The Sick Building Syndrome

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Definition and History

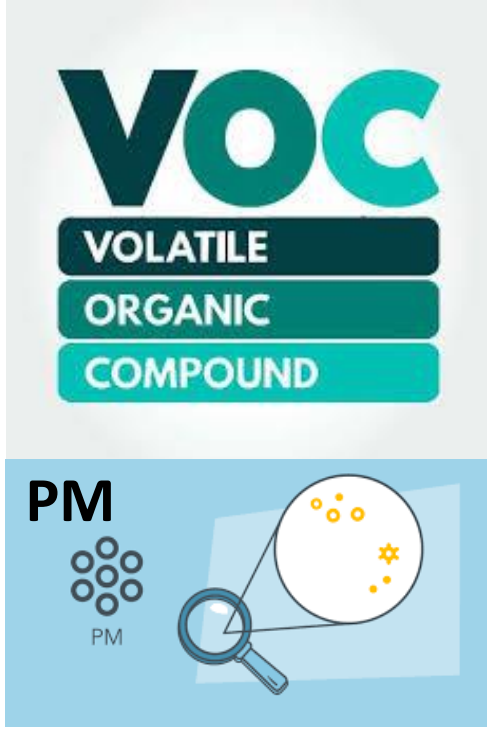
Sick Building Syndrome: a syndrome of uncertain aetiology consisting of non-specific, mild upper respiratory symptoms (stuffy nose, itchy eyes, sore throat), headache and fatigue, experienced by occupants of 'sick buildings'; (also) the environmental conditions existing in such a building; abbreviated SBS . (Oxford English Dictionary (OED), 1989)

First reported during the 1960s, yet it was not until the 1980s that further reports began to be published, raising awareness of this newfound 'common' problem (Health and Safety Executive, 1992).

Sequence of Events

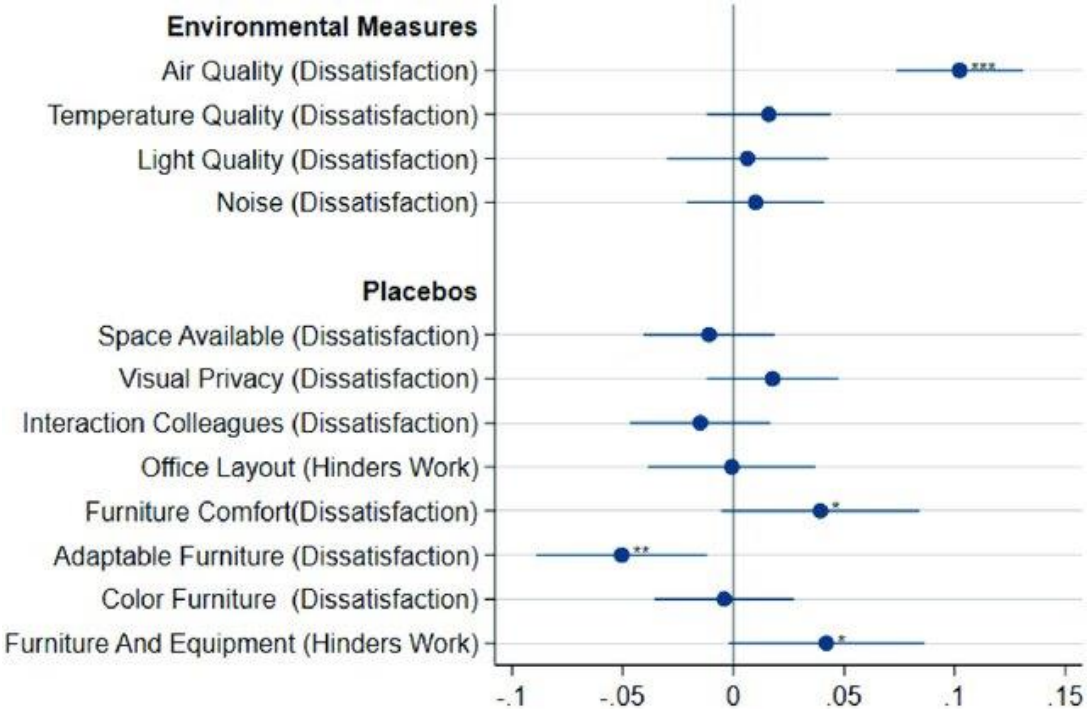
The reasons for buildings becoming ‘sick’ stemmed from the drive for energy efficiency:

- Need to make buildings air-tight
- Climate control systems, including ventilation and air circulation
- Open plan floor-by-floor layouts to maximise use of ventilation systems
- New synthetic materials (plastics, solvents, adhesives, synthetics carpets, etc.)
- New types of equipment (computers, printers, fax machines)



Causes of SBS

No single cause has been identified to cause SBS (NHS)



The amount of outdoor ventilation per individual occupant was initially (1970s) set at five cubic feet per minute (5 cfm). ASHRAE) revised the amount per occupant to 15 cfm in the 1990s, raised to 20 cfm for offices and up to 60 cfm for areas of specific use where heavy pollution may accumulate, or is produced (Bialous and Glantz, 2002)

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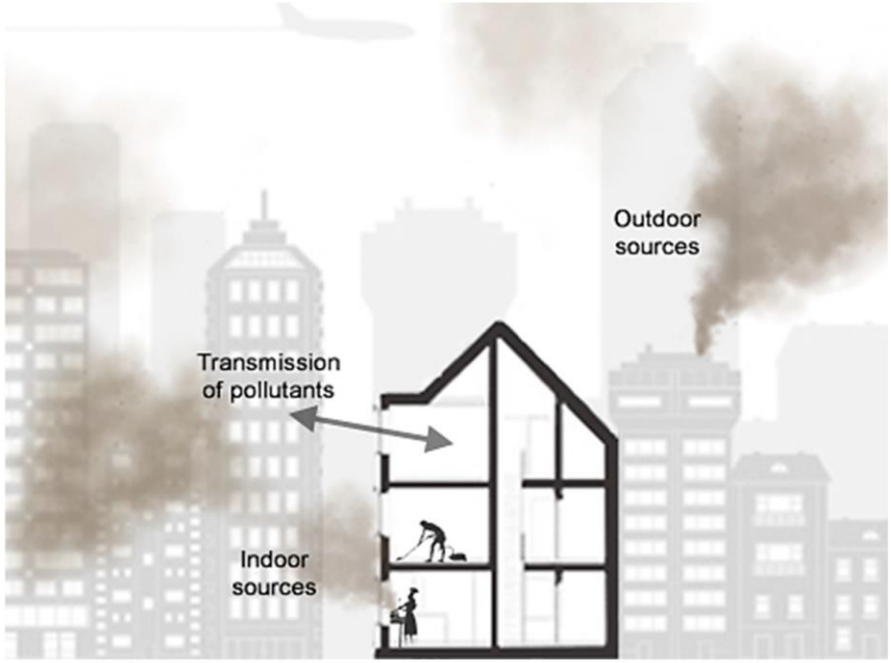

