Measuring for healthy buildings:
New metrics in POE studies

Ben Humphries
Director, Architype

ARCHITYPE

Primary school design evolving through POE

Staunton-on-Wye
Endowed (2010)
POE with TSB

The Willows (2009)
POE through a KTP
with Oxford Brookes
University

Bushbury Hill (2011)
POE with Coventry
University

Wilkinson (2013)
POE with Coventry
University

Burry Port Community (2015)
POE with UCL

St Luke's 2008
POE through a KTP
with Oxford Brookes
University

Bessemer Grange
(2010)
POE with TSB

Oak Meadow (2011)
POE with Coventry University

Hackbridge Primary
School (2018)
POE with UCL

Monitored primary school buildings

2 pre-PH, 3 first and second generation PH and a 1970s ‘control’

European Union
European Regional Development Fund

Coventry University

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Monitored parameters

European Union
European Regional Development Fund
Coventry University
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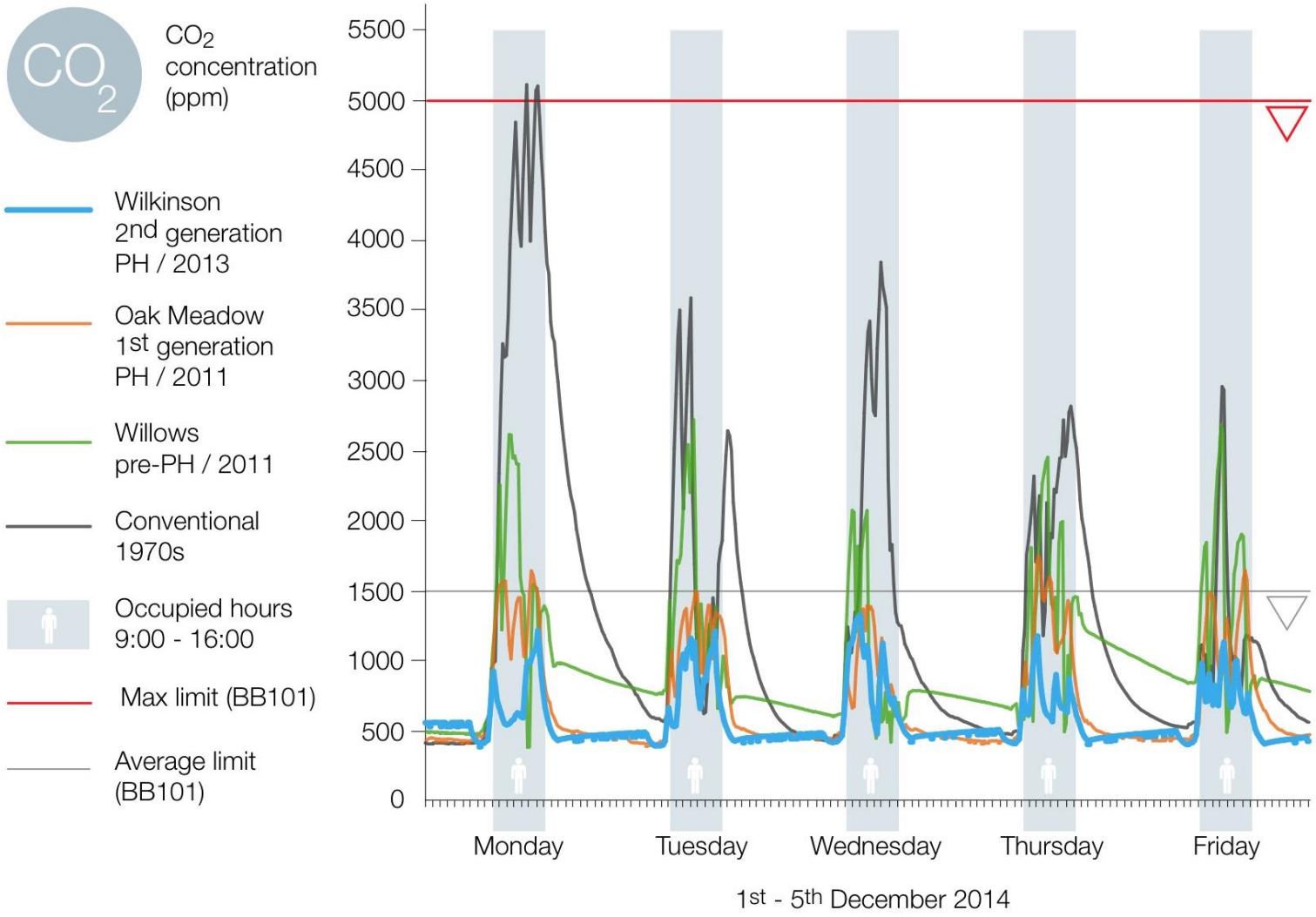
Monitoring results



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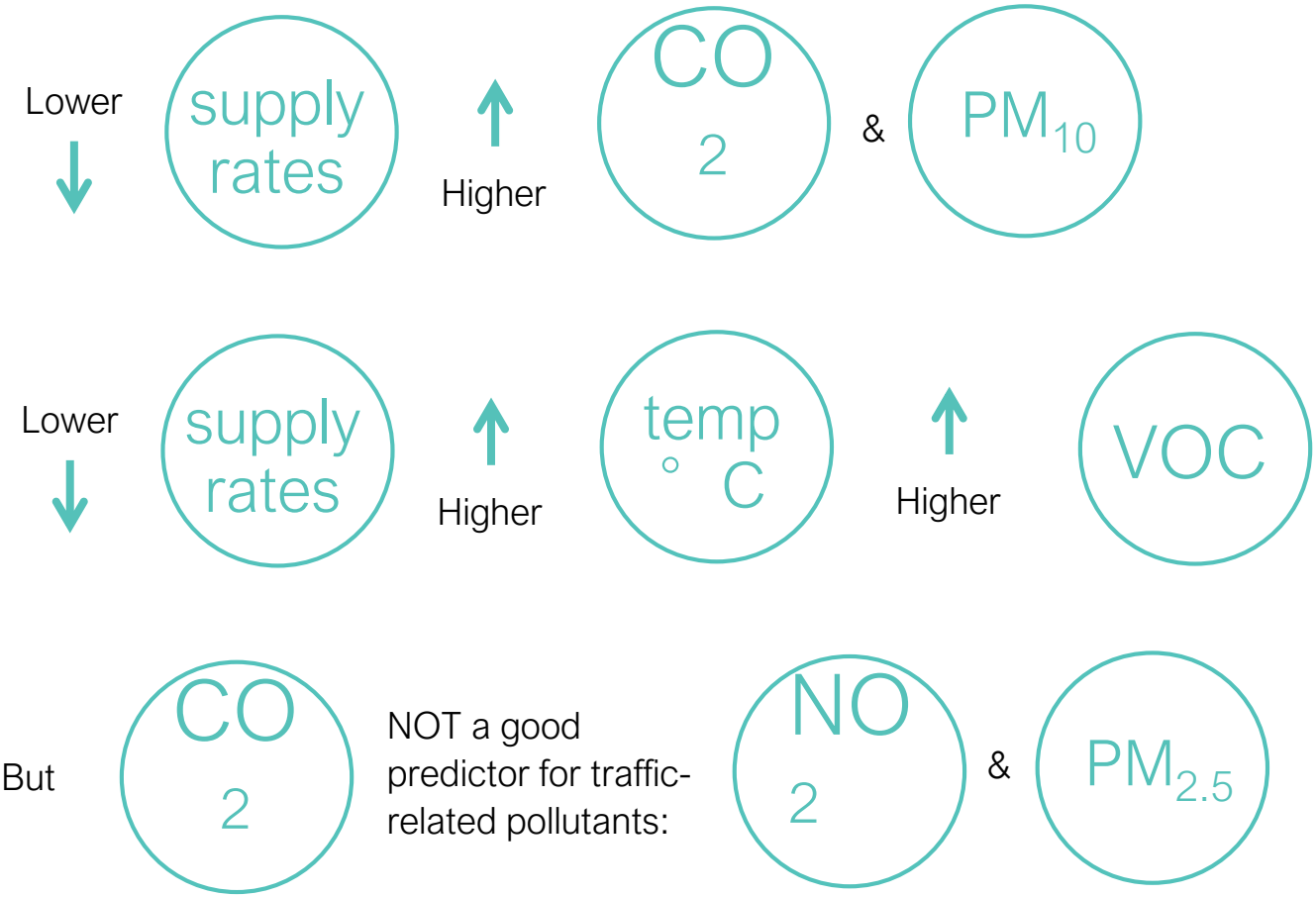
Which metrics for IAQ evaluation?

