Towards Good Building Indoor Environmental Quality (IEQ)

Presented by :
Ms Jennifer Yap, MSc
Environmental Hygiene Research Programme

ehi
Environmental Health Institute

National Environment Agency

BCA GREEN MARK

Minimum mandatory point of 50 points
- Energy efficiency (min 30 points)
- Other green features (min 20 points)

Indoor Environment Quality	Points
Indoor air quality performance	8
Indoor air pollutant	2
lighting quality	5
Thermal comfort	2
Internal noise level	1

IAQ Audit - to conduct an full IAQ audit three yearly that complies with ~~NEA's Guidelines for Good Indoor Air Quality in Office Premises~~ or SS554:2009 Code of Practice for `Indoor air quality for air-conditioned buildings'
[8points] [ENRB 4-1(a)]

What is Indoor Environmental Quality (IEQ)?



Quality of the AIR in a built environment

Acceptable indoor air quality

Acceptable indoor air quality is defined as "air in which there are no known contaminants at harmful concentrations as determined by cognizant authorities and with which a substantial majority (80% or more) of the people exposed do not express dissatisfaction

- 80% of ppl is satisfy
- harmful concentration is within limit.

Green building provides the healthier place for us to live in by **ensuring good IEQ**

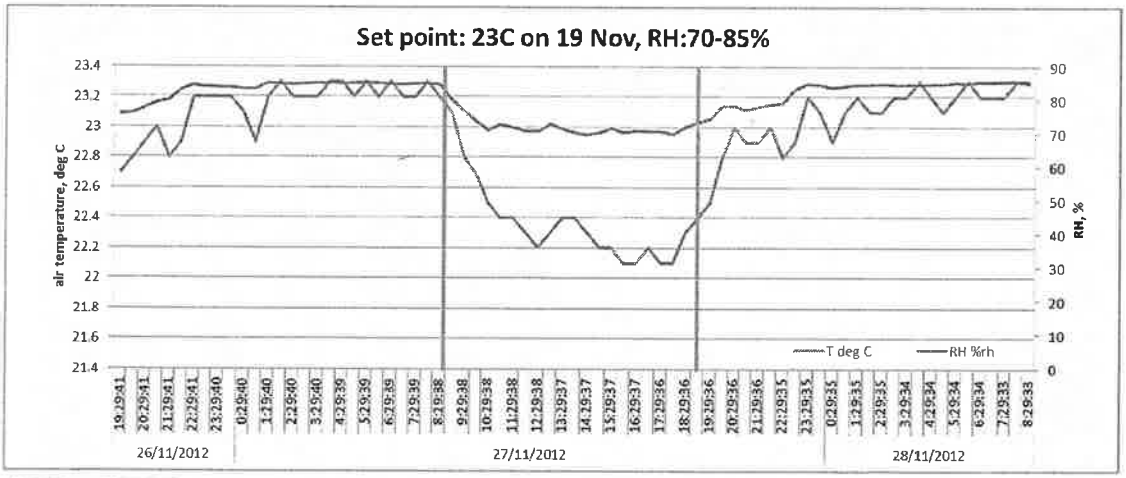


Ms Maria Atkinson, Global Head of Sustainability, Lend Lease

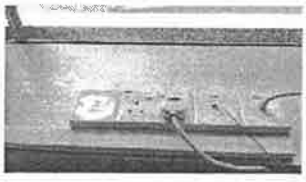
Indoor Air Quality (IAQ) - **a multi-factorial issue**

IAQ parameters	Health effects
Mould	Allergic Reactions - Hypersensitivity - Asthma
Carbon dioxide	Headache Fatigue
Formaldehyde	Human carcinogen
Respirable suspended particles	Fine particles can lodge deeply into the lungs and cause inflammation

Leaky building envelope, low heat load and jammed chilled water valve resulted in high RH and mould growth





