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Management of Indoor Air Quality in Air-Conditioned Buildings for Good Environmental Health

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1 Indoor air quality & health

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Indoor air quality affects health and wellbeing of occupants

Indoor air quality (IAQ) generally refers to –

The **quality of air in a building** environment, **in relation to the health and wellbeing** of those who occupy space within it

A healthy and comfortable indoor environment is important as a large amount of our time are spent indoors






Indoor air quality affects the overall indoor experience

Good Indoor Air Quality is associated with –

+ Better health & comfort

+ Occupants' satisfaction

+ Higher productivity

Poor Indoor Air Quality could result in –

- Sick building syndrome (SBS)
  e.g. Headache, watery eyes, allergy, respiratory irritations

- Acute / Chronic diseases
  e.g. Respiratory & cardiovascular diseases, cancers

- Dissatisfaction & loss in productivity

- Unplanned expenditure ($$$) for mitigations



Common indoor pollutants of the built environment

Human-related pollutants

CO_2 **Bacteria**



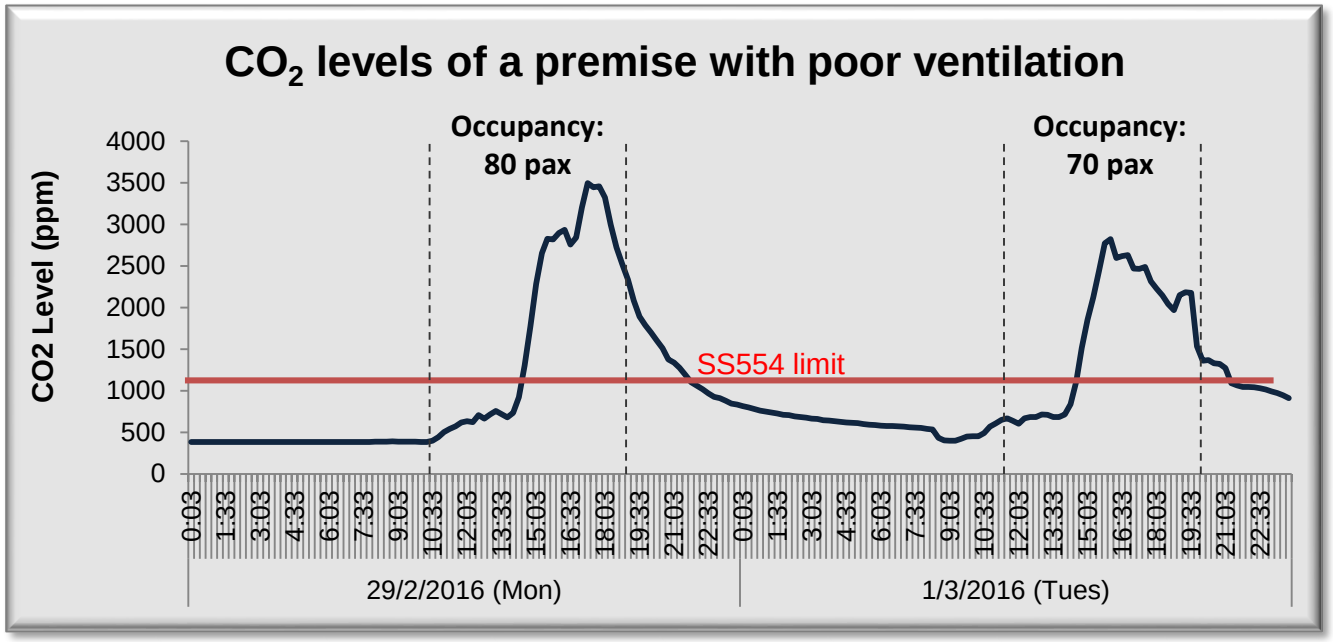
Activities-specific pollutants

VOC, PM





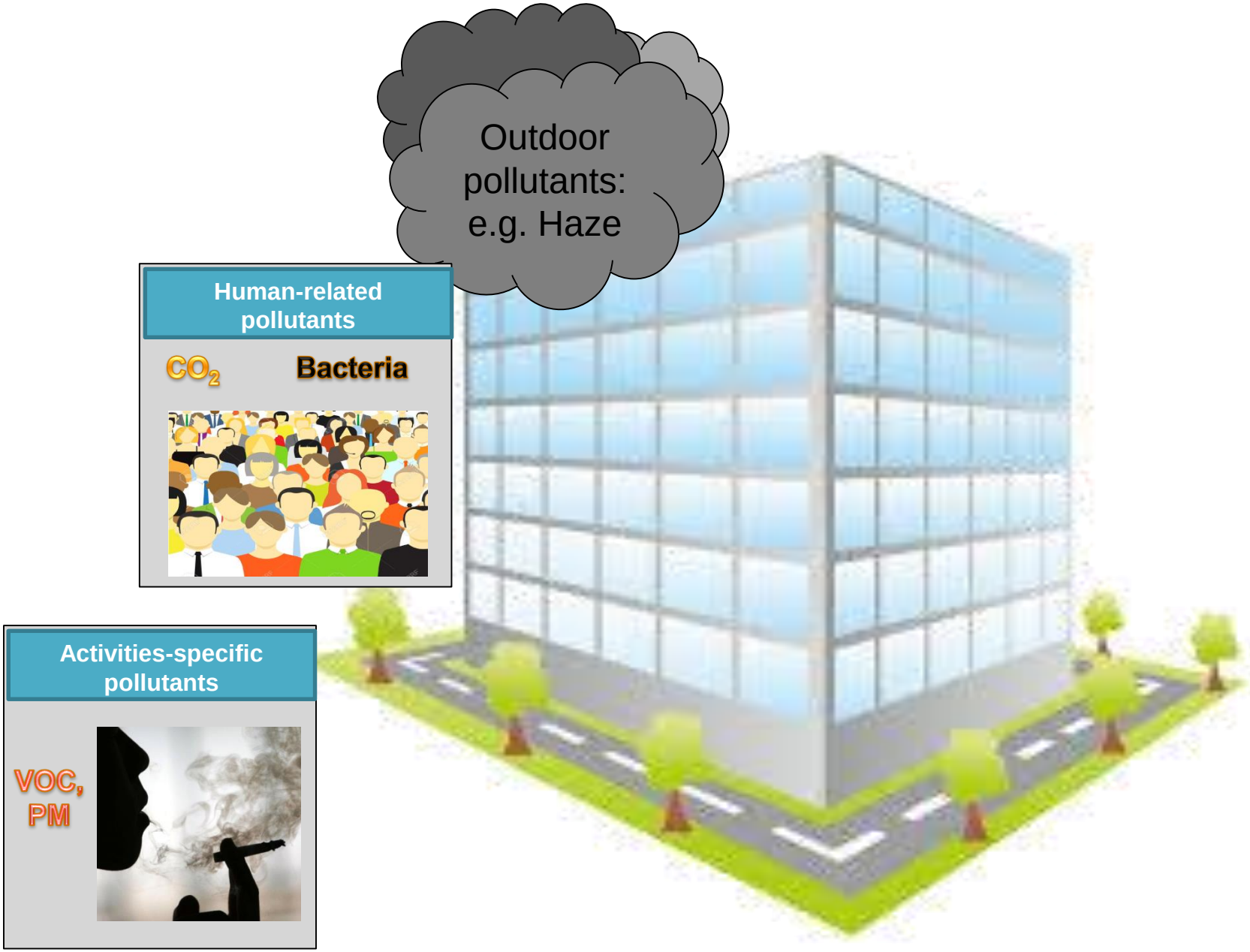
Poor IAQ due to insufficient ventilation



- Build up of CO_2 at a premise with high occupancy, with little ventilation

- CO_2 concentration is commonly used as a surrogate indicator for assessing indoor air quality (IAQ) and ventilation adequacy. When CO_2 concentration exceeds the acceptable limit, other pollutant concentration may also be high and the ventilation is deemed to be inadequate.