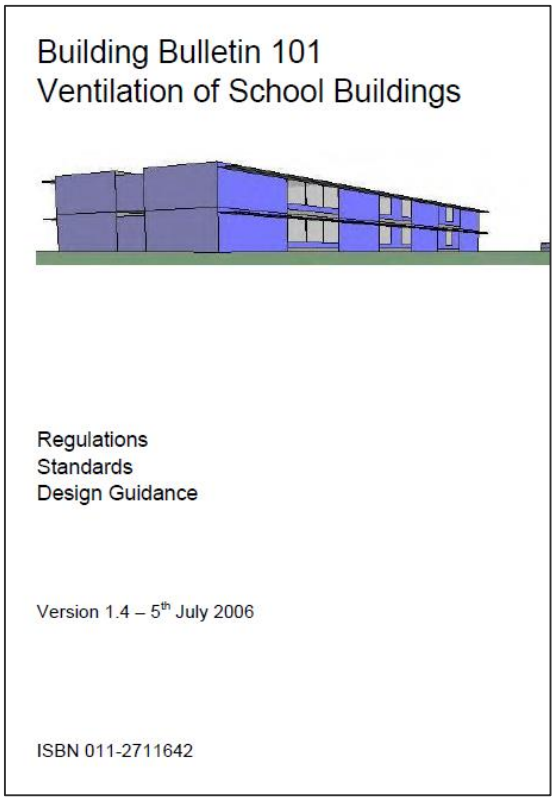
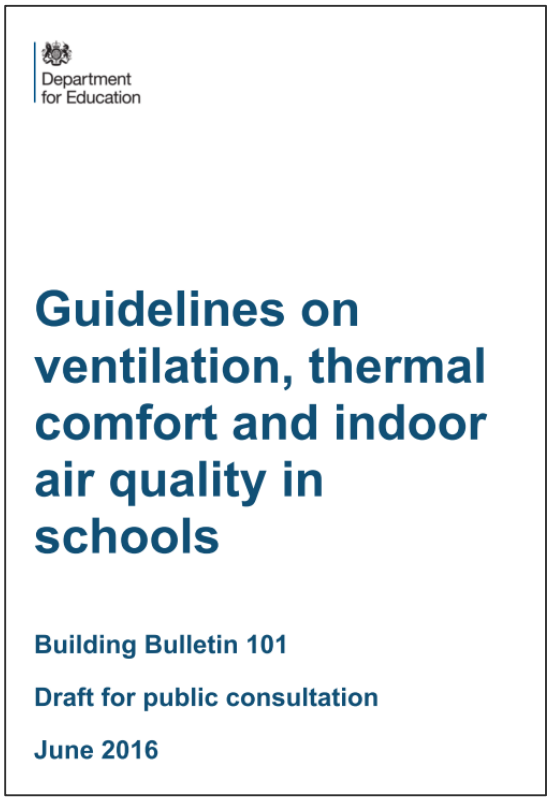
Is CO_2 a good proxy for indoor air quality in classrooms?

A study by Chatzidiakou, Mumovic and Summerfield (2015) found evidence that:



Also, recommended: informed selection of construction materials, interior finishing and correct timing of ventilation.

Guidelines for ventilation in school buildings

	Current Building Bulletin 101 Ventilation design in schools (EFA, 2006)	**New** Draft Building Bulletin 101 for public consultation (DfE, 2016)
		

Guidelines for ventilation in school buildings

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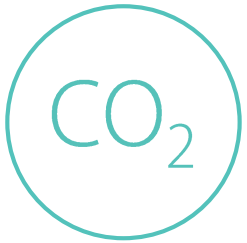
	Max daily average **< 1500 ppm** Max peak daily **< 5000 ppm** Achievable at all times **< 1000 ppm**	Mechanical vent. mode Max daily average **< 1000 ppm** Max for 20' consecutive **< 1500 ppm*** **design occupancy*	Natural vent. mode Max daily average **< 1500 ppm** Max for 20' consecutive **< 2000 ppm*** **design occupancy*
		Most of the time over a year: (new builds): Outside + 800 ppm ~ **< 1200 ppm** (refurbishments): Outside + 1350 ppm ~ **< 1750 ppm**	

Guidelines for ventilation in school buildings

	Current Building Bulletin 101 Ventilation design in schools (EFA, 2006)	**New** Draft Building Bulletin 101 for public consultation (DfE, 2016)
Biological stressors		Endotoxin Biological stressors included endotoxin, specific fungal and bacterial groups House-dust mites, horse, dog, cat allergens SINPHONIE Guidelines for schools in Kephalopoulos et al. (2014)
TVOC	Total VOC 8-hour average*: < 300 µg/m^3 • Not covering activity related emissions (cleaning, painting, etc.) • Extract (20 l/s/machine) to account for laser printers & dry photocopier emissions of TVOCs (25 mg/h) and ozone (3 mg/h) From AD F Building Regulations for non-domestic buildings (HM Government, 2010) (HM Government, 2010)	

Guidelines for ventilation in school buildings

	Current Building Bulletin 101 Ventilation design in schools (EFA, 2006)	**New** Draft Building Bulletin 101 for public consultation (DfE, 2016)
		Benzene: No safe level Naphthalene < 10µg/m^3 year average Xylenes: < 870 µg/m^3 week average Styrene :< 260 µg/m^3 week average Toluene: < 260 µg/m^3 week average Formaldehyde (VVOC) 100 µg/m^3 30-min average, Polcyclic Aromatic Hydrocarbons (PAHs) and indicator Benzo[a]pyrene (BaP) No safe level Trichloroethylene (T3CE) No safe level Tetrachloroethylene (T4CE) < 250 µg/m^3 (year) 1,3-butadiene (WHO, 2010) Included in monitoring: a-pinene, d-limonene (Kephalopoulos et al. (2014)