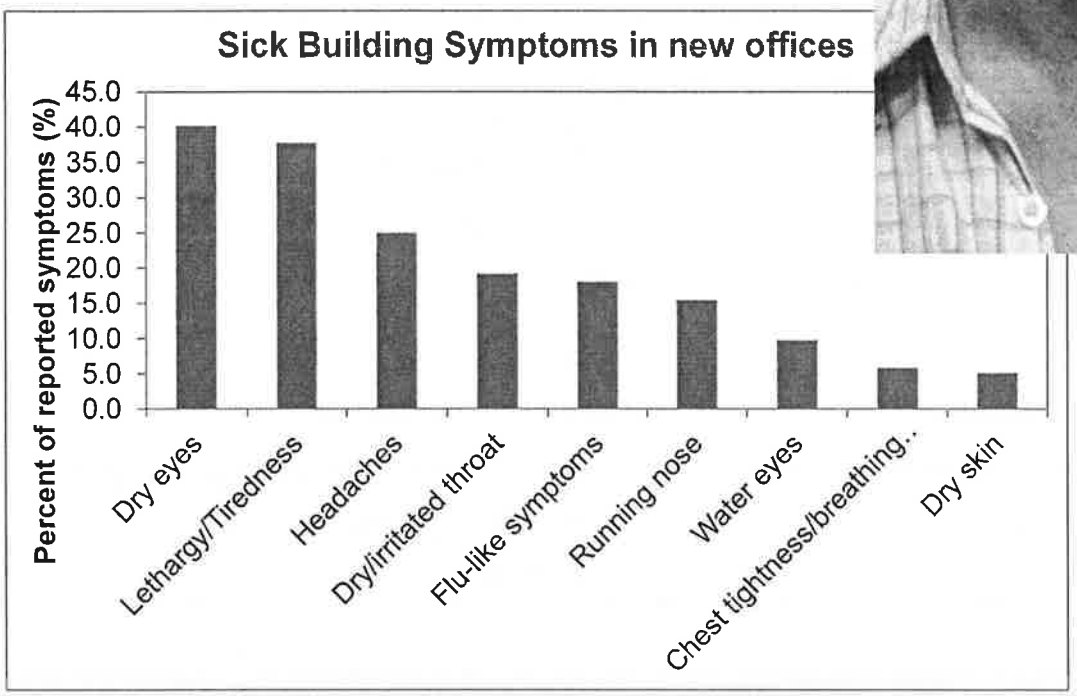




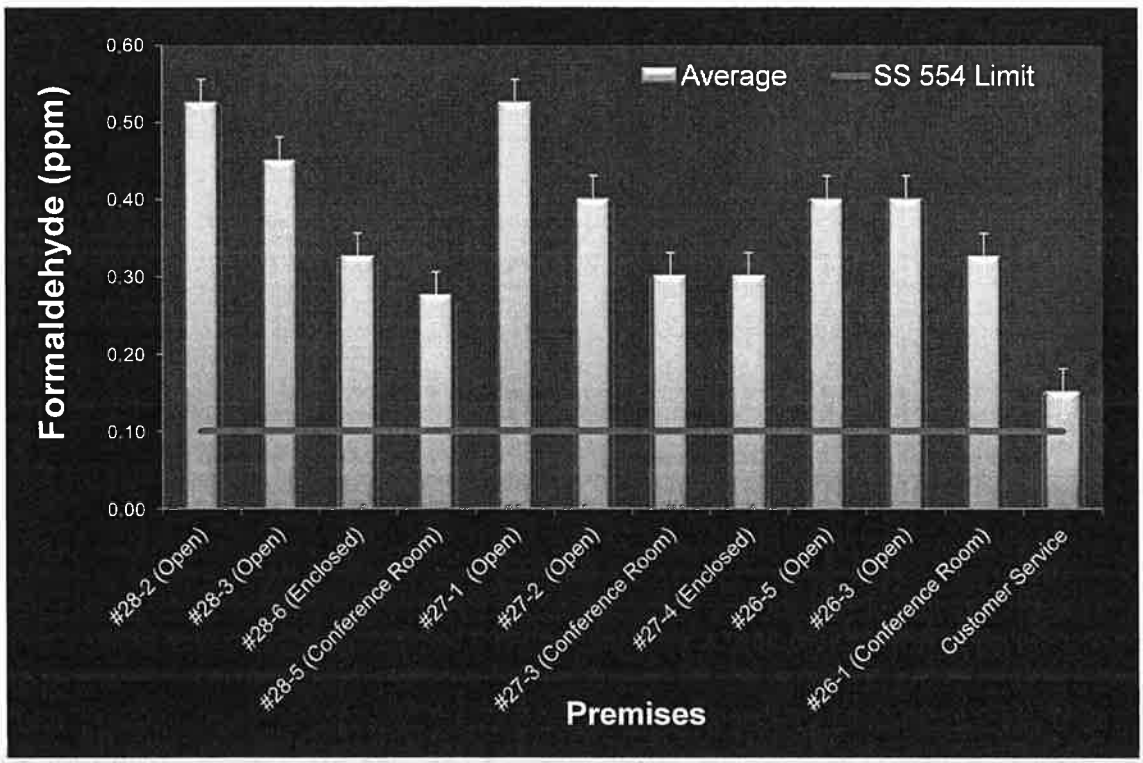
Moved into new offices after renovation

Questionnaire: 120 respondants





High level of formaldehyde and other VOCs in new offices



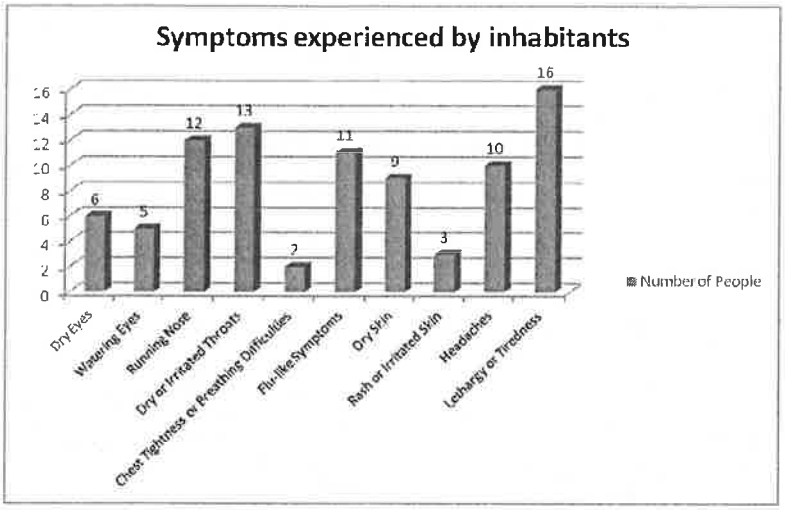
Mould exposure and nasal and pulmonary infection



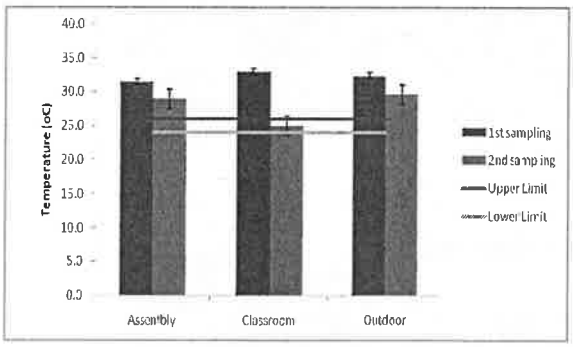
Aspergillus spp