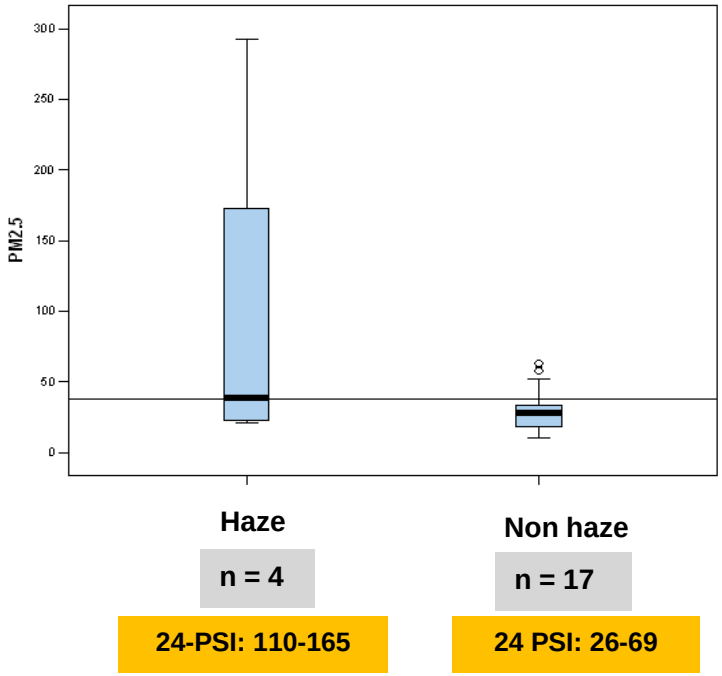
Common indoor pollutants of the built environment

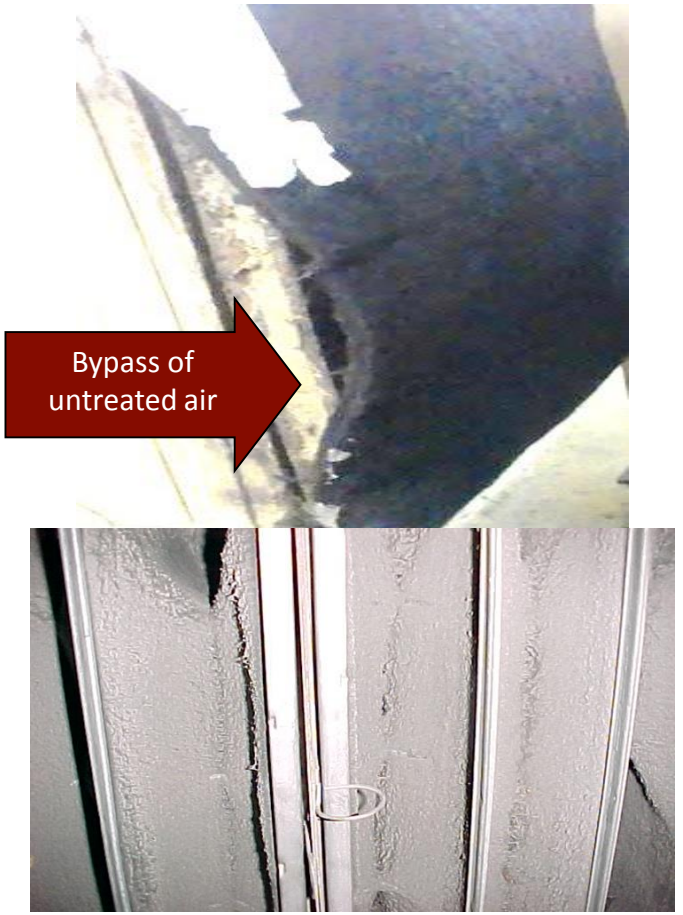


Poor IAQ due to infiltration of polluted outdoor air

- Ventilation provided but polluted outdoor air (e.g. during haze) introduced into indoor environment