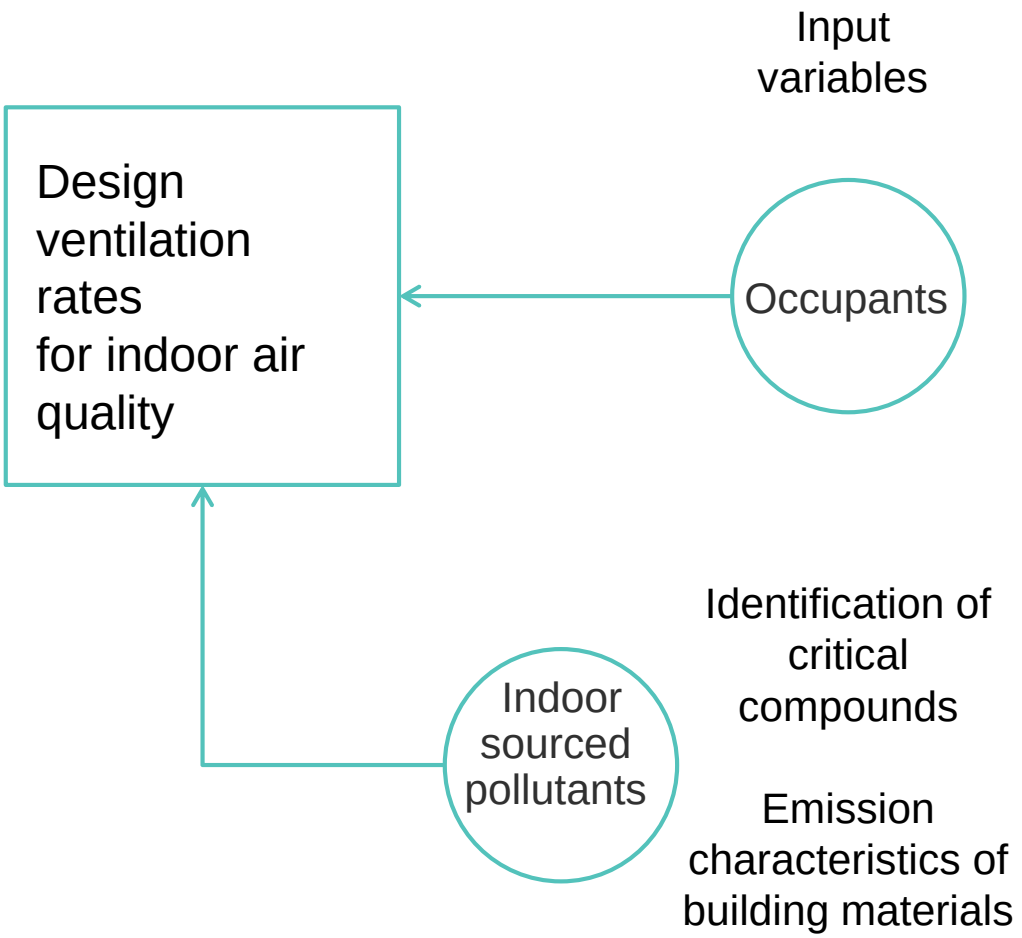
Indoor air quality – the role of material specification

Source control

"The control of **emissions** of non-human pollutants shall be the primary strategy for maintaining acceptable indoor air quality."

Ventilation

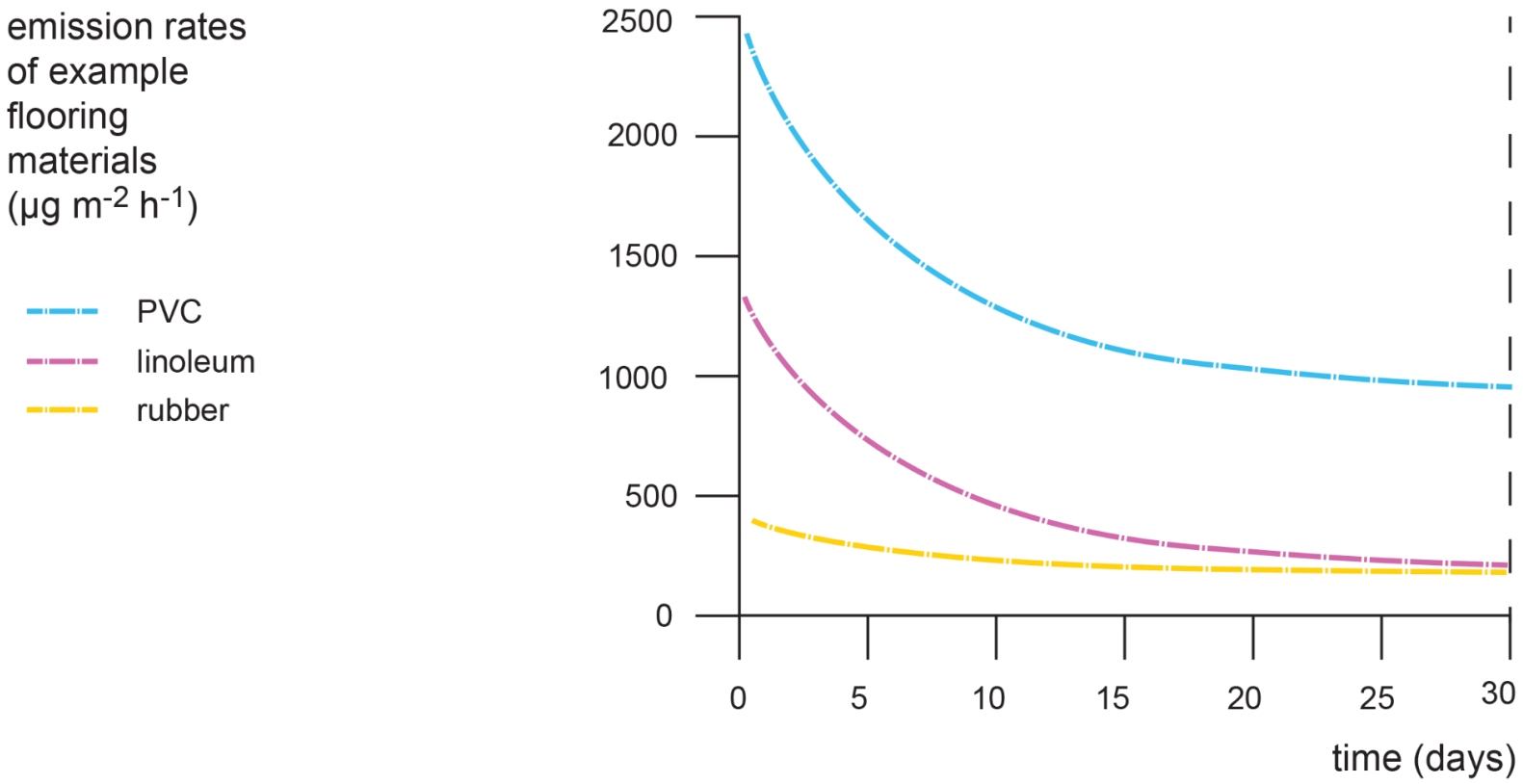
"Once these are identified they can be eliminated / decreased with ventilation"



ASHRAE Standard 62.1 (ASHRAE, 2017), British Standard BS ISO 17772-1:2017, DfE (2016)