Aspergilosis nasal



Kindergarten
One issue replaced with another

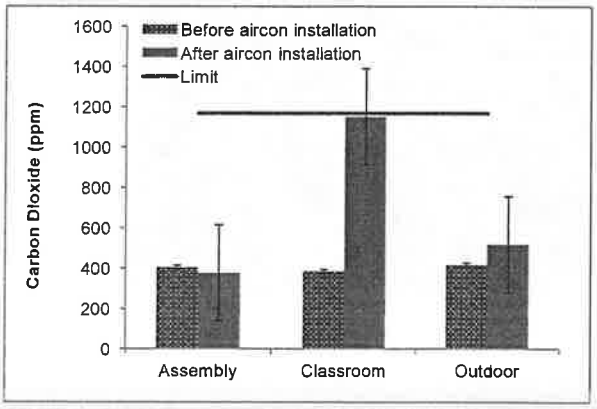


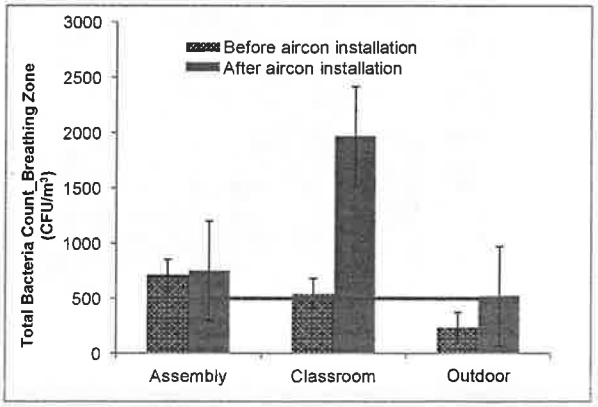
Kindergarten with glass roof and car park below classrooms

1. Overheating, tired teachers and children
2. Exhaust from car park infiltrated into classrooms

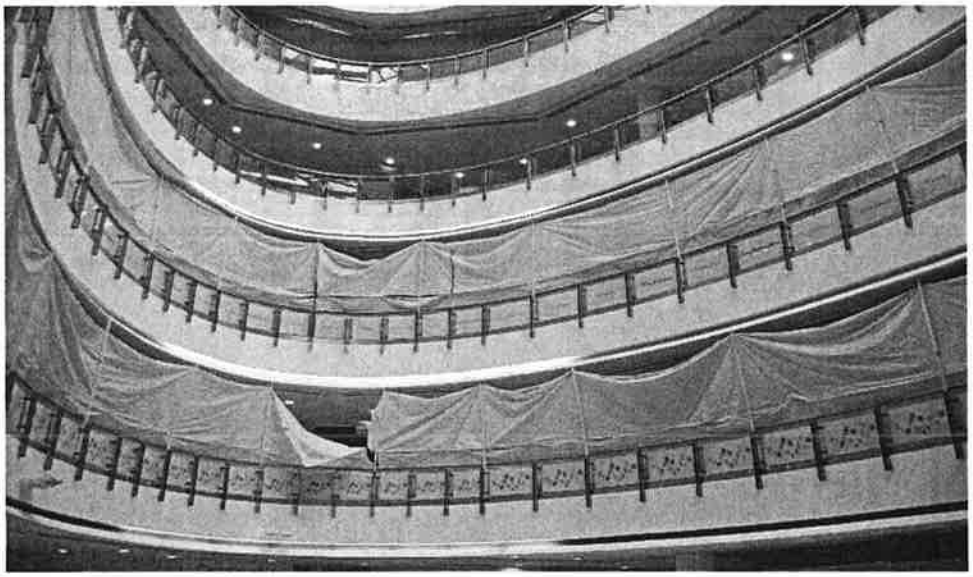
Solution: Installation of split air con unit

