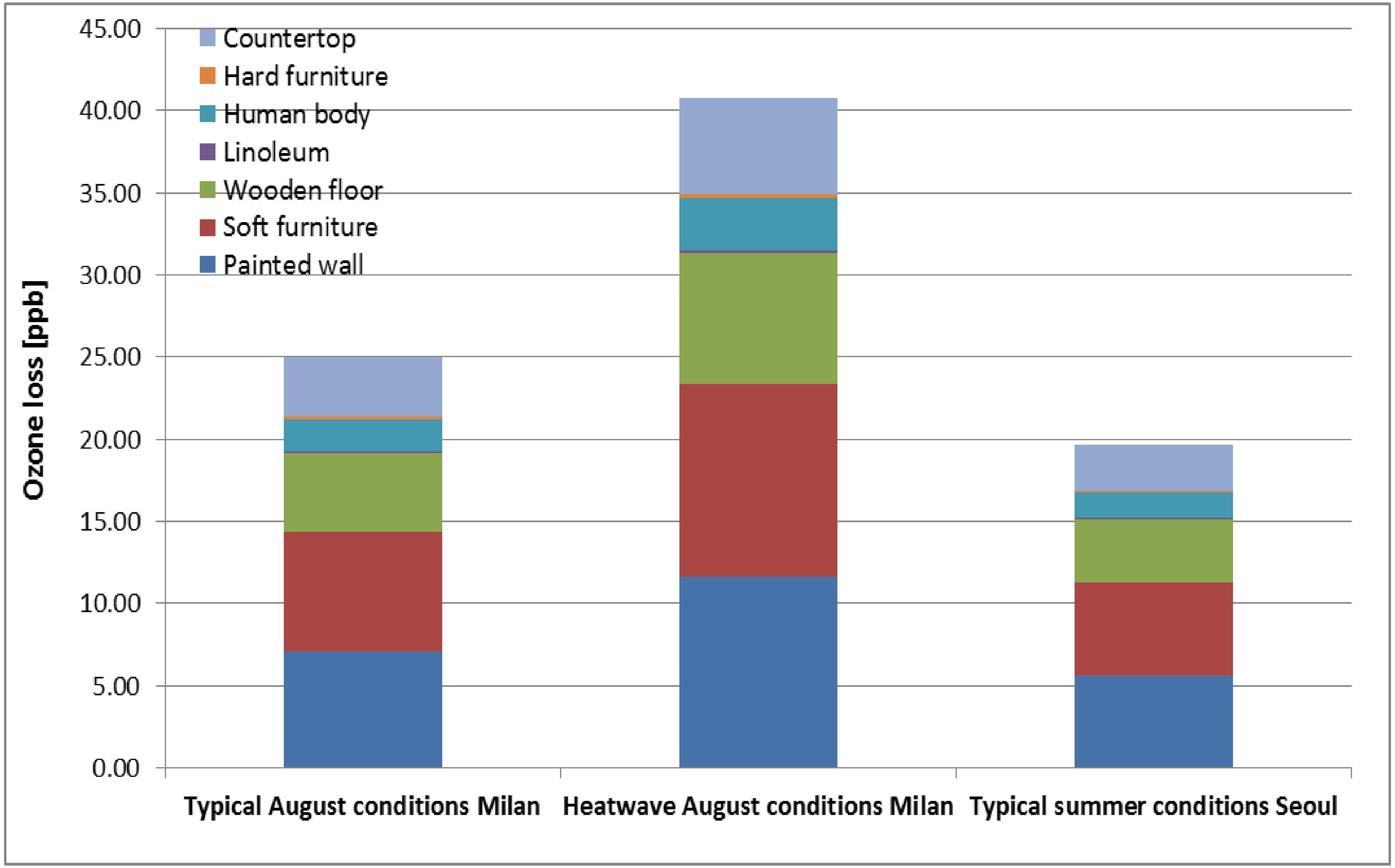
INdoor CHEMical Model in Python

- Solves indoor air species concentrations with time
- Assumes a single well mixed environment
- Based on the Master Chemical Mechanism (MCM)
- Open source with no “black box” processes
- Extensive documentation
- INCHEM-Py can be downloaded from https://github.com/DrDaveShaw/INCHEM-Py