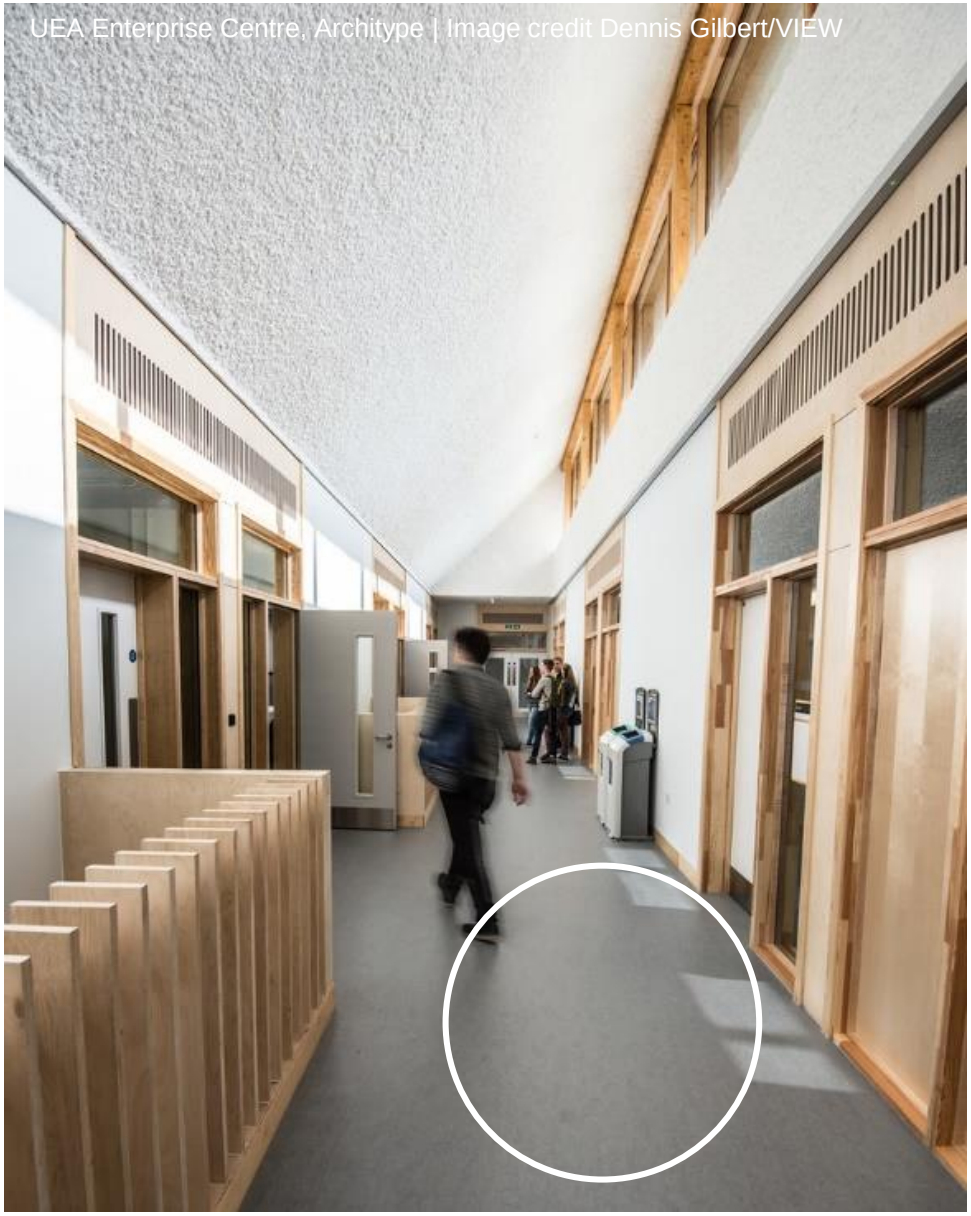
Indoor air quality – the role of material specification

Finishing materials palette effect on IAQ: most materials emit VOCs but emissions can vary in type as well as magnitude.



Graph reproduced from Wilke et al. (2004)

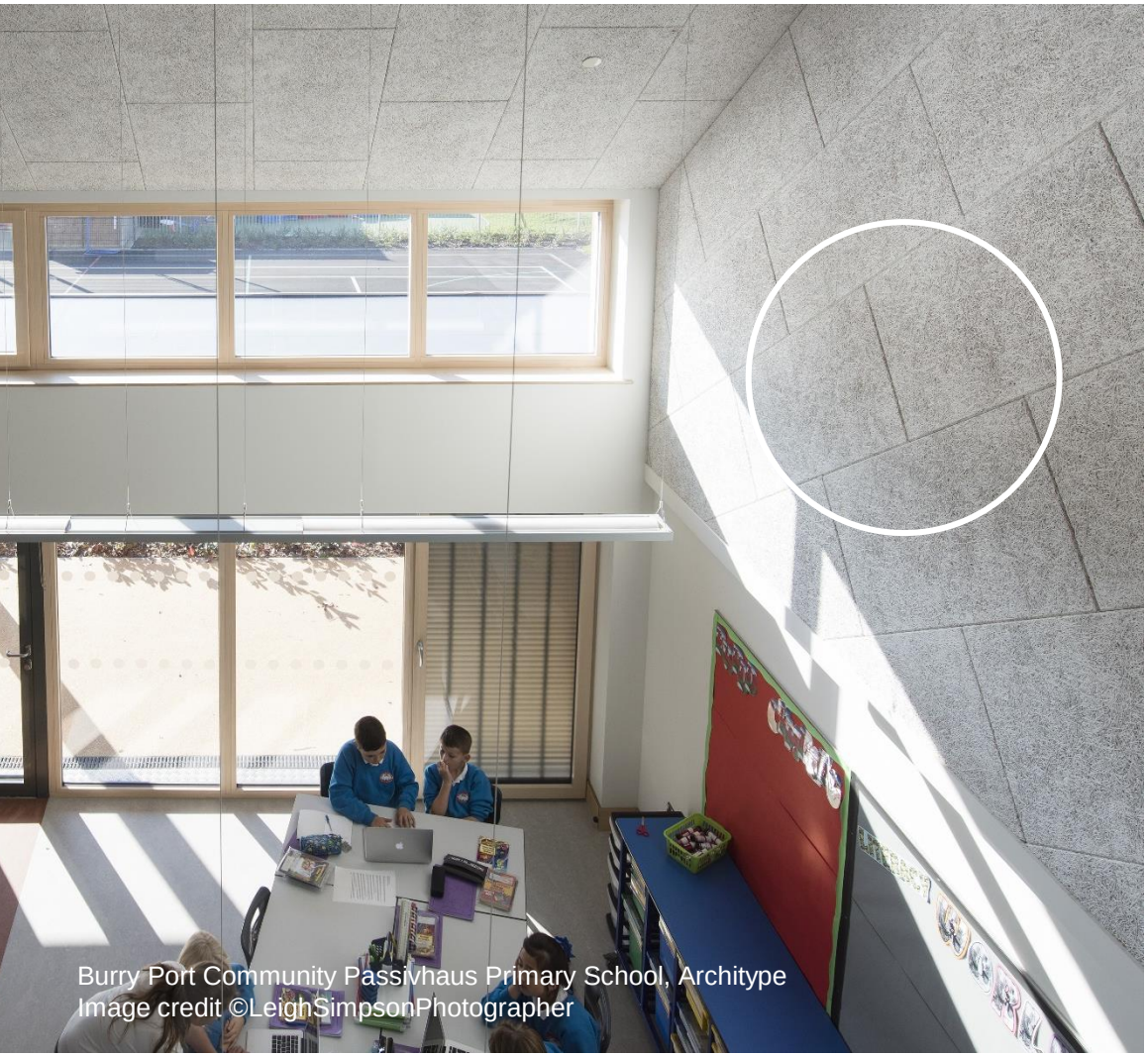
Indoor air quality – the role of material specification