1. Temp comfortable
2. High bacteria and CO2





Watery eye and severe cough in tenants who were exposed to renovation dust for months





Ms Maria Atkinson: The value of Green Buildings

Presented during BCA Breakfast Talk For CEOs, 2 Oct 08

Balance good IAQ with optimal energy use: A powerful approach

Proper design and regular maintenance of the air-conditioning system will provide comfortable and healthful indoor environments be consistent with the goal of optimizing energy use in buildings

SS 554 : 2009 Code of Practice For IAQ in Air-conditioned Buildings

Scope: all air-conditioned premises, except

- Residentials(apt unit)
- Factory production areas
- Hospitals and polyclinics
- Laboratories
- Smoking room

To purchase: singaporestandardseshop@toppanleefung.com or visit the website at http://www.singaporestandradseshop.sg for the details

Improving IAQ

- from design to facility management

Improving IAQ: Design stage

To protect IEQ, the designer must understand IAQ problems and seek to eliminate potential sources of contamination that originate from outdoors as well as indoors

- Outdoor air intake should not near any pollution sources (eg: kitchen exhaust, cooling tower)
  - Wind direction, adjacent structure
- Provide efficient cooling
  - Additional cooling needed if
    - In the enclosed room with floor to ceiling partition
    - Near windows
    - Heat generating equipment (eg: server)

Improving IAQ: Design stage

- Readily accessible and easily cleanable surfaces
  - Wall paper and carpet avoided
- Provide local extraction ventilation for pollutive activities
  - Cooking
  - Renovation work
  - Photocopying
  - Smoking
- Provide air purging system
  - not feasible for 24-hr operating AC sys

Carpet is a known haven for microbes in indoor environments. Mary Jo Vesper & Stephen Vesper, USEPA

Improving IAQ: Construction stage

i. **Off-gas the building material to permissible VOC level before installation**
   - **Why introduce carcinogenic agents into indoors?**

ii. **No unrelated installation**

iii. **Prevent damage caused by leaks**
   - **Many buildings here are STILL leaky!!! Why?**

Finnish guideline "Classification of Indoor Climate, Construction, & Building Materials", first introduced in 1995, 2nd edition in 2001.
(http://www.rts.fi/english.htm)

Improving IAQ: Construction stage

- Flexibility in providing cooling capacity
  - Disturbance of designed air flow
    - Presence of partition
  - Additional heat load
    - Heat stress: radiant heat in enclosed room
    - Server room needs more cooling
- Smooth surface to reduce dust accumulation, ease for cleaning

Improving IAQ: Construction stage



i. Outdoor air filtered for particulate

- SS553: Outdoor air filtered with MERV 1 or better
- SS554:Outdoor air to be filtered with MERV 6 or better
- Still not a common practice here

ii. Clean air duct before commissioning

- Do you know how much dust generated during construction?
- Hygiene of air-conditioning system

SS553: Code of Practice for Air-conditioning and mechanical ventilation in buildings
SS554: Code of Practice for Indoor Air Quality for Air-conditioned Buildings

Improving IAQ: Operation & Maintenance

- Many with central air-conditioning systems
- Most do not have effective air filters for particulate matter (except labs, cleanrooms etc)
- Select efficient air filter to achieve the required cleanliness
  - ASHRAE 52.2 Minimum Efficiency Reporting Value (MERV)
    - Pri filter: MERV of 6 – to protect AC equipment
    - Sec filter: MERV of 13- remove PM2.5 & microbes
  - Avoid by pass of air filter
- Regular maintenance - prevention is better than cure
  - Regular change of air filter (depend on pressure drop, eg : by 2X)
  - Regular cleaning for major AC component (coil, drain pan)
  - Rectify water leaking problem promptly

Minimum efficiency reporting value (MERV) for air filters developed by the American Society of Heating, Refrigerating and Air-Conditioning Engineers, or ASHRAE. MERV ratings range from 1 to 20. MERV 13 and above effective in removing fine PM

Improving IAQ: Operation & Maintenance

i. Calibration of sensor/thermostat

ii. Stop condensation
  - Avoid too much differences in air temperature of adjacent wall

iii. Prevent microbial when water is present
  - Avoid sediment accumulation
    - Cooling towers - Compliance of EPH (Cooling Tower & Water Fountains) Regulations 2001

Improving IAQ: Renovation

i. Effectively isolated from the occupied zones

ii. Satisfactory indoor environment secured

iii. The building materials used should not be toxic
   - Sufficient time for venting before installation

iv. Provide local exhaust system
   - Especially painting, adhesive work

v. Conduct during off-peak period

vi. Rebalance the air after renovation
   - Not a common practice here!