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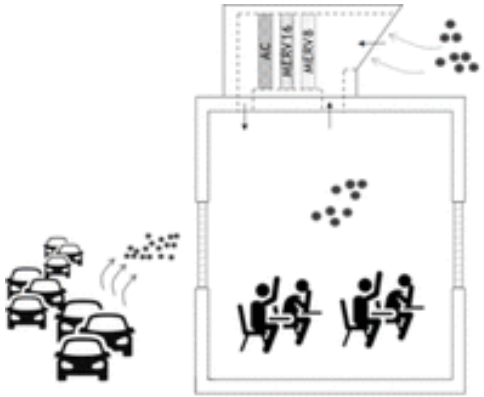
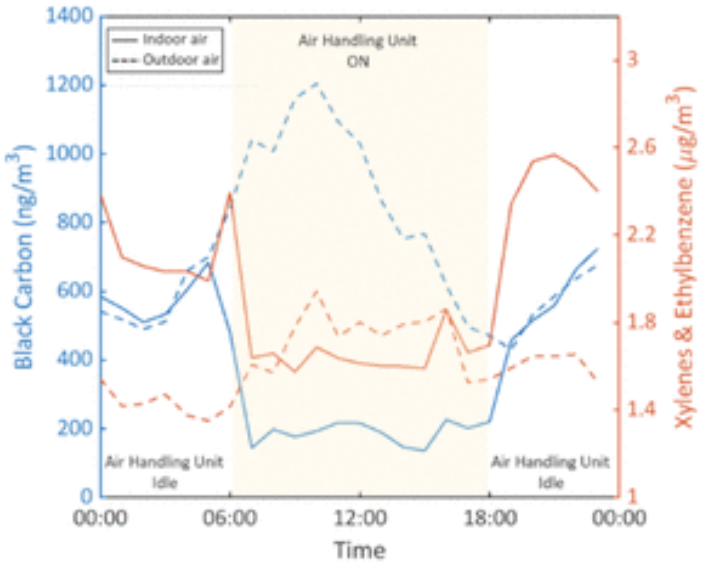
Use of High-Efficiency Air Cleaning

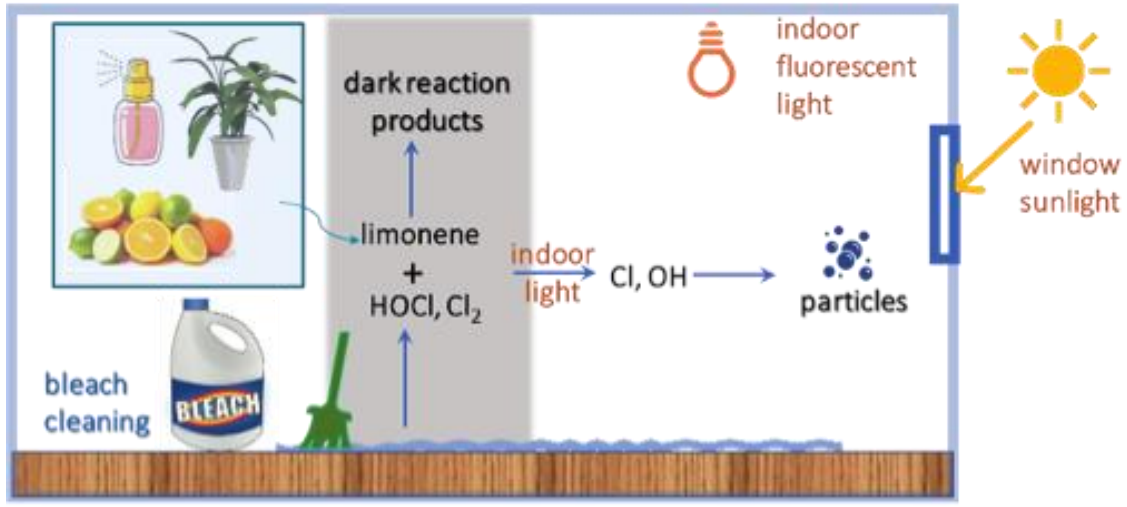


High-efficiency air-cleaning resulted in:

- Particle removal > 94%
- BTEX removal > 80%
- NO_2 removal 61 – 96 %
- Removal of indoor reactive organics
- Suppression of indoor SOA formation

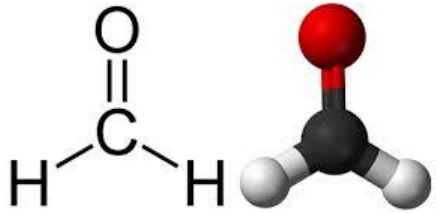


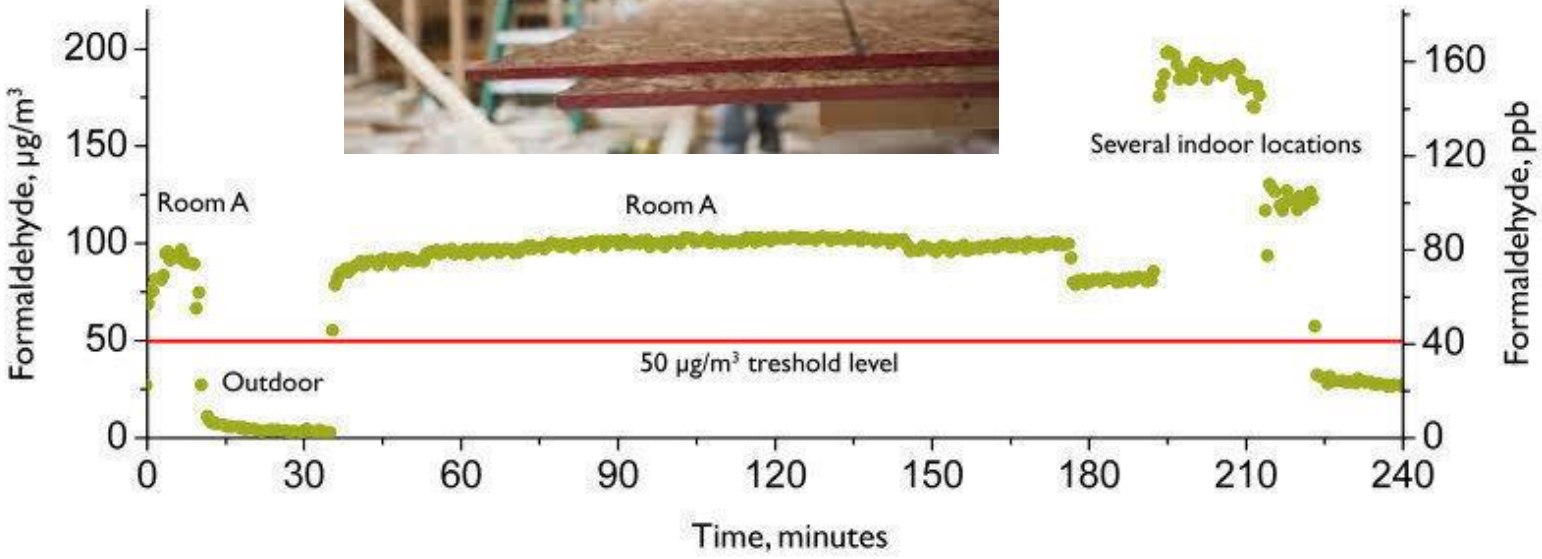
(Laguerr et al., 2020)



Volatile Organic Compounds (VOCs)

VOCs are carbon-based (organic) compounds that have a high vapour and low water solubility, and therefore evaporate at ambient temperatures within a building. Sources: photocopiers, printers, cleaning supplies, glues.