PM2.5 in indoor spaces during haze and non-haze periods

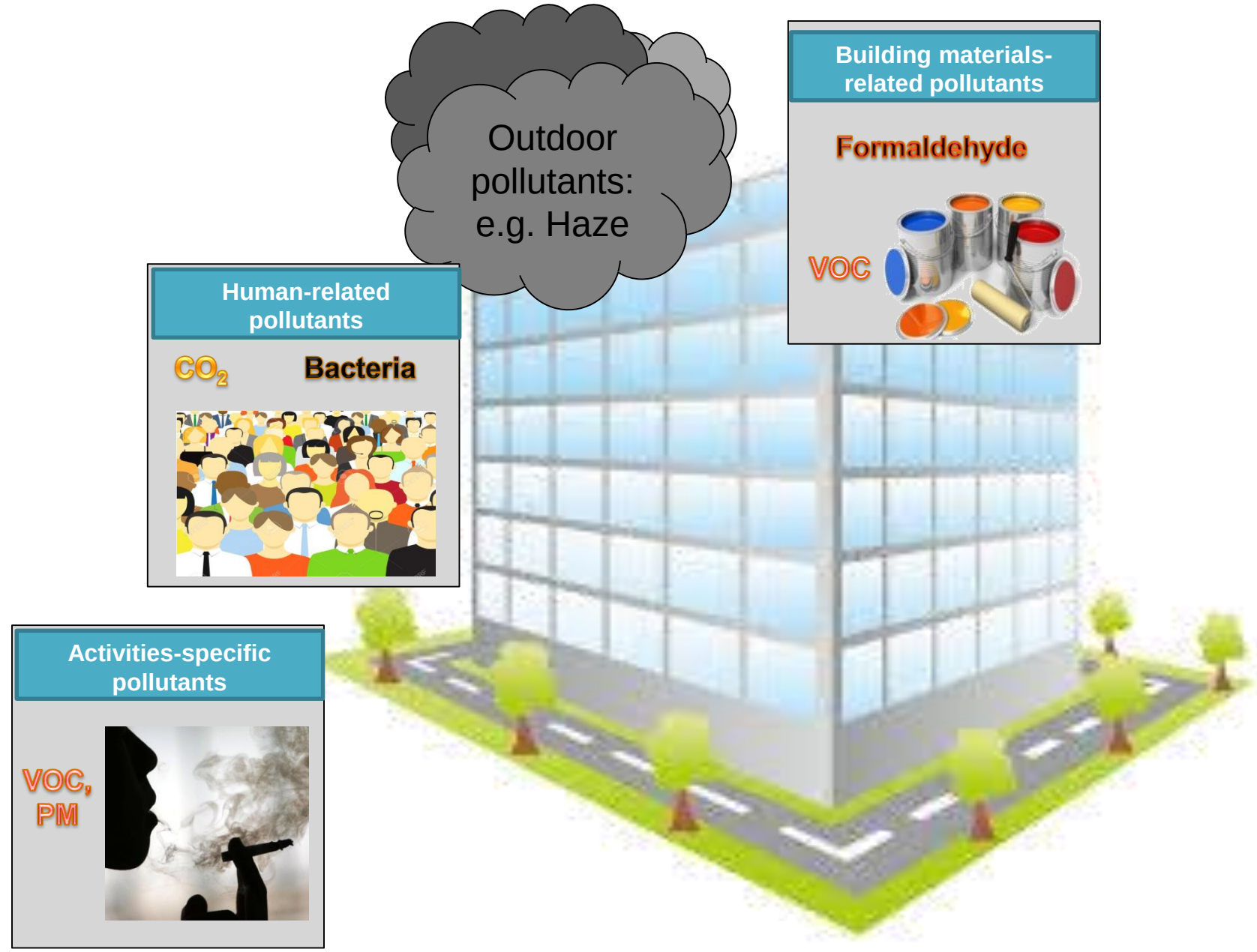




- Leaky envelop or centralized air-conditioning systems with inefficient air filters or with filters improperly installed or maintained.

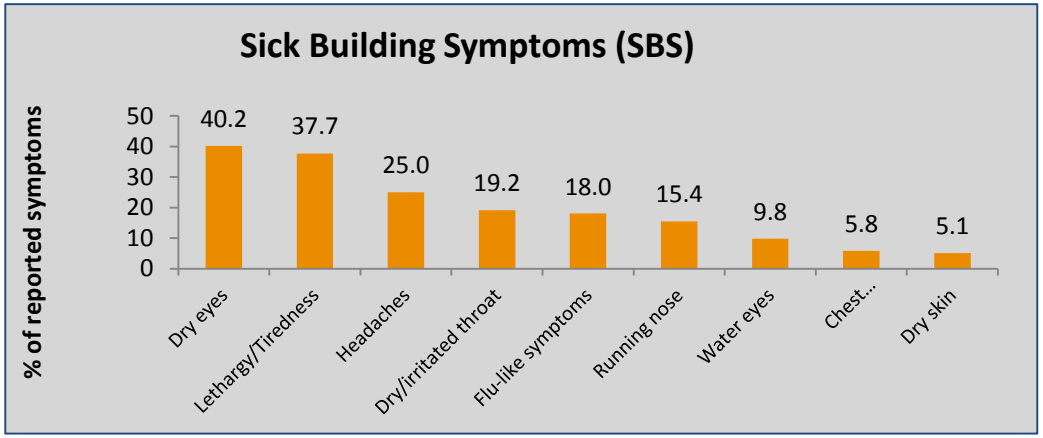
Examples of low efficient filters that are not fitted properly onto the ACMV system