Shaw, D., & Carslaw, N. (2021). An open source Python box model for indoor air chemistry. *Journal of Open Source Software*, https://doi.org/10.21105/joss.03224

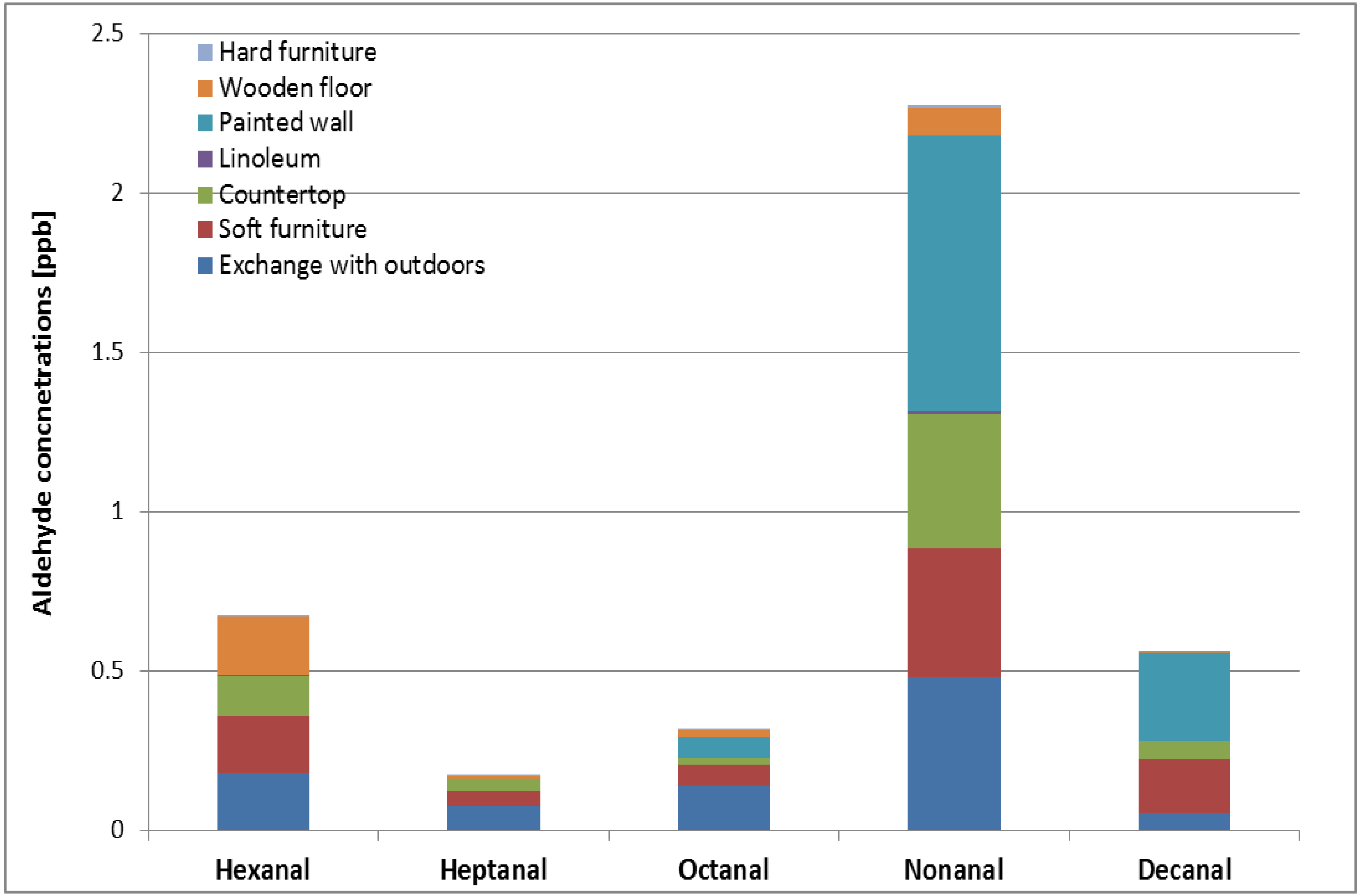
Ozone deposition on internal surfaces: different cities