UEA Enterprise Centre, Architype | Image credit Dennis Gilbert/VIEW

Indoor air quality – the role of material specification

UEA Enterprise Centre Architype Image credit ©DarrenCarter/MorganSindall

Indoor air quality – the role of material specification



Burry Port Community Passivhaus Primary School, Architype
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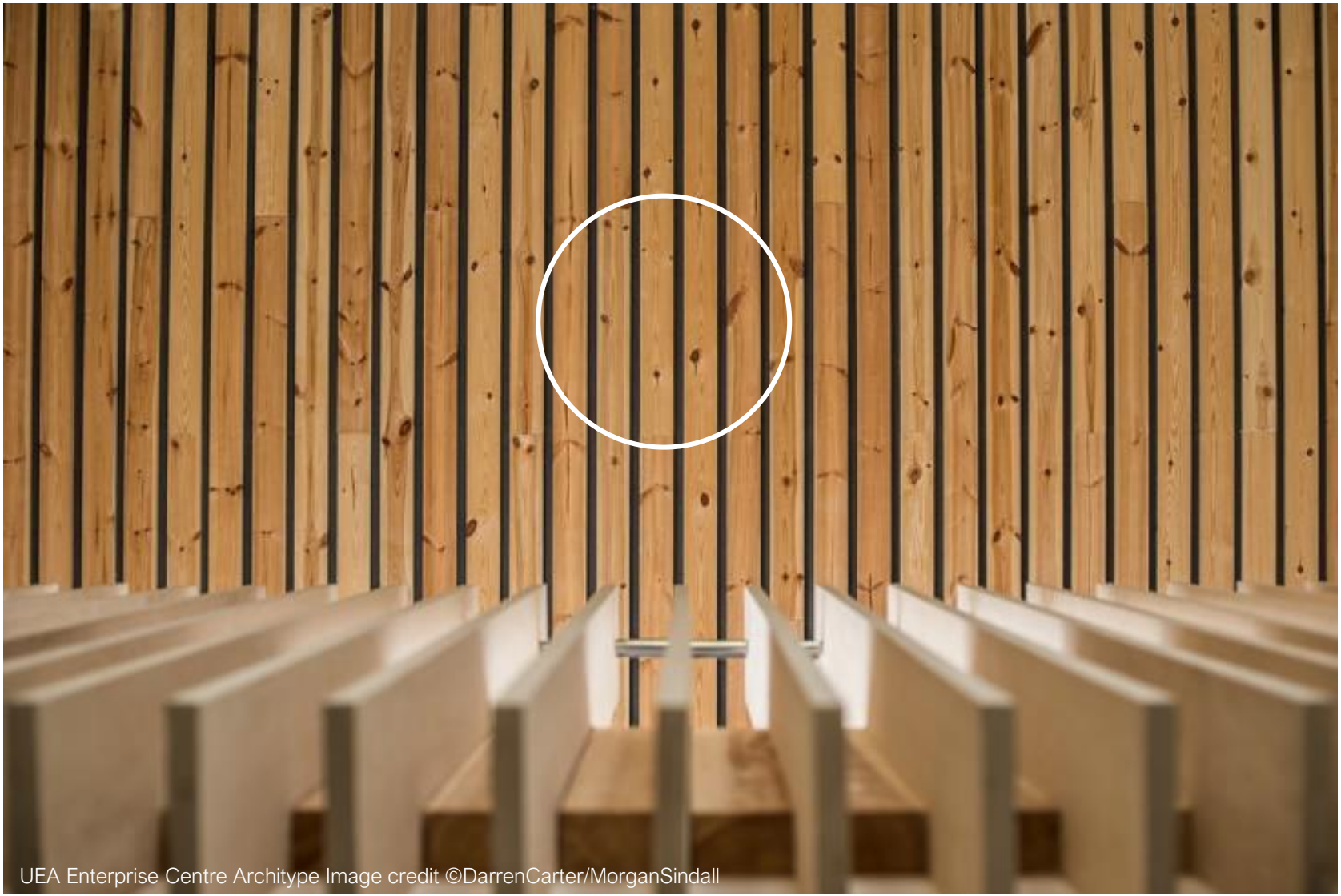
Indoor air quality – the role of material specification



UEA Enterprise Centre Architype Image credit ©DarrenCarter/MorganSindall

Indoor air quality – the role of material specification

Burry Port Passivhaus Primary School Architype Image credit ©LeighSimpsonPhotographer

Indoor air quality – the role of material specification

Bushbury Passivhaus Primary School, Architype | Image credit ©LeighSimpsonPhotographer

Ongoing research – objectives

Evaluating:

Indoor air quality in Passivhaus classrooms using additional metrics

Contribution of materials to indoor air pollution in Passivhaus schools

The effect of classroom conditions on health, comfort & wellbeing

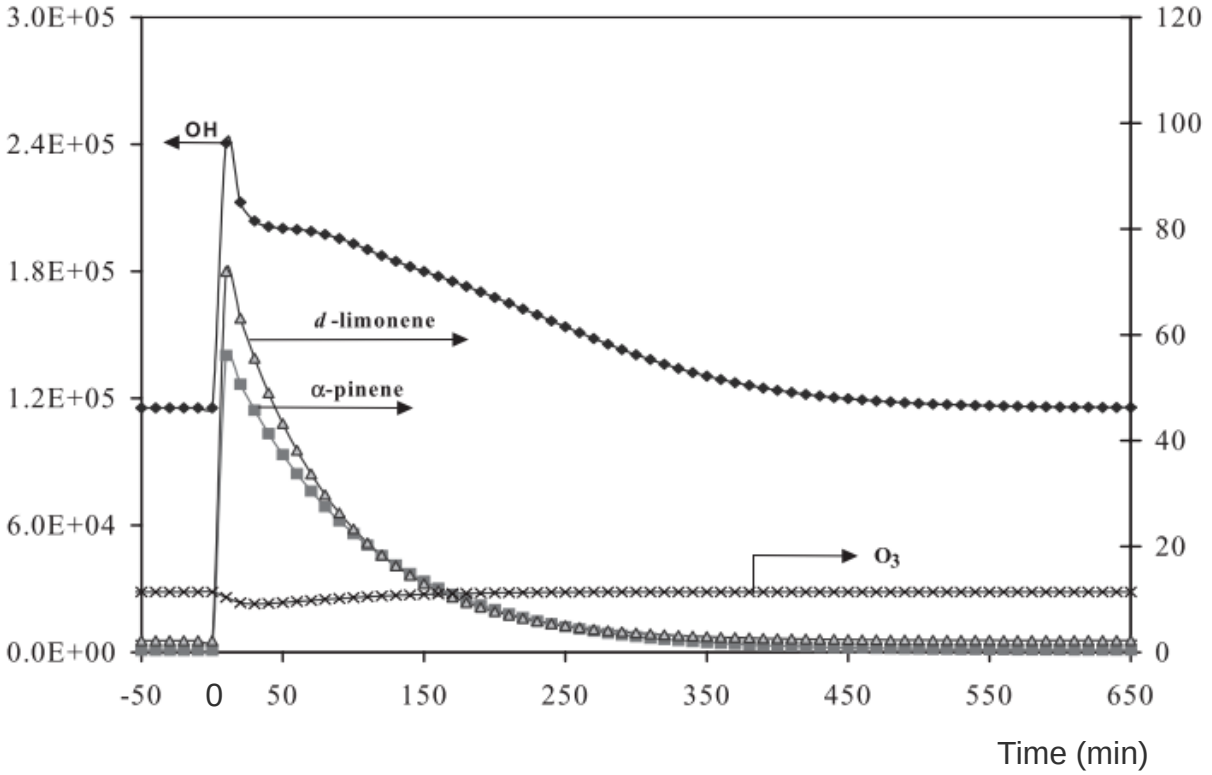
PhD Research Project | Chryssa Thoua UCL IEDE | Prof Dejan Mumovic, UCL IEDE | Prof Matija Strlic UCL ISH | Mark Lumley, Architype | David Drewe, Historic England | Dr Anna Mavrogianni, UCL IEDE

SEAHA ARCHITYPE Historic England UCL

air quality monitoring: real-time sampling

Active sampling: captures important events (e.g. emissions from cleaning) for better interpretation of results and to make decisions such as correct timing of ventilation strategy.