Common indoor pollutants of the built environment



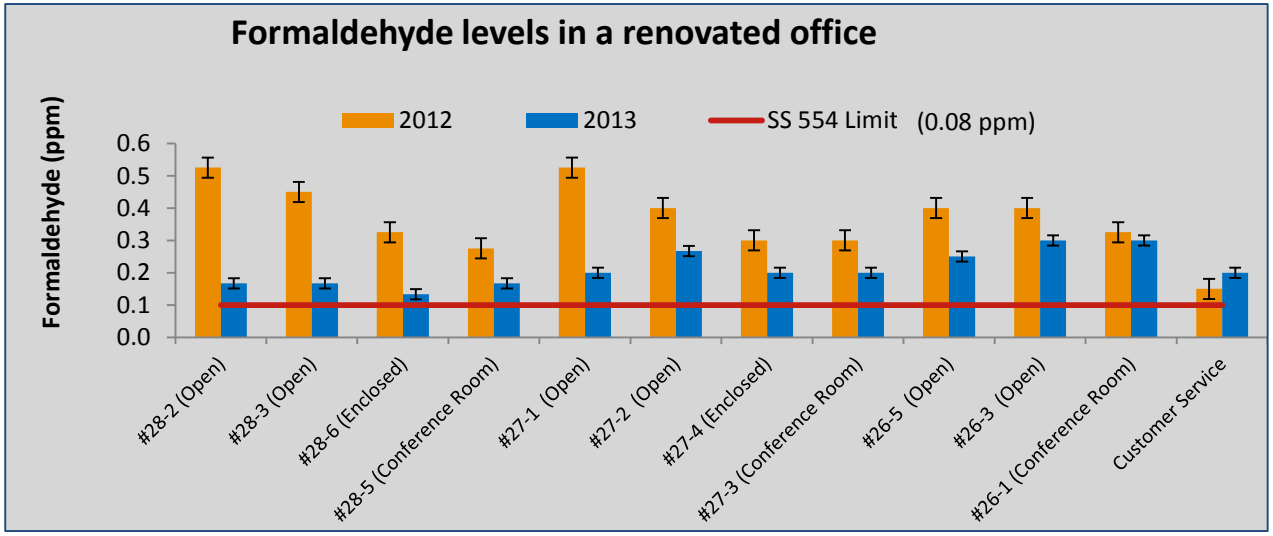
Poor IAQ due to toxic chemicals from indoor furnishings

High formaldehyde levels in a renovated office in a commercial building





A case of skin irritation from exposure to excessive formaldehyde



Remediation work may be lengthy (> 1 year) and costly (health and energy cost)

Emissions of Formaldehyde and Volatile Organic Compounds from indoor furnishings

Building and furnishing products may contain chemical additives which can off-gas formaldehyde and volatile organic compounds (VOC)

- Formaldehyde and some species of VOC are carcinogenic

Typical indoor sources

Adhesives/glues, carpets, furniture, paints, composite woods, varnishes & cleaning agents, textiles, **vinyl floorings**, wall insulation, etc



Health Effects of formaldehyde

Short-Term (Acute)	Long-Term (Chronic)
Eye, nose and throat irritations	Increased risk of:
Headaches / dizziness	Cancer
Nauseas	Liver damage
Skin rashes	Kidney damage
Worsening of asthma symptoms	Damage to nervous system