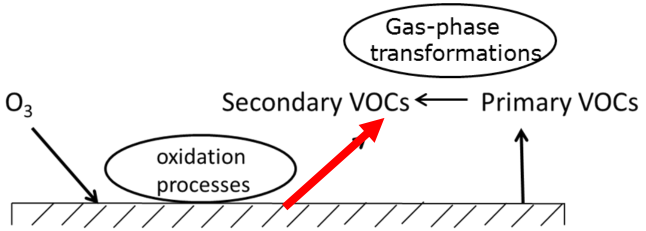




About 80% of ozone from outdoors is deposited on surfaces under these conditions

Emissions from surfaces



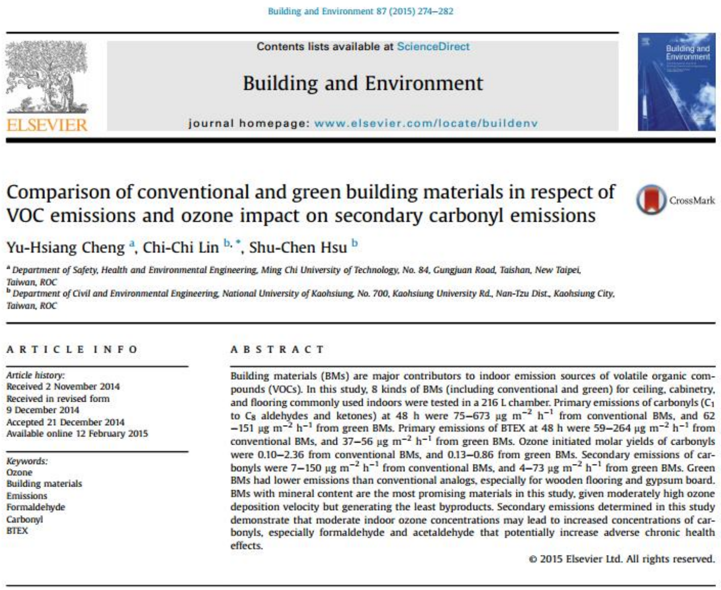


Typical summer Milan

- Painted surfaces dominate nonanal and decanal emissions
- Wooden floors more important for hexanal

Green Building Materials (GBMs)

- Market for GBMs is increasing
- GBMs intended to have low toxicity and minimal primary chemical emissions
  - After 48 h, HCHO (BTEX) emission rate <80 (<190) mg/m^2/h
- Are they better for IAQ?



Building and Environment 87 (2015) 274–282

Contents lists available at ScienceDirect

Building and Environment

journal homepage: www.elsevier.com/locate/buildenv

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

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ARTICLE INFO

Article history:
Received 2 November 2014
Received in revised form
9 December 2014
Accepted 21 December 2014
Available online 12 February 2015

Keywords:
Ozone
Building materials
Emissions
Formaldehyde
Carbonyl
BTEX

ABSTRACT

Building materials (BMs) are major contributors to indoor emission sources of volatile organic compounds (VOCs). In this study, 8 kinds of BMs (including conventional and green) for ceiling, cabinetry, and flooring commonly used indoors were tested in a 216 L chamber. Primary emissions of carbonyls (C_1 to C_8 aldehydes and ketones) at 48 h were 75–673 μg m^{-2} h^{-1} from conventional BMs, and 62–151 μg m^{-2} h^{-1} from green BMs. Primary emissions of BTEX at 48 h were 59–264 μg m^{-2} h^{-1} from conventional BMs, and 37–56 μg m^{-2} h^{-1} from green BMs. Ozone initiated molar yields of carbonyls were 0.10–2.36 from conventional BMs, and 0.13–0.86 from green BMs. Secondary emissions of carbonyls were 7–150 μg m^{-2} h^{-1} from conventional BMs, and 4–73 μg m^{-2} h^{-1} from green BMs. Green BMs had lower emissions than conventional analogs, especially for wooden flooring and gypsum board. BMs with mineral content are the most promising materials in this study, given moderately high ozone deposition velocity but generating the least byproducts. Secondary emissions determined in this study demonstrate that moderate indoor ozone concentrations may lead to increased concentrations of carbonyls, especially formaldehyde and acetaldehyde that potentially increase adverse chronic health effects.