Improving IAQ: Quality Control

- Explore the potential IAQ risk
  - Risk = Probability X Outcome
  - Implement precautionary measures
- IAQ audit conducted by accredited IAQ Consultants by SAC or internationally recognized organization
  - Retrieving list of IAQ Consultant at SAC website :
  1) Type in this hyperlink at internet - http://www.sac-accreditation.gov.sg/cab/acab/Pages/ACTL-Overview.aspx
  2) Under Scheme, select Calibration and Testing Laboratories
  3) Under Field, select Environmental Testing
  4) Under Area, select Indoor Air Quality
  5) You should see the list of IAQ companies appear on the screen.
- *Please note the term of reference for each company is different as they are accredited for different testing methods.*

Note: *SAC: Singapore Accreditation Council*

Action plan in rectifying IAQ issues

i. Walk-through inspection
   - Trace the pollutant pathway

ii. Collate feedback from occupants
   - Trace the symptoms suffered, duration of occurrence

iii. Environmental sampling
   - Any obvious deviation from recommended parameters

iv. Building remedial measures
   - Deemed to be the best for the benefit of occupants/building

Humidity and microbial growth

Occurrence:

i. Dumping of the air directly from diffuser to surfaces
   - Air at dew point condense at surfaces

ii. Intermittent use of AC

iii. Water seepage from bursting of water pipe

iv. Infiltration of hot outdoor air into indoors

Mold growth:

i. Amplify rapidly and in large amount, destroy surface they grow on

ii. Cause allergenic reaction & possible respiratory illness

iii. Lengthy exhaustive journey for mold remediation

Conduct an IAQ audit

once every 3 years

- Sampling air for contaminants and indicator
- To obtain snapshot of current conditions
- Unusual reading interpreted based upon site-specific condition

Recommended limits of indoor air quality parameters

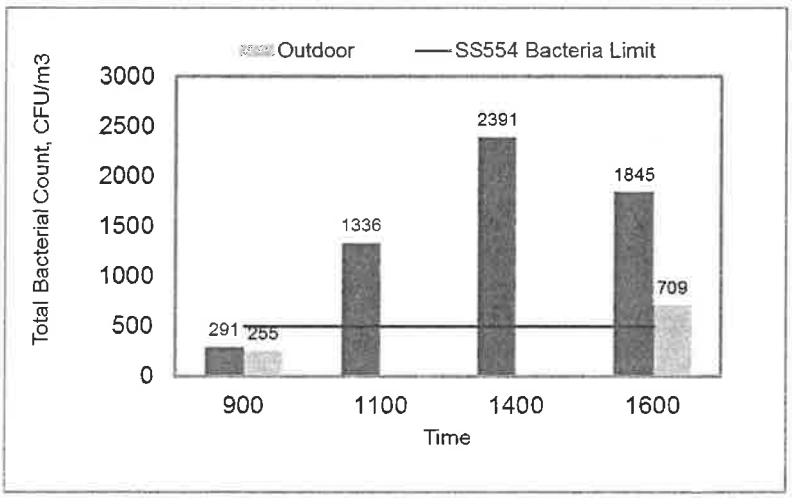
1996 IAQ Guidelines has superseded by SS554

	1996 Guidelines	SS554 2009
Frequency of IAQ audit	At least once every 2 years • 6 months after commissioning of ACMV	• At least once every 3 years* • 6 months after commissioning of ACMV • Renovation before occupancy

* To be aligned with **WSH (Risk Management) Regulations 2006**

Address the gaps in current guidelines

	1996 Guidelines	SS554 2009
Sampling duration	8-hours basis	• 8-hour basis • ½-hour (4-time slots) • Detection tubes - ½-hour (4-time slots) • Determined by competent person (target specific)



No. of sampling points

	1996 Guidelines	New SS CP on IAQ 2009
No of sampling points	Indoor Based on the floor area	• Based on the number of occupied floor • Sample size with 90% confidence that at least from the 10% floors with the highest IAQ levels is included in the sample.

1996 IAQ Guidelines has superseded by SS554

	1996 Guidelines	SS554 2009
Acceptable IAQ parameters	11 parameters	• Recommended parameters (Table 1): 10 • Targeted contaminants (Table 2) : 10

Table 1: Thermal comfort parameters

	1996 Guidelines	New SS CP on IAQ 2009
1) Operative temperature Avg between air temp and radiate temp	22.5-25.5 °C	24-26 °C
2) Relative humidity (RH)*	< 70%	• <65% (new building after 2009) • <70% (existing building) * during peak & common part-load conditions)
3) Air velocity	0.25 m/s	0.10-0.30 m/s