Common indoor pollutants of the built environment

Outdoor pollutants: e.g. Haze

Building materials-related pollutants

Formaldehyde

VOC



Human-related pollutants

CO_2 Bacteria



Activities-specific pollutants

VOC



Activities-specific pollutants

VOC, PM



Cooking-related pollutants

PM2.5 VOC CO



Pollutants from specific activities

VOC from hair products

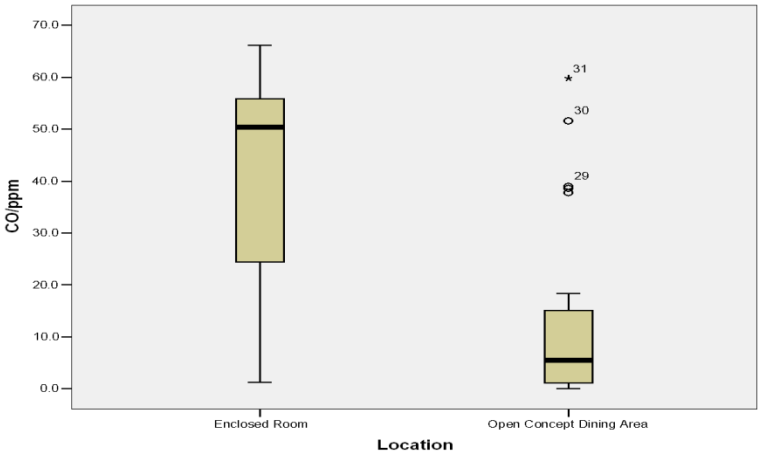
Article

Indoor Air in Beauty Salons and Occupational Health Exposure of Cosmetologists to Chemical Substances

Alexandra Tsigonia [1,2], Argyro Lagoudi [3], Stavroula Chandrinou [3], Athena Linos [2], Nikos Evlogias [1] and Evangelos C. Alexopoulos [4,*]



Carbon monoxide from charcoal BBQ





Common indoor pollutants of the built environment

Outdoor pollutants: e.g. Haze

Building materials-related pollutants

Formaldehyde

VOC



Human-related pollutants

CO_2 Bacteria



Activities-specific pollutants

VOC



Activities-specific pollutants

VOC, PM



Moisture-related pollutants

Mold



Cooking-related pollutants

PM2.5 VOC CO



Poor IAQ due mold infestation

- Mold are ubiquitous eukaryotic organisms, comprising an abundance of species.
- Mold grow readily on most moist surfaces
- Profuse growth of mold suggest poor management of humidity, or water seepage

Environmental conditions of a mold-infested office	
% RH	72.3 -78.8
Air temp (^{0}C)	23.2-23.7



Mold growing on files

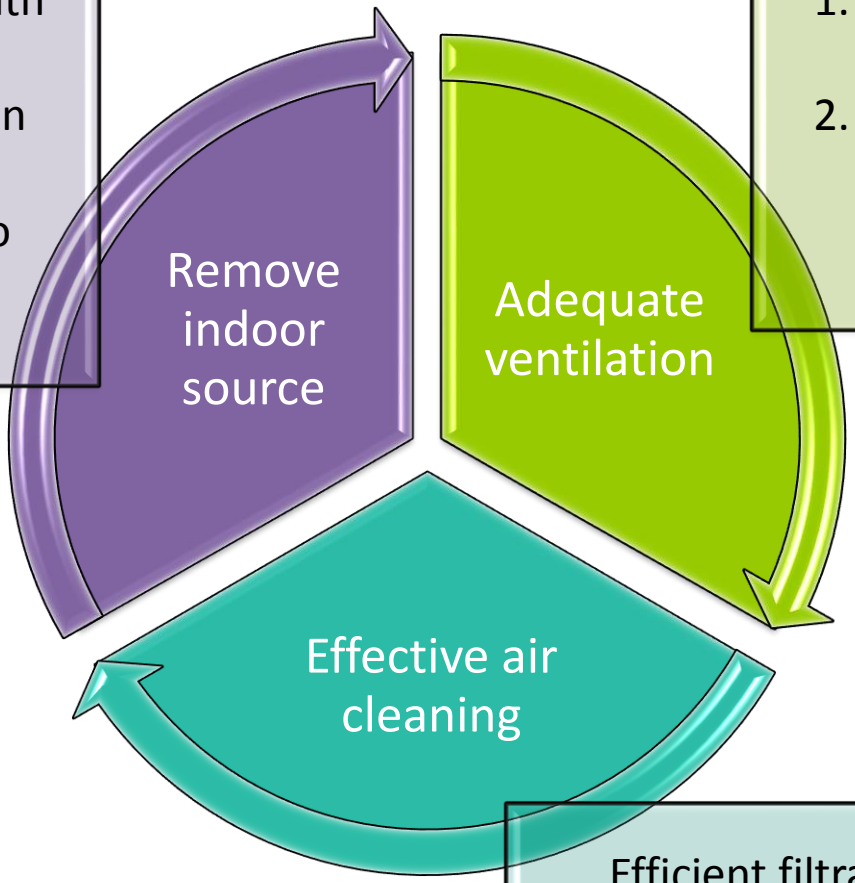
- Leaky envelop (e.g. window) that allows infiltration of rainwater or humid air that condenses on cooler indoor surfaces
- Water seepage in walls