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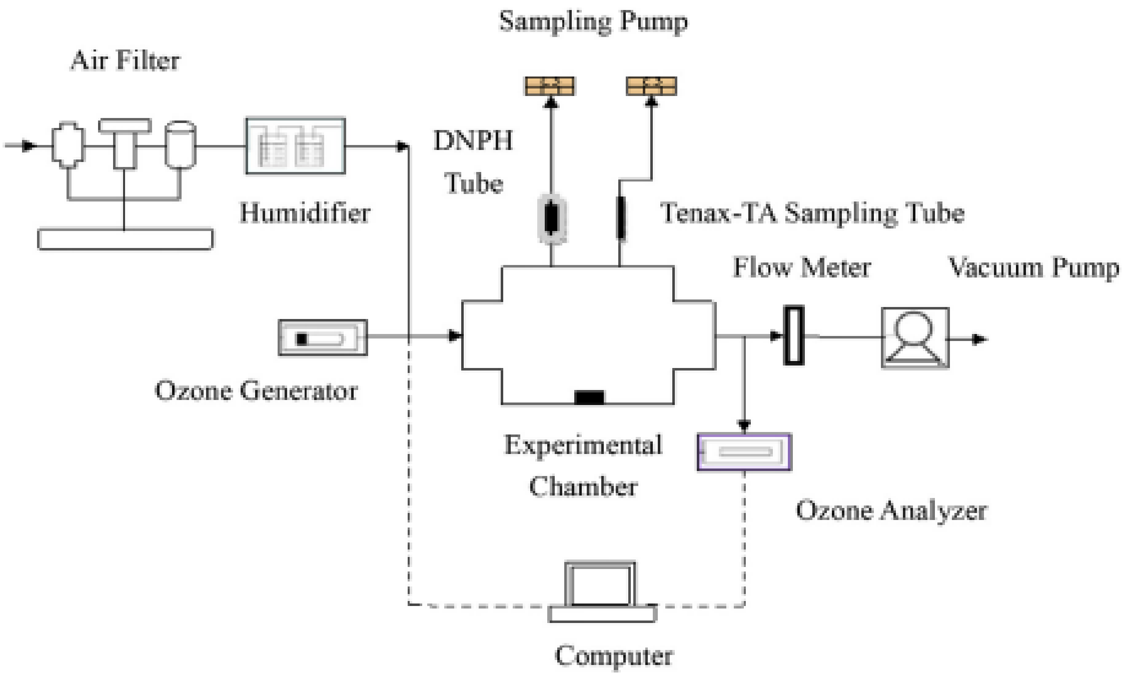


Fig. 1. Experimental system.

Ozone pumped in for first 4h then stopped until 48h when added again

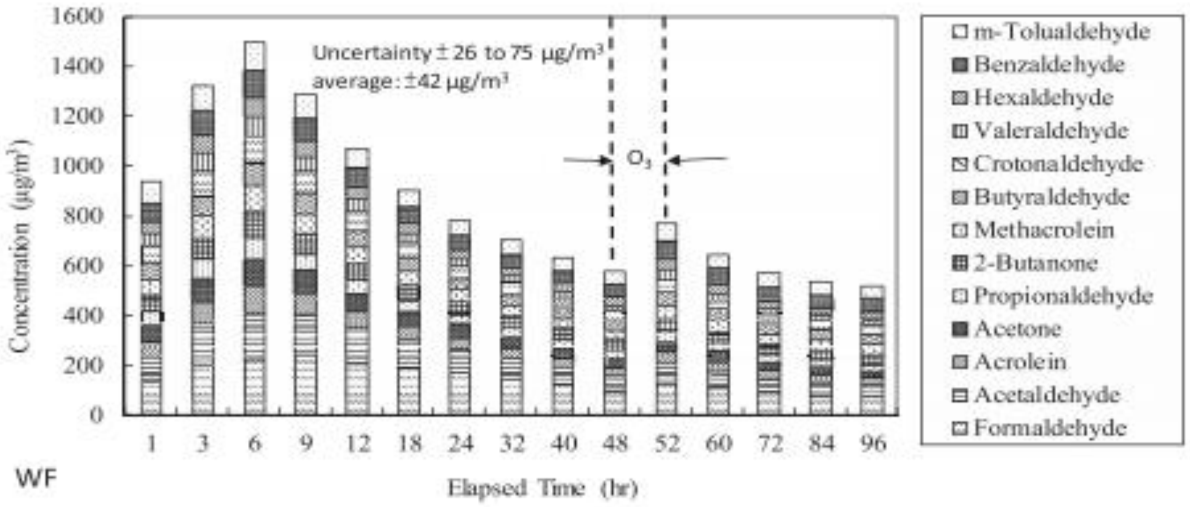
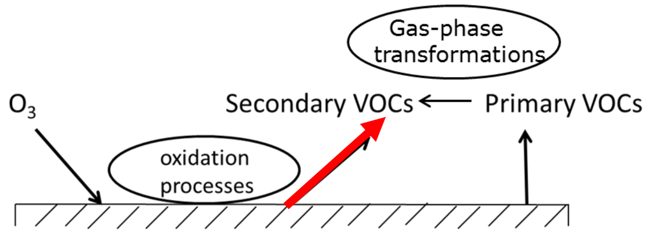