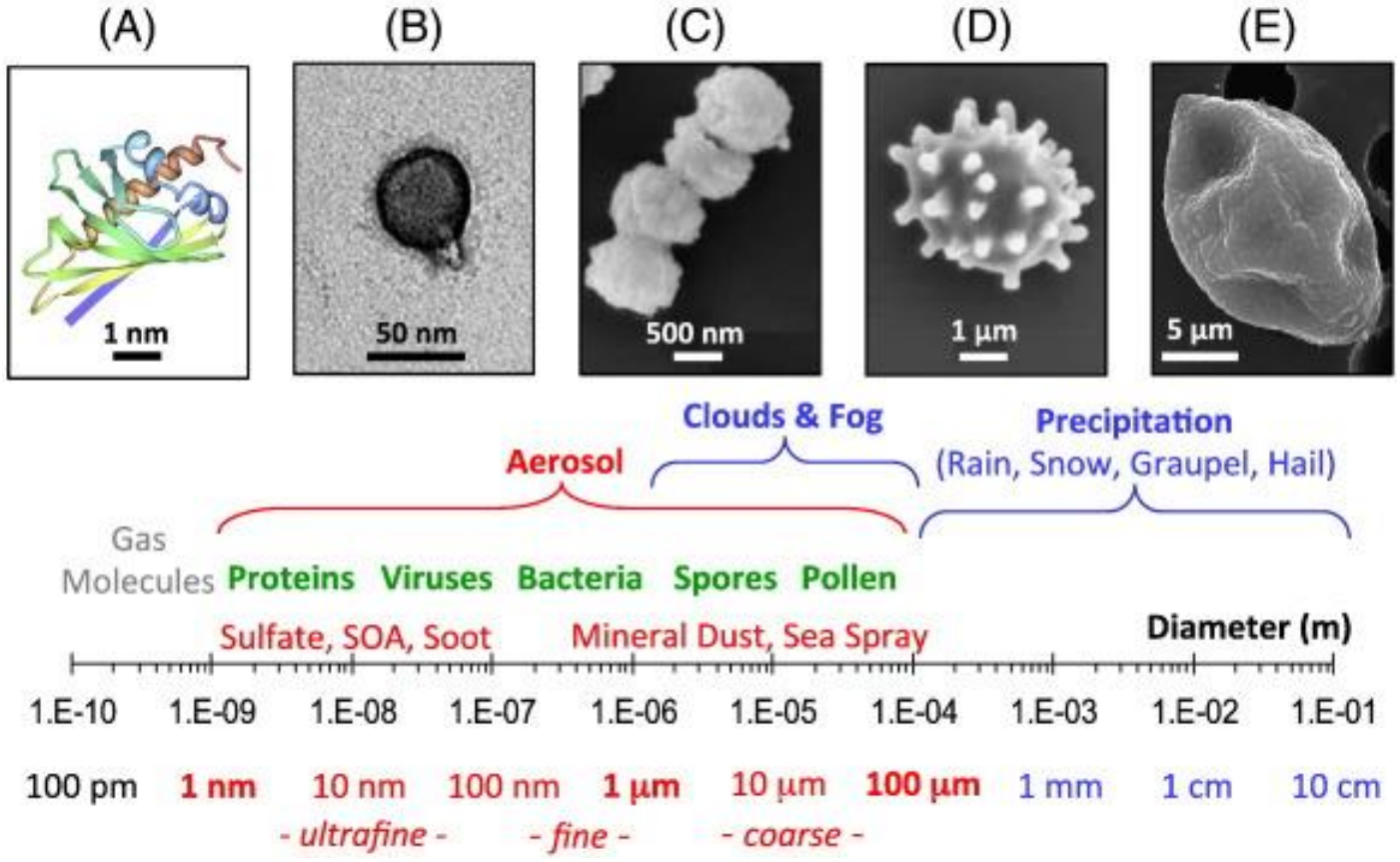


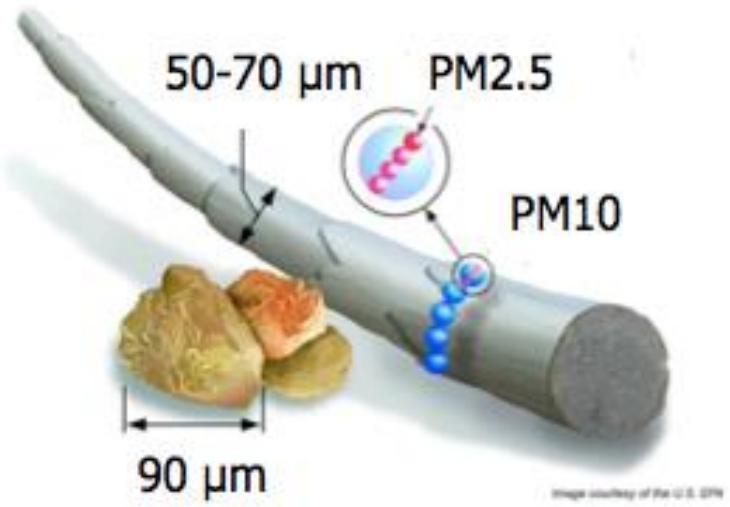


Inhalation effects in animals	Inhalation effects in humans	ppm in air	ppm ingested/day (mg/Kg)	Ingestion effects in animals
Bloody nasal discharge, pulmonary edema Death in 80% of mice at prolonged exposure to 40 ppm.	No Studies	>50	251 to 300	Decreased survival
			201 to 250	No studies
	Immediate danger to life and health at 20 ppm(NIOSH)	11 to 50		
Nasal tumors, squamous cell carcinoma, carcinoma in situ, meloblastoma, reduced survival, nasal precancer changes	Nausea, breathing discomfort, cough	6.0 to 10.9	151 to 200	Testicular effects (altered sperm morphology)
Nasal, eye & throat irritation, lower body weight, allergic responses, liver effects, testicular effects, chronic kidney & heart inflammation	Nasopharyngeal cancer, myeloid leukemias, sinonasal adenocarcinoma, DNA-protein cross links	2.0 to 5.9	101 to 150	Decreased water intake
			50 to 100	Decreased food intake & body weight, GI erosions, ulcers, & histo-pathologic changes, altered serum biochemistry & histopathology, occult kidney blood, changes in urine density & volume, altered kidney weight & histopathology
Increased DNA protein cross links. Change in pulmonary function, increased allergic responses, neurologic effects	Eczema, change in pulmonary function	0.6 to 1.9		
	Nasal and eye irritation, neurologic effects, increased risk of asthma and/or allergies	0.1 to 0.5	0 to 49	no effects