Table 1: Chemical parameters and particulate matter

	1996 Guidelines	New SS CP on IAQ 2009
4) CO_2 average below outdoor CO_2 level increased over the years	1000 ppm	700 above ambient
5) Total Voltaile Organic Compounds (TVOC)	3000 ppb	-same-
6) CO	9 ppm	-same-
7) Formaldehyde (HCHO)	0.1 ppm/ 120 $\mu g/m^3$	-same-
8) Respirable Suspended Particles (RSP)	150 $\mu g/m^3$	50 $\mu g/m^3$

Table 1: Biological Parameters

	1996 Guidelines	New SS CP on IAQ 2009
9) Total Viable Bacterial Counts (TBC)	500 CFU/m^3	500 CFU/m^3 Speciate when dominating by single species
10) Total Fungal Counts (TFC)	500 CFU/m^3	500 CFU/m^3 • When mainly leafy flora • Speciate when dominating by single species

- TBC/TFC - an indicator of sanitary condition
  - Only a fraction is culturable

Table 2: Contaminants not commonly found

	1996 Guidelines	New SS CP on IAQ 2009
1) PM 2.5	Nil	35 μg/m^3
2) UFP	Nil	• No limit, based on relativity • Trace the emission source
3) NO_2	Nil	100 μg/m^3
4) O_3	0.05 ppm	0.1 ppm
5) Radon	Nil	150 Bq/ m^3
6) Asbestos	Nil	0.01 fibre/cc Coupled with TEM/SEM

Contaminants not commonly found

	1996 Guidelines	New SS CP on IAQ 2009
7) Nicotine	Nil	Not detected
8) Pathogenic Bacteria	Nil	• Based on the pathogenicity of the species
9) Pathogenic mould	Nil	• Based on the pathogenicity of the species
10) Semi-VOC & VOC	Nil	Based on PEL

Volatile Organic Compounds (VOCs)

Organic compounds with a boiling point ranged from 50 to 260°C

Sources:

- ✓Building materials
- ✓Cleaning agents
- ✓Paints
- ✓Adhesives
- ✓Lacquers
- ✓Cosmetics
- ✓Textiles

Volatile Organic Compounds (VOCs) generated by microbes

- Present in the air at low $\mu g/m^3$ levels
- Produce by microorganisms and produces musty/earthy smell
- Types of VOCs
  - Hydrocarbons
  - Alcohols
  - Ketones
  - Ethers
  - Esters
  - Terpenes & terpene derivatives
    - Geosmin, α- & β-pinene
  - Unpleasant odour



Love the smell of a new car? Read this

LONDON — The distinctive smell inside a new car, often a source of satisfaction to owners, comes from the same form of pollution that causes sick building syndrome, a study in Japan shows.

It said the smell in a new car could contain up to 35 times the health limit set for volatile organic chemicals in cars in Japan, making its enjoyment akin to glue-sniffing, The Telegraph newspaper reported yesterday.

The chemicals found included ethyl benzene, xylene, formaldehyde and toluene used in paints and adhesives. In high densities, these cause symptoms linked with the sick building syndrome: headaches, dizziness and respiratory problems.

The study by a Japanese public-health researcher found that it took three years for the level in new cars to fall below the limit set for vehicles by the Japanese Health Ministry.

According to The Telegraph, Mr Toshiaki Yoshida, the Osaka Institute of Public Health's chief researcher, analysed the air inside a new minivan every week for the first two months and every month after that. The car was driven 5,600 km a year.

On delivery, the van was found to contain 113 kinds of volatile organic chemicals, mostly hydrocarbons. It took four months for these to fall below the safe limit. But the levels rose again in the hot summer months — even after two years.

Said Mr Tim Williamson, of the National Society for Clean Air: "Leaving the car at home is not only good for the environment, it is good for your health, too."

Osaka Institute of Public Health (ST 16 Jan 03)

The chemical found in a new car were ethyl benzene, xylene, formaldehyde and toluene used in paints and adhesives. In high concentration, these cause SCS: headaches, dizziness, respiratory problems, etc.

Formaldehyde (HCHO)