Fig. 3. Variation of carbonyl concentrations over time for WF. "±"in the figure are the uncertainties for low concentration, high concentration and average uncertainty.



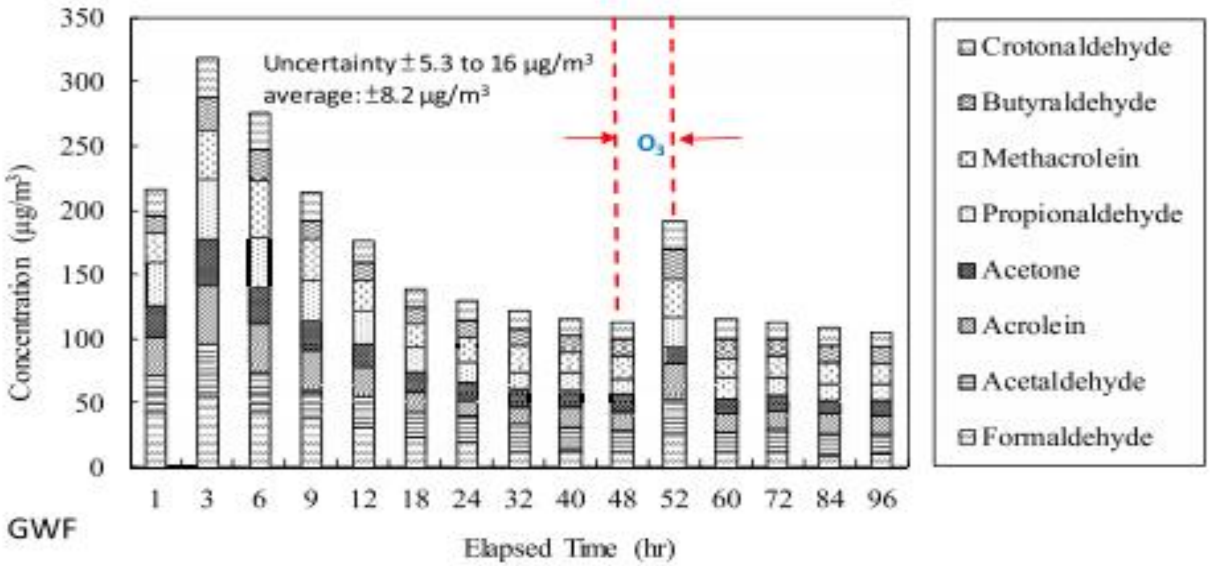


Fig. 4. Variation of carbonyl concentrations over time for GWF. "±"in the figure are the uncertainties for low concentration, high concentration and average uncertainty.