Particulate Matter (Aerosols)

Particulate Matter: sum of solid and/or liquid particles having diameters from a few nanomaters to 100 micrometers that are suspended in the breathing air





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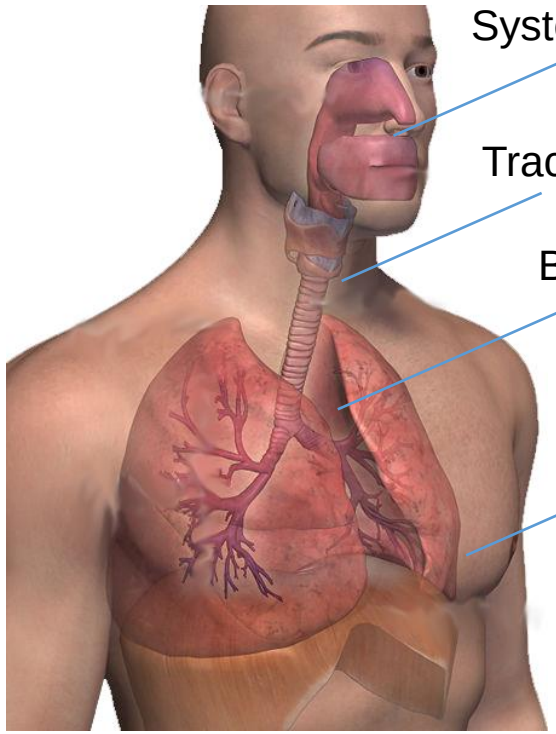


LETTER

doi:10.1038/nature15371

The contribution of outdoor air pollution sources to premature mortality on a global scale

J. Lelieveld[1,2], J. S. Evans[3,4], M. Fnais[5], D. Giannadaki[2] & A. Pozzer[1]

Assessment of the global burden of disease is based on epidemiological cohort studies that connect premature mortality to a wide range of causes[1–5], including the long-term health impacts of ozone and fine particulate matter with a diameter smaller than 2.5 micrometres ($PM_{2.5}$)[3–9]. It has proved difficult to quantify premature mortality related to air pollution, notably in regions where air quality is not monitored, and also because the toxicity of particles from various sources may vary[10]. Here we use a global atmospheric chemistry model to investigate the link between premature mortality and seven emission source categories in urban and rural environments. In accord with the global burden of disease for 2010 (ref. 5), we calculate that outdoor air pollution, mostly by $PM_{2.5}$, leads to 3.3 (95 per cent confidence interval 1.61–4.81) million premature deaths per year worldwide, predominantly in Asia. We primarily assume that all particles are equally toxic[5], but also include a sensitivity study that accounts for differential toxicity. We find that emissions from

scenario indicate that the contribution of outdoor air pollution to premature mortality could double by 2050.

GBD[5] we also include desert dust (which is largely natural) with $PM_{2.5}$; hence strictly speaking we assess the effects of atmospheric composition.

The air quality guidelines of the World Health Organization (WHO) and national regulatory policies are based on exposure response functions that rely on $PM_{2.5}$ mass concentrations, implicitly treating all fine particles as equally toxic without regard to their source and chemical composition. However, expert elicitation suggests that carbonaceous particles are more toxic than crustal material, nitrates and sulfates[10]. A recent study[25] finds that $PM_{2.5}$ from coal combustion leads to increased mortality risk from cardiovascular disease and LC, but that the evidence is much weaker for other sources, whereas estimates using non-specific $PM_{2.5}$ mass alone may underestimate the total effect of $PM_{2.5}$ on mortality. Further, this study did not find support for mortality from biomass combustion and soil dust particles[25]. However,

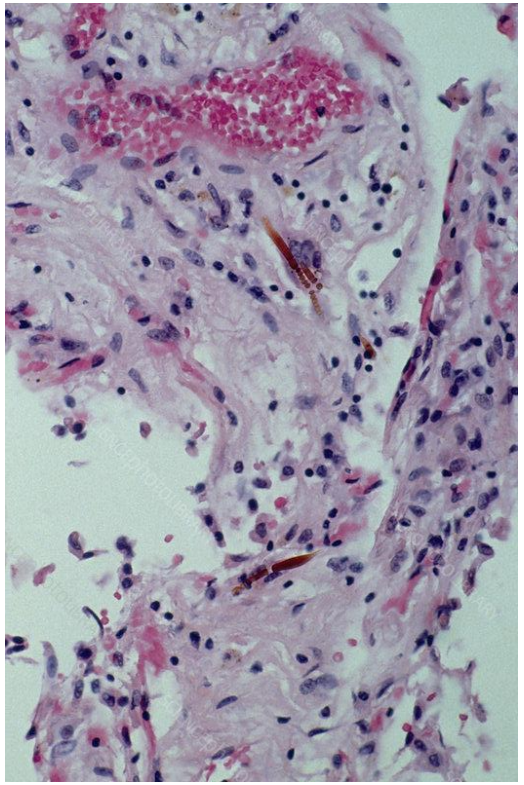
$PM_{2.5}$ related mortality in 2010 is 3.15 million people with a 95% confidence interval (CI95) of 1.52–4.60 million. The main causes are CEV