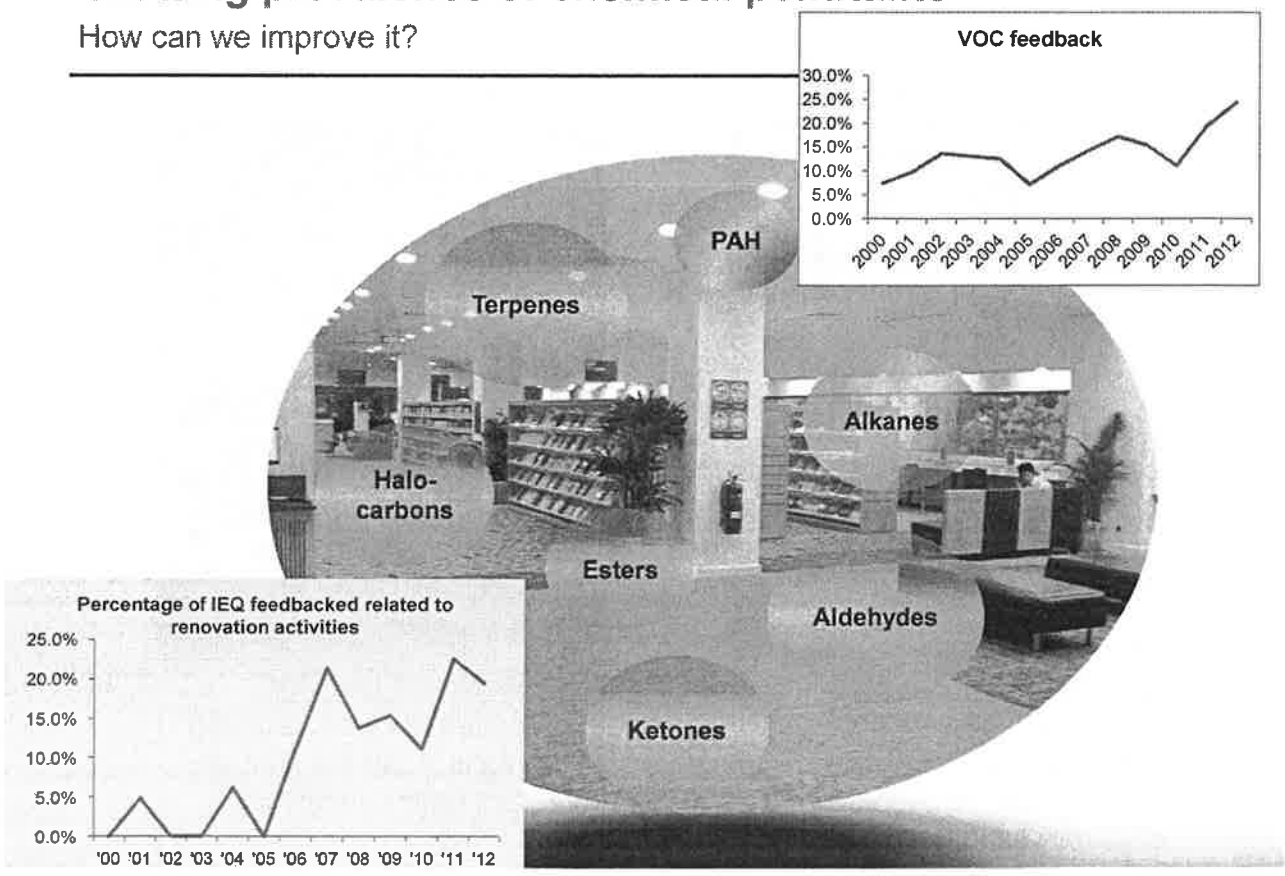
- Belongs to the VOC family
- Give off strong smell in high concentration

Sources:
- Adhesives
- Cleaning fluids

Health effects:
- Eye and respiratory irritant
- Designated a human carcinogen in a 2004 International Agency for Research on Cancer evaluation (*Cogliano et al*, 2005)

Growing prevalence of chemical pollutants

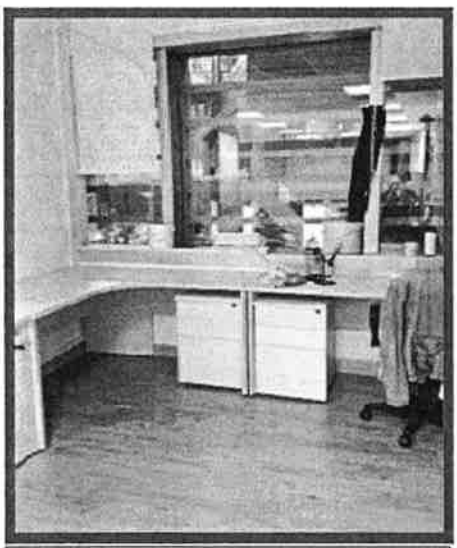
How can we improve it?



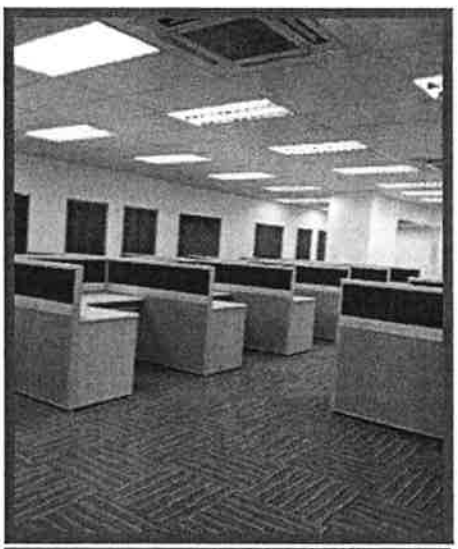
Some specific chemical s emitted from new office