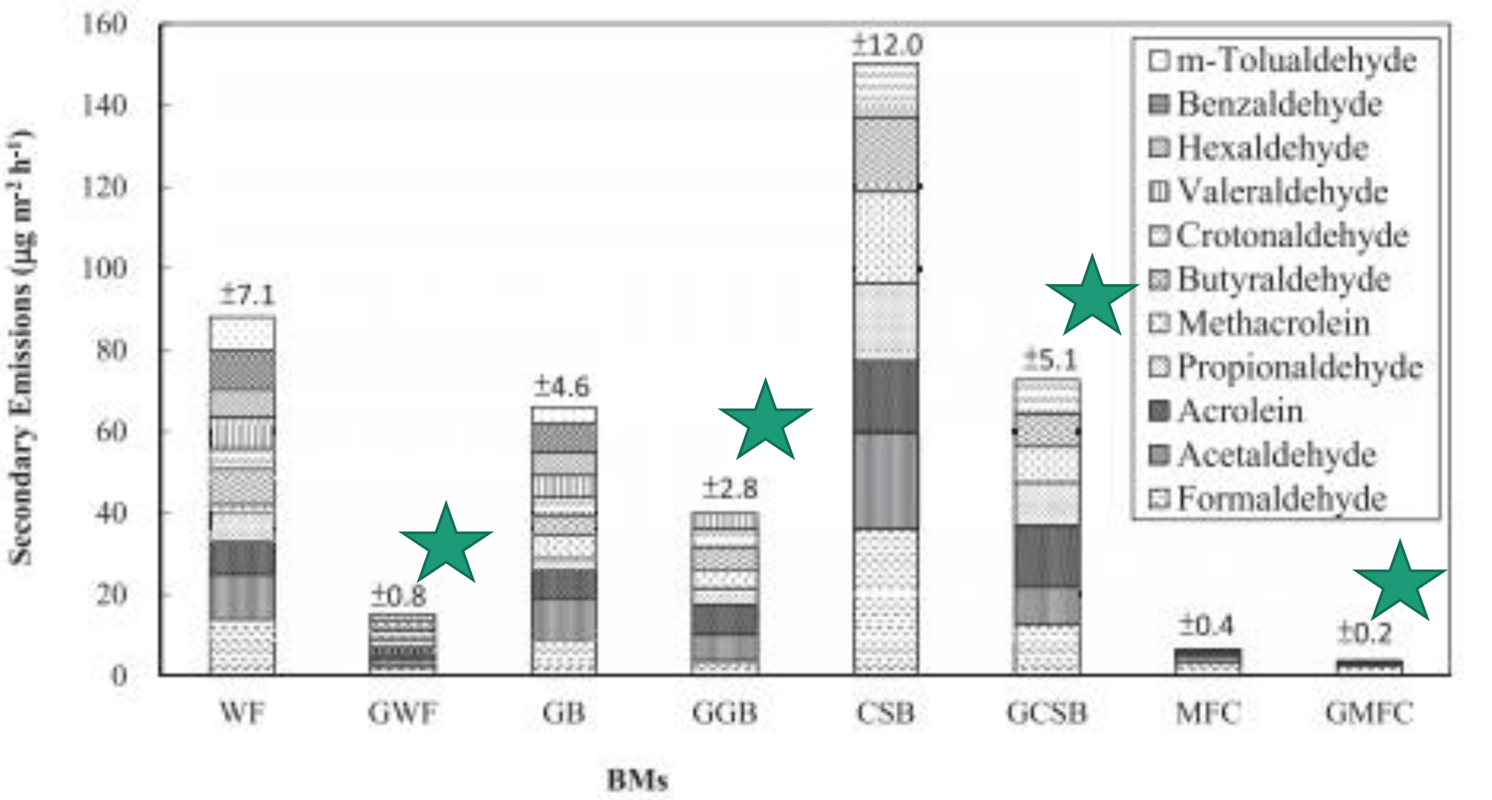


Fig. 10. Secondary carbonyl emissions from BMs. "±"above each column is the larger of propagated instrument error or standard error of the sum secondary emissions of each detected carbonyl.

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

- In all cases, emissions from green materials lower than from traditional
- Ozone deposition velocities onto green materials also lower than for traditional materials

Summary

- Many sources of chemicals that contribute to high VOC concentrations indoors (~ 10 x higher than outdoors)
- 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 be better for IAQ than traditional BMs
  - Lower primary emissions (particularly important for first 12 months following installation)
  - Secondary emissions also lower (important over lifetime of BM)
  - Health implications especially for HCHO
- Need more information on:
  - Deposition rates to surfaces
  - Emission yields of chemicals from different surfaces
  - More studies on benefits of GBMs