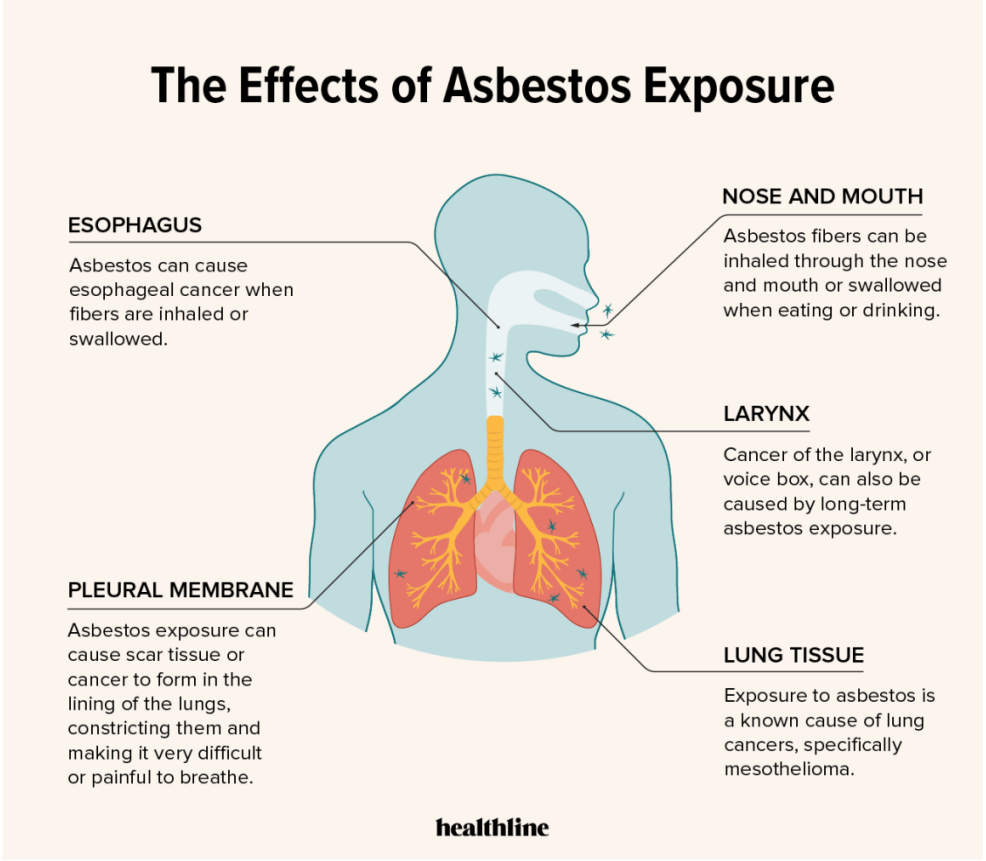
… we calculate that outdoor air pollution, mostly by PM2.5, leads to 3.3 million premature deaths per year worldwide …

Particulate Matter: the case of Asbestos

Asbestos is a naturally occurring fibrous mineral that was commonly used as an insulating and fire-resistant material in building construction until the late 20th century.

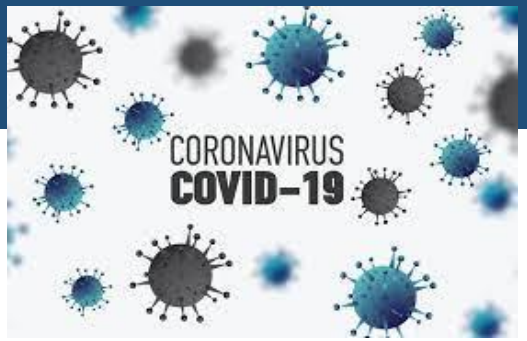
Asbestos (Tremolite)



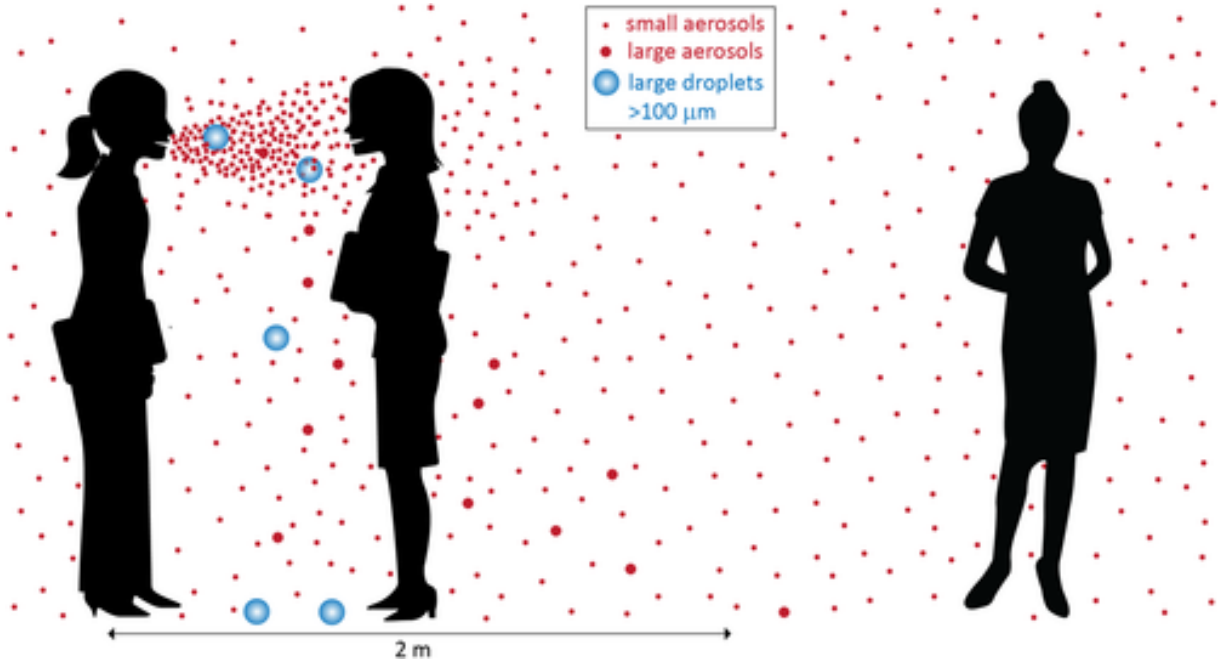


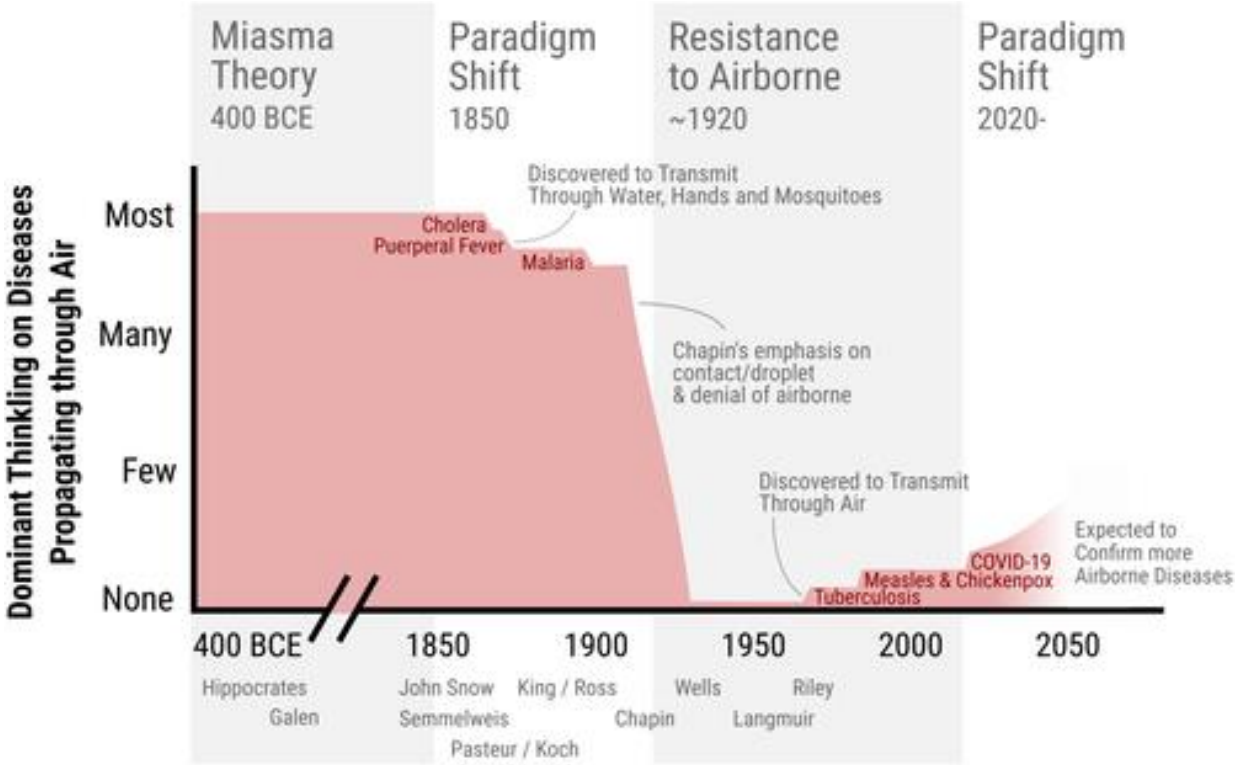
Banned or restricted in many countries in the 1990s-2000s