Indoor hydroxyl radicals (molecules $OH \cdot cm^{-3}$)

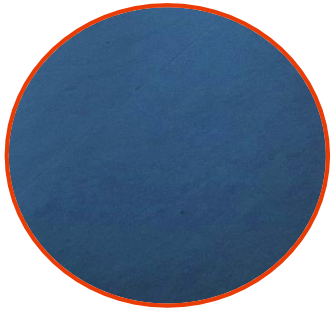


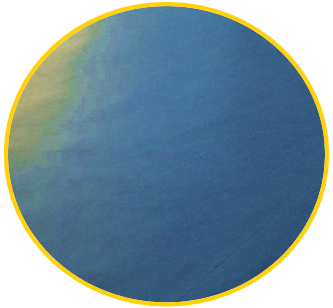
Indoor d-limonene a-pinene & ozone levels (ppb)

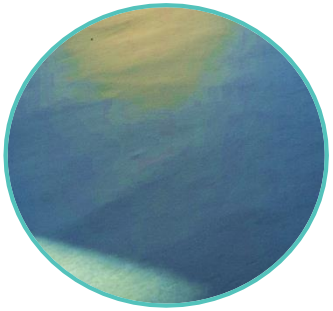
Graph shows predicted indoor limonene, pinene, ozone and hydroxyl radical levels during a typical clearing operation (at time 0 min). Source: Sarwar et al. (2002).

air quality monitoring - passive sampling

Passive sampling enables to distinguish emissions of different types of compounds. Especially important for evaluation of exposure risk and source apportionment

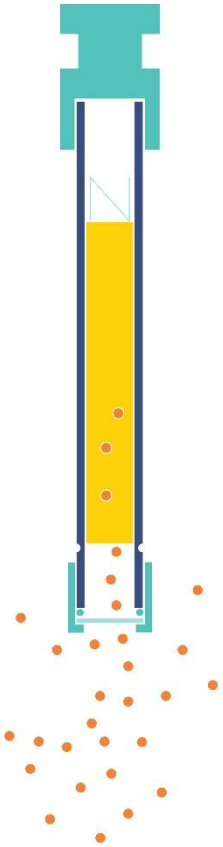






Vinyl	Rubber	Linoleum
dodecane, tridecane, tetradecane, hexadecane, a-pinene, toluene, xylenes, 1,2,4-trimethylbenzene, 1,3,5-triethylbenzene, 1,2,3,5-tetramethylbenzene, some unknown substituted benzenes, naphthalene, 2-methylnaphthalene, butanol, octanol, 2-ethyl-hexanol, nonanol, phenethyl, alcohol, phenol, formaldehyde, acetaldehyde, cyclohexanone, vinyl acetate, butylacetate, TXIB.	hexane, 2-methylhexane, 3-methylhexane, 2-methyl octane, 3-methyl octane, nonane, decane, undecane, methyl cyclohexane, 1-methyl-4-methyethyl-cyclohexane, heptene, indene, isododecene, 4-vinyl-1-cyclohexene, styrene, a-methylstyrene, benzene, toluene, ethylbenzene, methylpropylbenzene, 1,3-diisopropyl benzene formaldehyde, acetone, acetophenone.	3-methylpentane, cyclopropane, cyclohexane, 1,2 dimethyl cyclohexane, a-pinene, 3-carene, toluene, trimethylbenzene, xylenes, C3-C11 aldehydes (including unsaturated aldehydes: 2-pentenal, 2-decenal and 2-undecenal), benzaldehydes, acetone, ethylmethylketone, C2-C8 aliphatic, carboxylic acids, fatty acids, butylformate, 2-methyl propanoate, 2-pentylfuran.

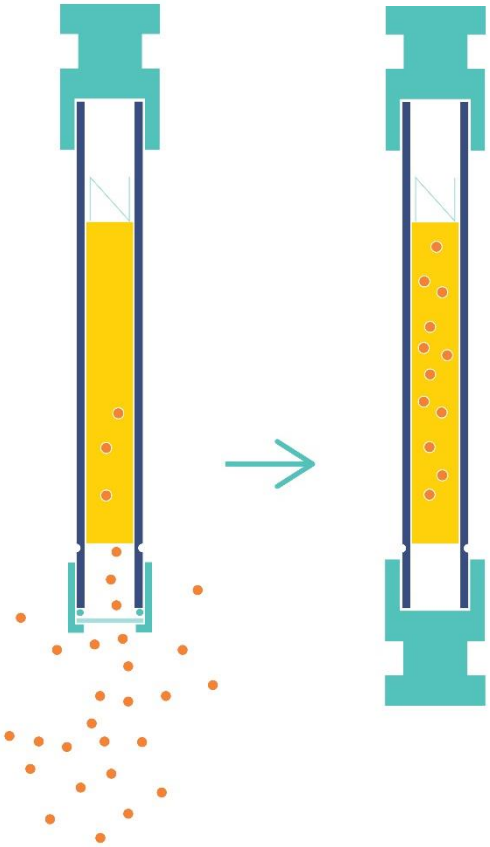
Air quality monitoring - passive sampling



The process for VOC sampling on sorbent tubes:

1 Exposure of the sampler for a week.
The flow of air is controlled by the diffusion caps and can be calculated.

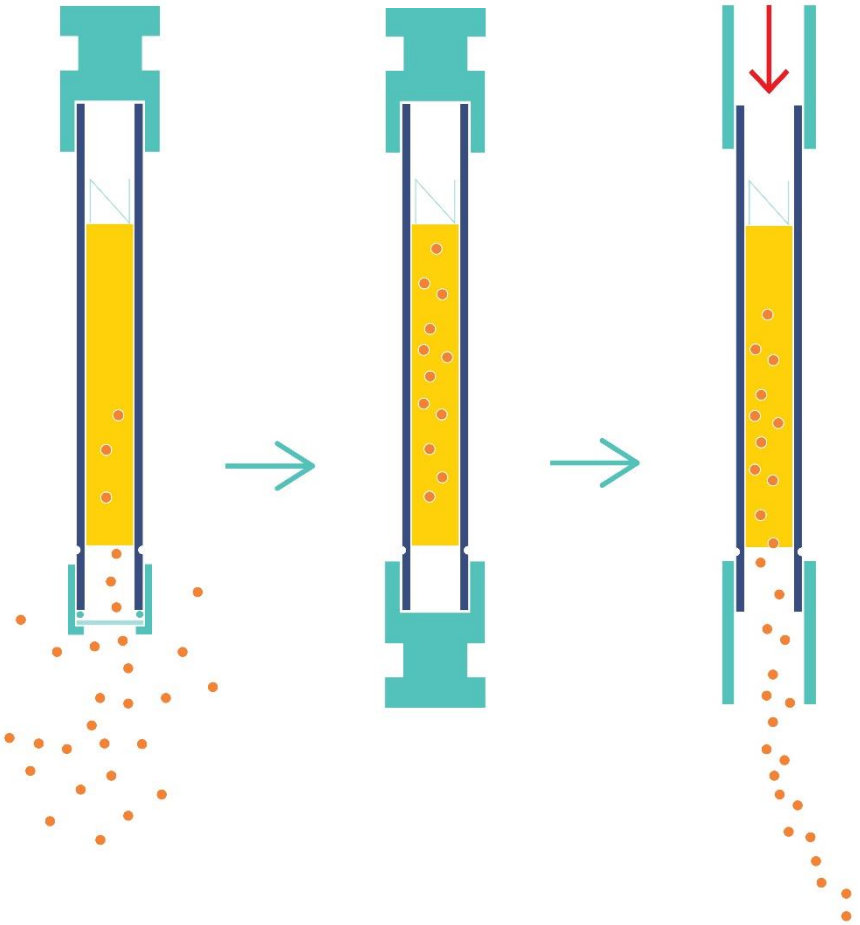
Air quality monitoring - passive sampling