2 Managing Indoor Air Quality

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3 key strategies to guide IAQ management

1. Ask for products with low chemical-emission. Labels can be used as guides.
2. Control moisture to prevent mold growth.



1. Provide adequate outdoor air intake.
2. Provide exhaust systems, adjust for activities that generate pollutants.

Efficient filtration improves IAQ and protects the ACMV system.

Renovation/retrofitting using low chemical-emitting products can reduce indoor chemical pollutants

Low chemical pollution when low-VOC & formaldehyde-free materials were used



IAQ measurement done 1 day after renovation:
Formaldehyde: Not detected
TVOCs: 16 ppb
(SS554 limit - 1000 ppb)

Low emission materials that are certified by the Singapore Green Building Council (SGBC) or the Singapore Environment Council (SEC) will carry their respective labels.

SINGAPORE GREEN BUILDING PRODUCT
Singapore Green Building Council Certification

GreenLabel SINGAPORE

Prompt remediation is necessary when signs of mold infestation appears

- Mold can affect health of the occupants
  - Health effects may include allergic reactions, irritation and skin rash.
  - Mold may also aggravate asthma.
  - Most symptoms are temporary and eliminated by correcting the mold problem.
- The presence of **visible water damage or stains, visible mold, and/or odors from microbial growth**, is a warning and calls for necessary action to remediate the source of the water accumulation or mold infestation.

Steps to manage mold growth

1. Address water or moisture problems promptly. Keep RH within acceptable limits.

2. Investigate musty smell, do not mask smell using air fresheners

3. Clean / rid mould patches as soon as possible to prevent rapid proliferation

Efficient filters can improve IAQ and keep ACMV systems clean

- Higher MERV rating, better removal of fine particles

ASHRAE 52.2 Minimum Efficiency Reporting Value (MERV)	Composite average particle size efficiency, % in size range, µm		
	0.3 to 1.0	1.0 to 3.0	3.0 to 10.0
6	-	-	$35 \le E_3$
14	$75 \le E_1$	$90 \le E_2$	$95 \le E_3$

Higher rating

- Efficient filters can keep ACMV systems clean and reduce the need for cleaning. Damaged or dirty ACMV system are less efficient.