Bio-Aerosols

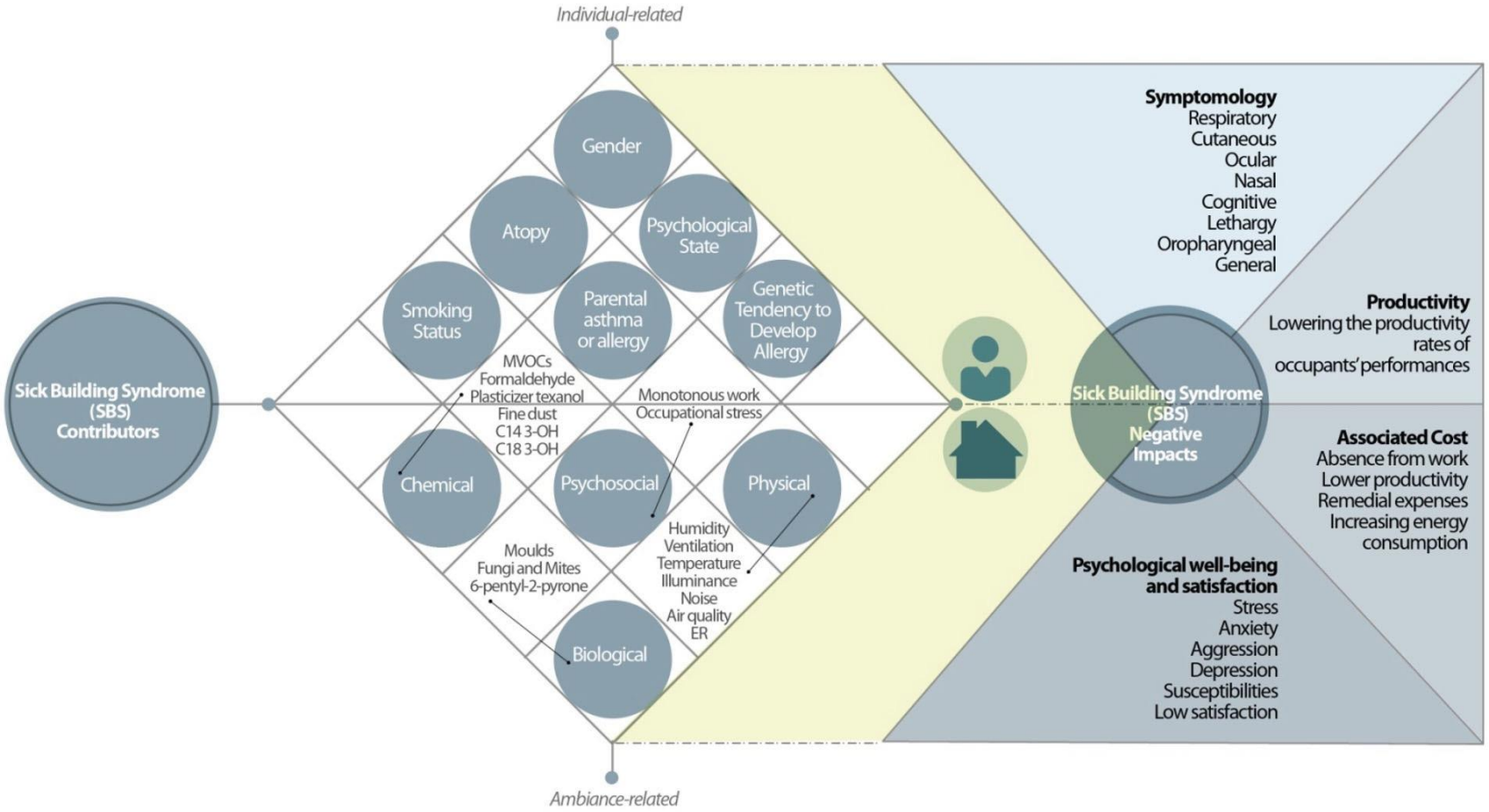


Bio-aerosols: biological matter suspended in the breathing air





Impacts of SBS



Respiratory: Allergic Rhinitis - Sinus congestion - Influenza like symptoms - Dry Cough - Throat irritation - Wheezing - Shortness of breath - Dry mucus membranes - Hoarseness of the voice - Sensitivity to odors - Asthma - **Cutaneous:** Skin rashes - Itchy skin - Dry skin - Erythema - Lip irritation and dryness - Seborrheic dermatitis - Periorbital eczema - Rosacca - Uritcaria - Itching follicu-litis - **Ocular:** Eye dryness - Eyes itching - Eyeswatering - Gritty eyes - Eye Burning - Visual disturbances - Light sensitivity - Swollen eyelids - **Nasal:** Runny nose - Sneezing - Blocked nose - Nose bleeding - **Cognitive:** Functional headache - Migraine headache - Tension headache - Sinus headache - Mental confusion - Lethargy: Lethargy - Difficulty in concentrating - Mental fatigue - General fatigue - Drowsy - **Oropharyngeal:** Throat dryness - Throat irritation - **General:** Nausea - Dizziness - Hypersensitivity reactions - Deteriorating the pre-existing illnesses

What is the cost of SBS?