2 Transportation to the laboratory for analysis.
The tube is sealed with long term storage caps.

Image source: www.markes.com

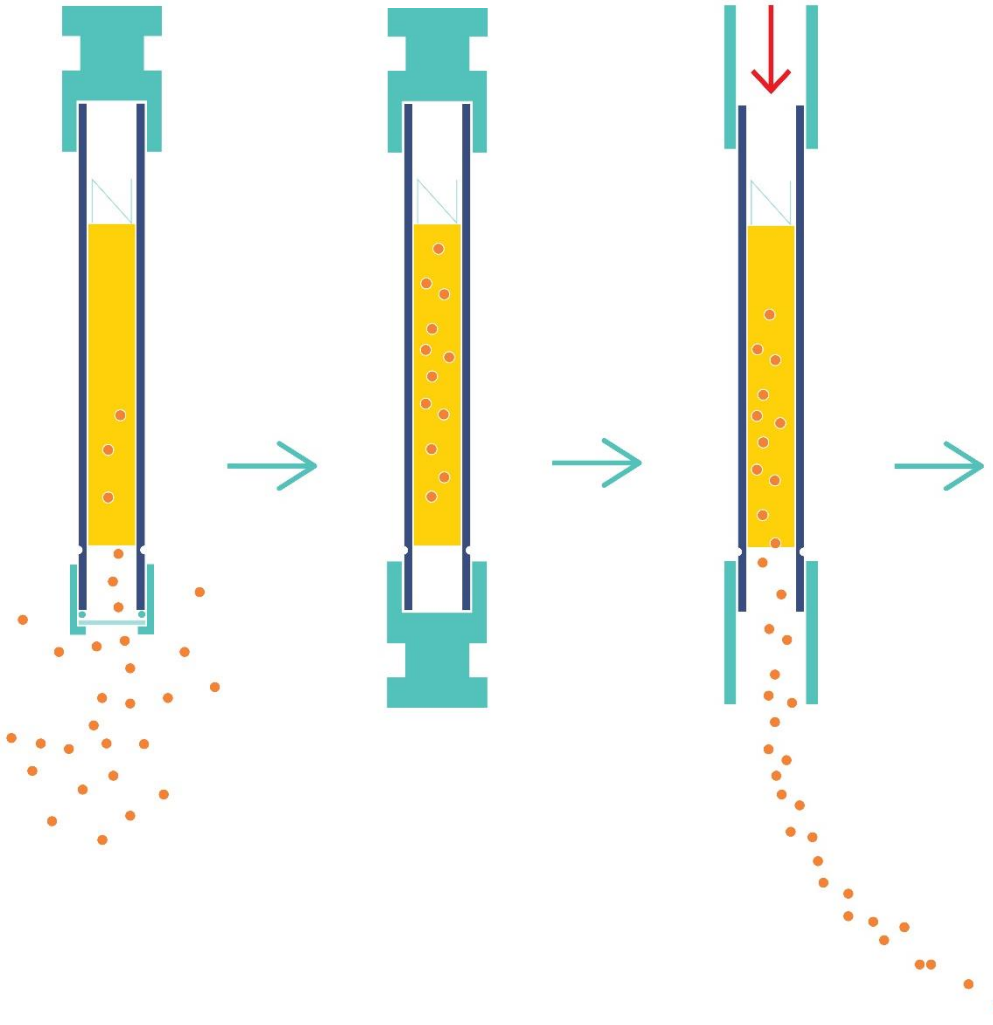
Air quality monitoring - passive sampling



3 Thermal desorption at the laboratory:

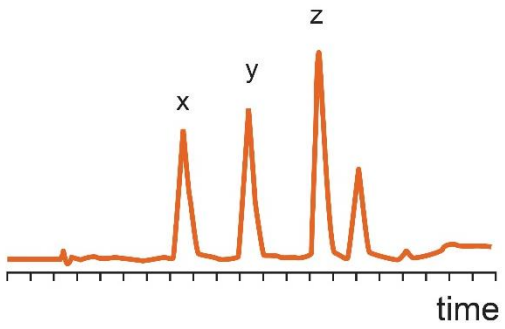
The sorbent is heated to high temperatures (~ 250°C).
The compounds are forced to leave the sorbent under the flow of carrier gas (helium or nitrogen).

Air quality monitoring - passive sampling

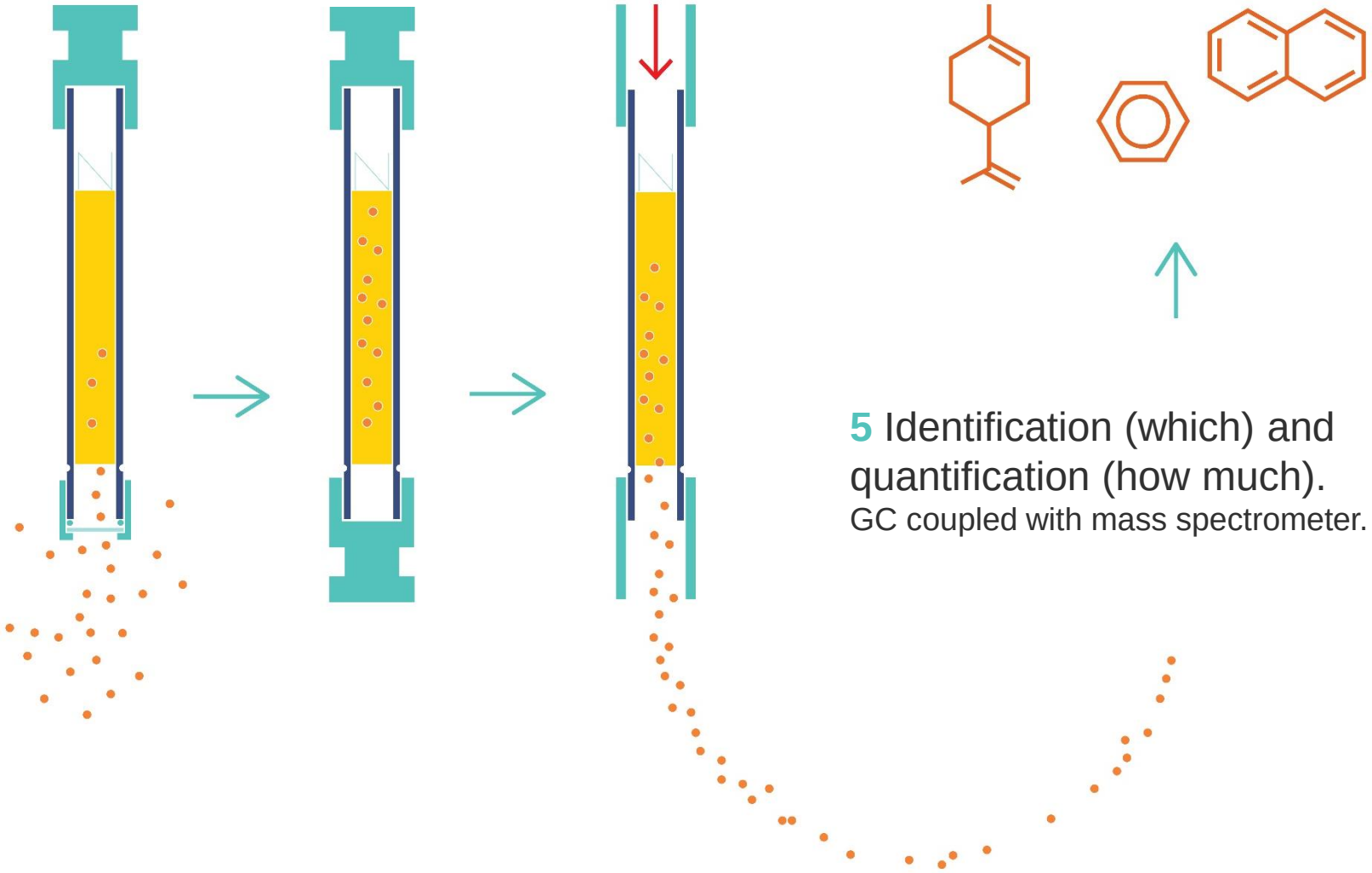


4 Separation of compounds

Using gas chromatography.