Picture of cooling fins when high efficiency filters was used



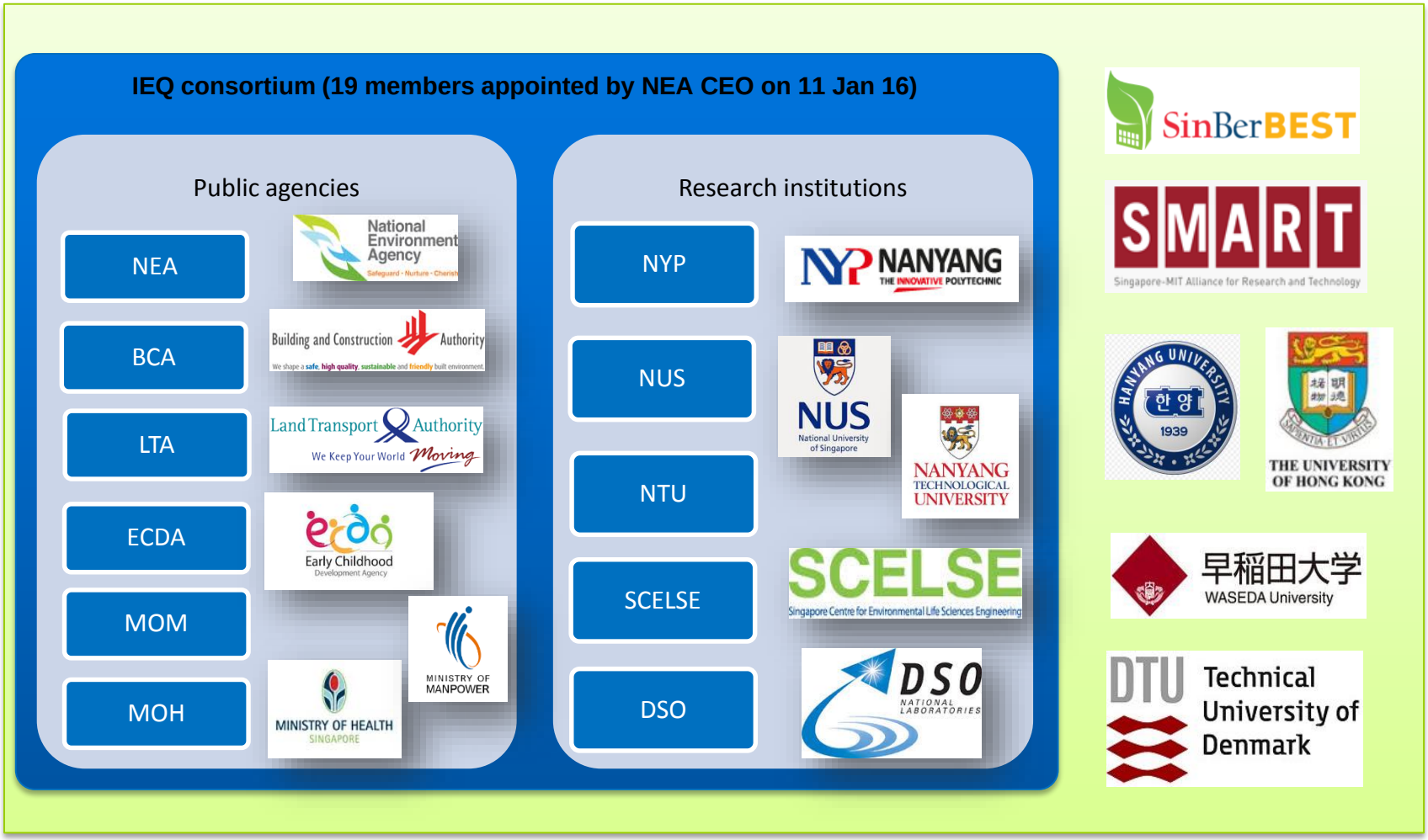
Picture of cooling fins when low efficiency filters was used

General indicators of IAQ (not-limited)

Parameter	Acceptable limit	Unit	Reference
i. Thermal comfort parameters			
Air temperature	23 to 25	°C	SS553:2016/ASHRAE 55-2010
Air movement	< 0.30	m/s	
Relative humidity	< 65 (for bldg designed to SS 553/554: 2009 ver onwards) < 70 (for other bldg) (under peak and common part load conditions)	%	ASHRAE 62.1-2013
ii. Chemical parameters			
Carbon dioxide	700 above outdoor (8 hr)	ppm	ASHRAE 62.1-2013
Carbon monoxide	31 (1 hr) 9 (8 hr)	ppm	WHO Guidelines for IAQ: 2010
Formaldehyde	100 (30-min) 0.08 (30-min)	$\mu g/m^3$ ppm	
Total volatile organic compounds (TVOC)	1000 (8 hr)	ppb	Based on local data
Respirable suspended particles	50 (24 hr)	$\mu g/m^3$	WHO Air Quality Guideline: 2005
PM 2.5	37.5 (24 hr)	$\mu g/m^3$	
iii. Biological Parameters			
Total viable bacteria count	1000	cfu/m^3	Hong Kong's IAQ Certification Scheme (2003)

Acknowledgement

A collaborative network of international and local experts



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Thank you