Estimating the cost of SBS is challenging, but it can be broken down to:

Productivity Losses

10s of bEUR/yr

Medical Costs

> 50 bEUR/yr

Legal Costs

300 kEUR/case

Repairs

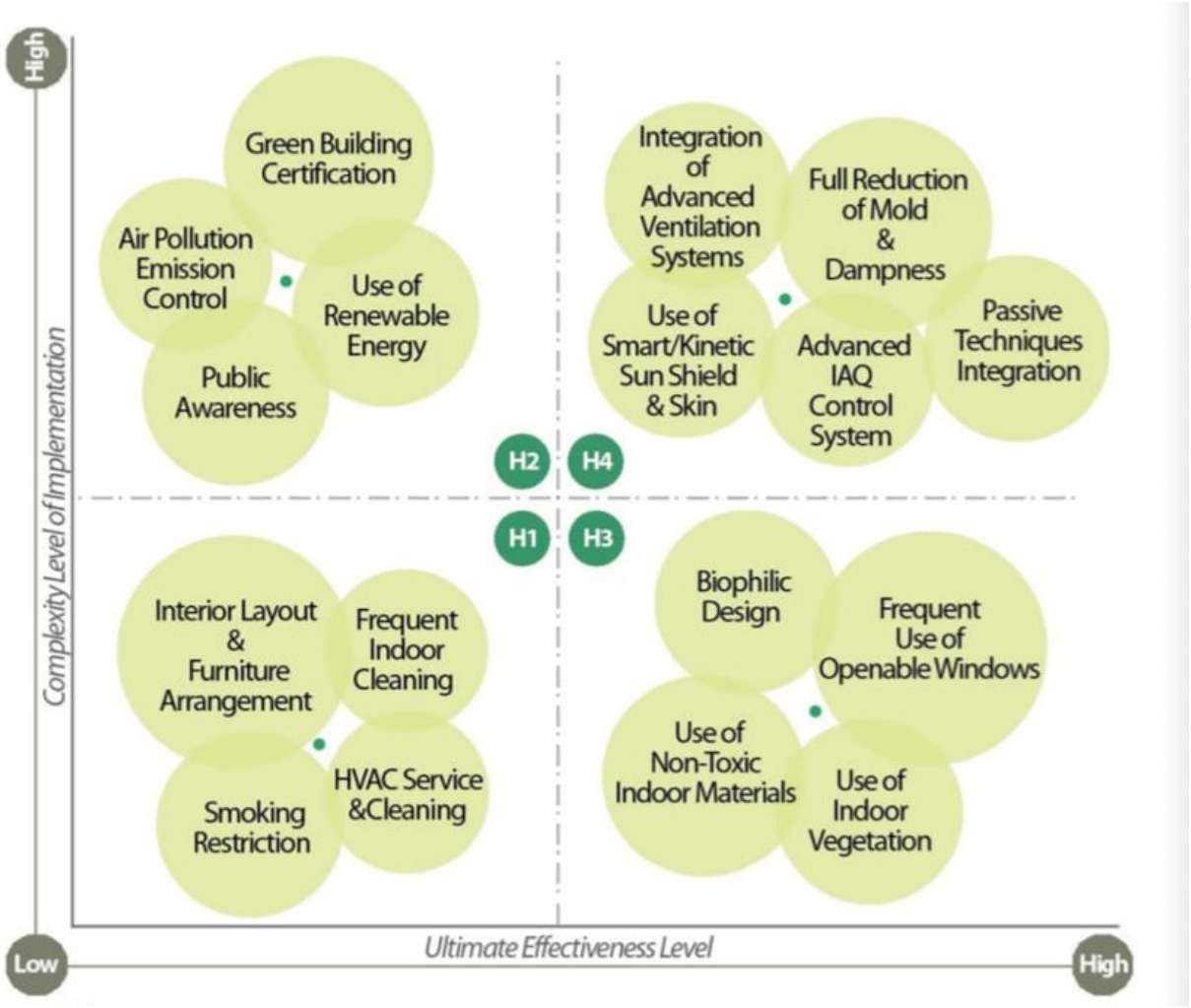
100s mEUR/yr

Reputation Damage

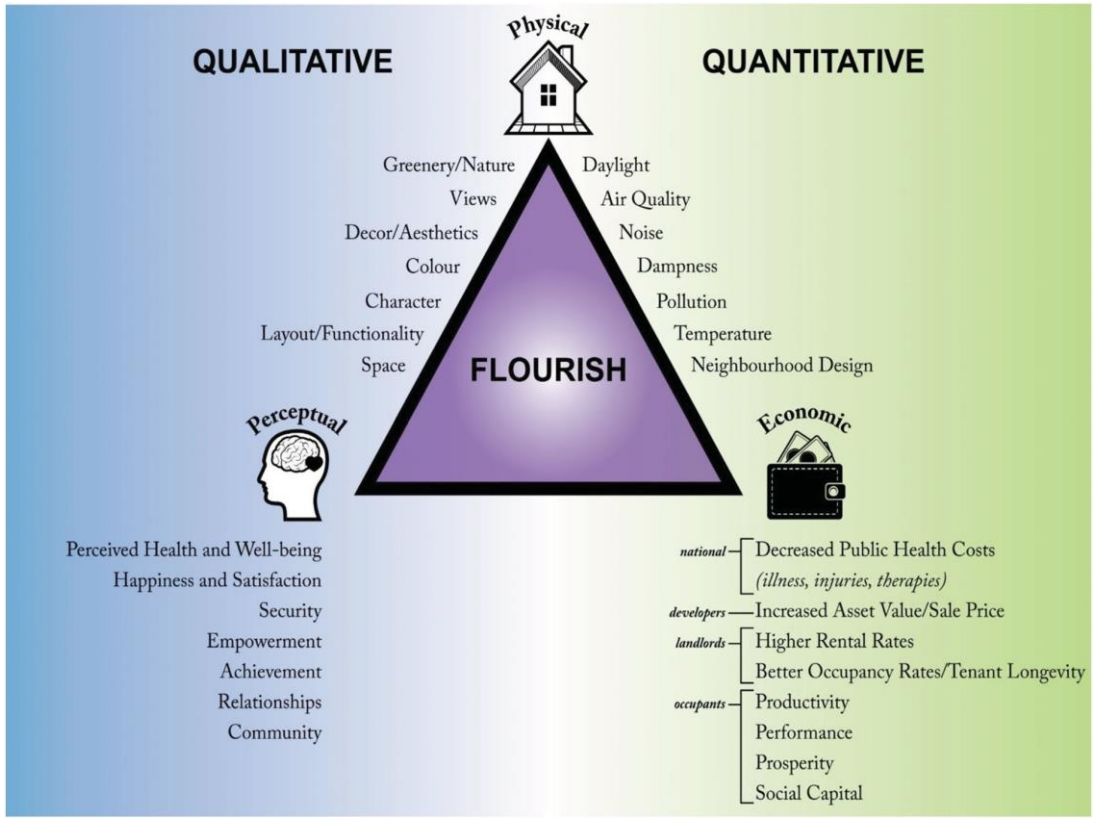
Hard to estimate

100s of billions of EUR annually

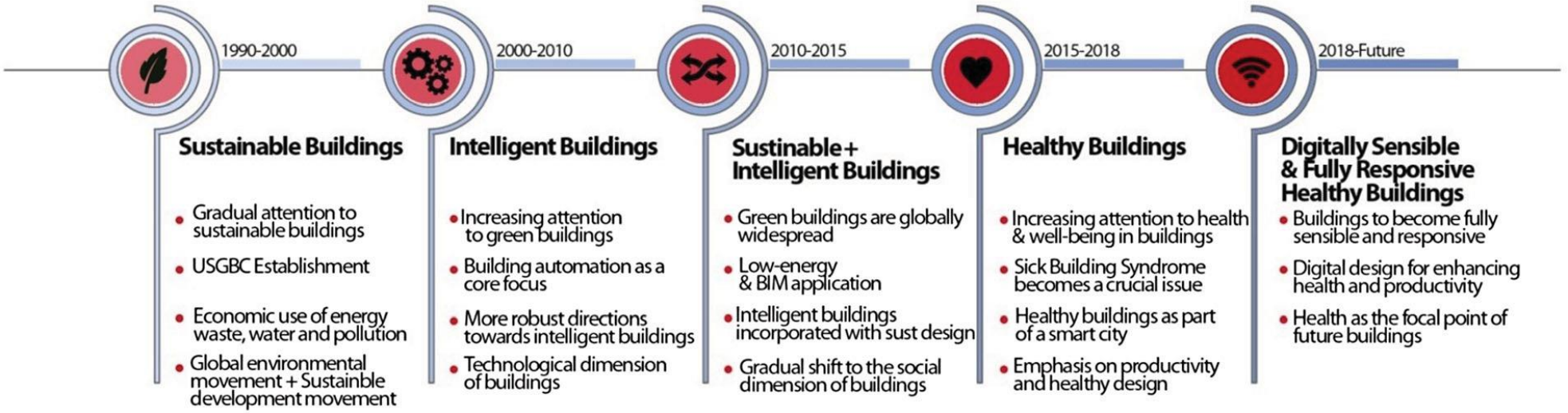
Mitigation Strategies



Healthy building: built environment that encourages positive well-being of human beings.



Evolution of Strategies



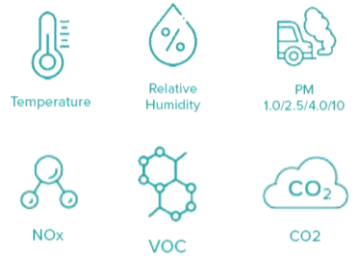
Indoor Air Quality Monitoring

Reference Instruments

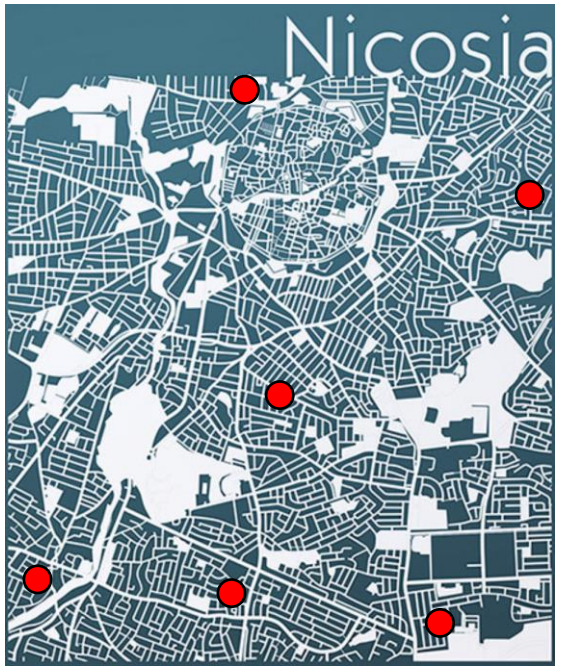
< 0.1% accuracy
Bulcky and High Cost

Gas and PM Sensors

variable accuracy
Compact and Low Cost



VAISALA



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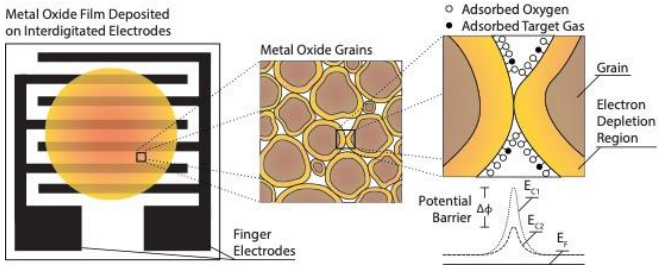
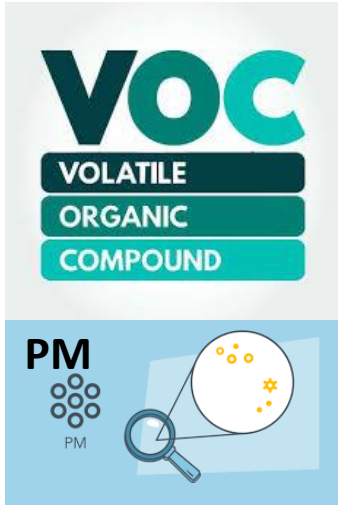
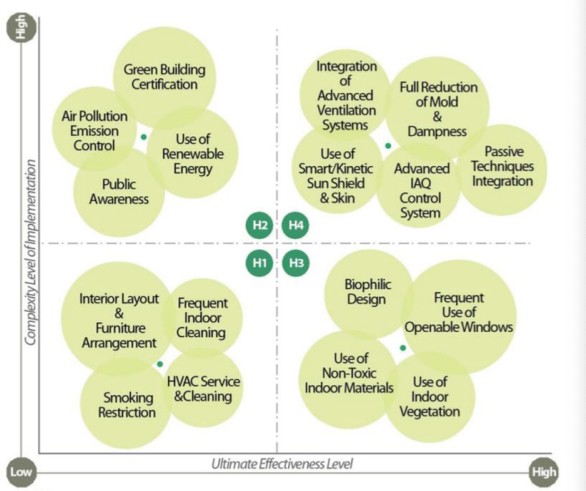
The CyI Instrumentation & Nanotechnology Lab



Summary


Poor Indoor Air Quality
Poor Lighting
Poor Ergonomics
Sick Building Syndrome
Uncomfortable Acoustics
Electromagnetic radiation
Psychological stress
Others


VOC
VOLATILE
ORGANIC
COMPOUND
PM
PM


High
Low
Complexity Level of Implementation
Ultimate Effectiveness Level
Green Building Certification
Air Pollution Emission Control
Use of Renewable Energy
Public Awareness
Integration of Advanced Ventilation Systems
Full Reduction of Mold & Dampness
Use of Smart/Kinetic Sun Shield & Skin
Advanced IAQ Control System
Passive Techniques Integration
H1
H2
H3
H4
Interior Layout & Furniture Arrangement
Frequent Indoor Cleaning
Smoking Restriction
HVAC Service &Cleaning
Biophilic Design
Frequent Use of Openable Windows
Use of Non-Toxic Indoor Materials
Use of Indoor Vegetation


CO2
684


qlair Cloud
Outdoor Air Quality Data
Filter Life Cycle Monitoring
Indoor Air Quality Monitoring

Thank You!