Air quality monitoring - passive sampling



5 Identification (which) and quantification (how much).
GC coupled with mass spectrometer.

Air quality assessment: other evidence

In agreement with guideline indoor air quality strategies for source elimination and ventilation:

Good indoor air quality = Low VOC, natural materials spec + Passivhaus


Image credit: Architype


Image Credit:


Photo credit ©DarrenCarterMorganSindall

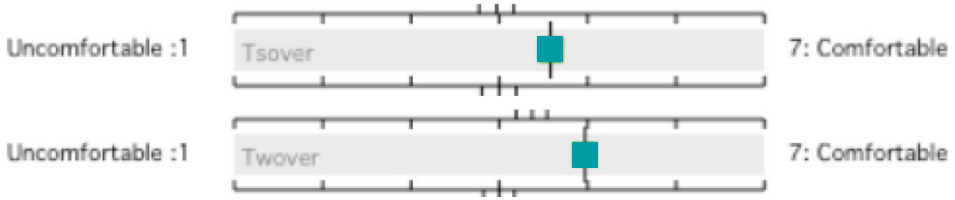
Other evidence on performance
(BUS survey results for UEA Enterprise Centre)

Air in summer: overall

Air in winter: overall

Temperature in summer: overall

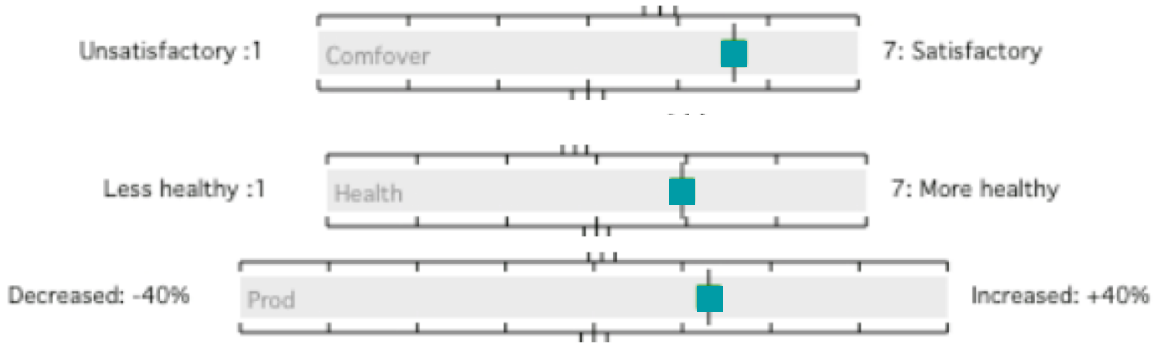
Temperature in winter: overall

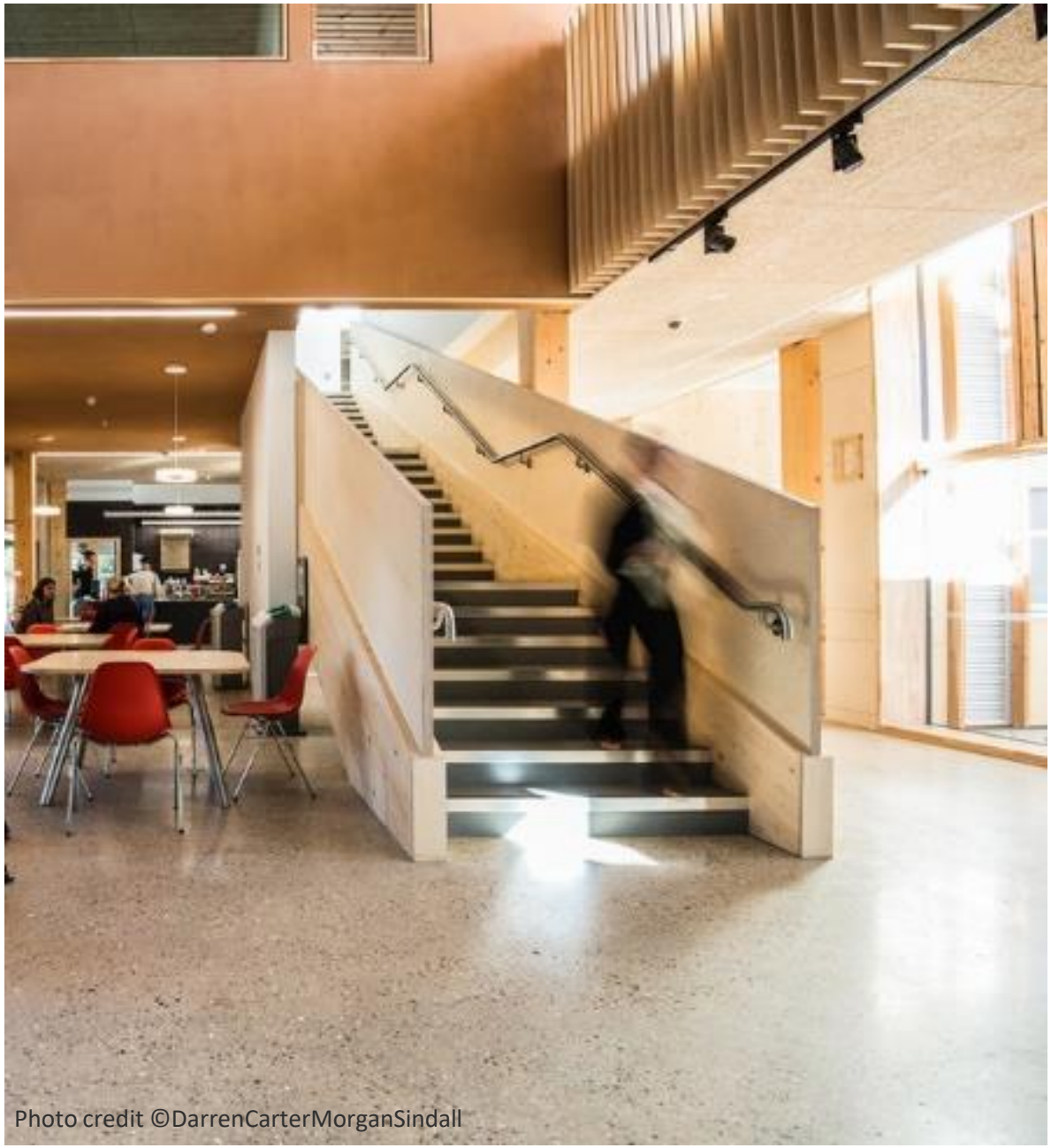


Comfort: overall

Health: perceived

Productivity: perceived





Thankyou

Ben Humphries
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