Chemical	Potential Source
2-Butanone (MEK)	Floor/wall covering
2-ethyl-1 hexanol	Floor/wall covering, adhesives
α-terpinene (1-methyl-4-isopropyl-1,3-cyclohexadiene)	Furniture polishes
α-pinene	Adhesives, gysum board, chipboard, wood
Propylbenzene	Adhesives, Floor/wall covering
d-limonene	Paints, adhesives, chipboard, furniture polish
Toluene	Solvent/water based adhesives, flooring materials
Trichloroethylene (TCE)	Paints, vanishes
1,2,4-Trimethylbenzene 1,2,3- Trimethylbenzene	Floor/wall covering, floor waxes

Green Procurement Policy: Low formaldehyde (0.12mg/m^3) and low VOCs (≤ 0.5mg/m^2/hr)



Specify Low VOC
Formaldehyde was not detected and TVOC was within 3 ppm (immediately after renovation)



No mention of low VOC
Formaldehyde was detected 10X higher than the limit of 0.1 ppm (immediately after renovation)

Building Remedial Measures

- **Formulation**
- **Implementation**
- **Evaluation**
  - **Track the efficiency of new measures**

Your building may close down

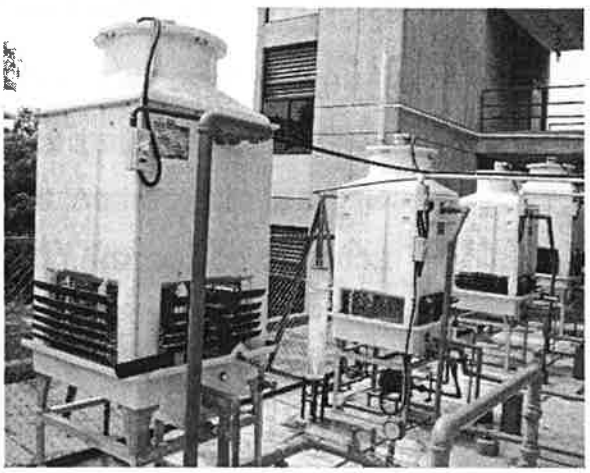
- **Environmental Public Health Act**
- **Section 45: Nuisance Order**
  - If any premises was found to be in such as to be a nuisance or dangerous to public health, the Director-General may compel the building owner to take remedial action to correct the problems

NEA (EHI)'s current role in IAQ

- Conducts research to further knowledge in IAQ
  - Look beyond chlorination for the control for *legionella* in cooling tower
  - Work with hospitals to evaluate efficacy of air cleaning tools

A Field Study on Conventional Chemical and Other New Water Treatments for *Legionella* Control In Cooling Towers

1. Copper-silver ionization
   - use CU 2+ & Ag+ ions
2. Ozone treatment
   - powerful oxidiser
3. Conventional Chemical
   - use conventional biocides
4. Electrolysis
   - use electric shock



Methodology

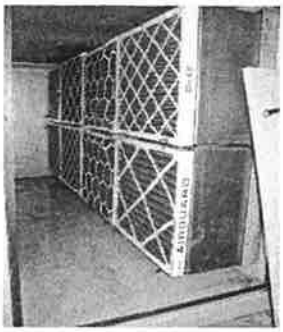
- **Water sampled** from basin on the third week of each month
  - Water samples tested for biological and chemical parameters
- **Maintenance** of cooling towers was done on the fourth week of each month
- **Biofilm sampled** from three points (basin, infill and water pipes) of each tower yearly.
- **Thorough cleaning** of the towers are done each year after the biofilm collection
- 2-years project

Treatment	Pros	Cons
Copper Silver Ionisation	Good control in free-living *Legionella* & other bacteria Water saving	Unable to eliminate sessile *Legionella* Possible external corrosion
Ozone	Low corrosion	Inconsistent microbial control due to frequent system failure
Chemical	Good control in free-living & sessile *Legionella*	Inconsistent control in total bacteria High corrosion indicator
Electrolysis	Good control in free-living and sessile *Legionella* & other bacteria	Possible external corrosion

Field Study using Nano-Scaled Covalent Bond Quarternary Ammonium Salts (NSCB-QAS) Coated Filters For Microbial Control In Outpatient Clinic In Hospitals

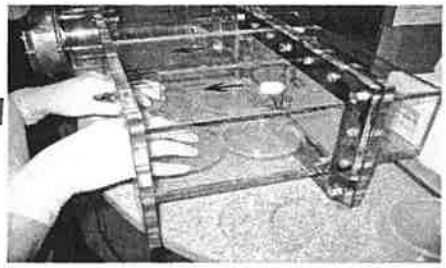
Anti-microbial coated filters

i. Emerging air cleaning tools
ii. Coating materials:
    - Plant extract
    - Disinfectants
    - Environmental friendly materials



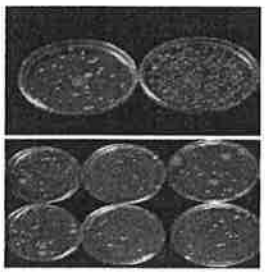


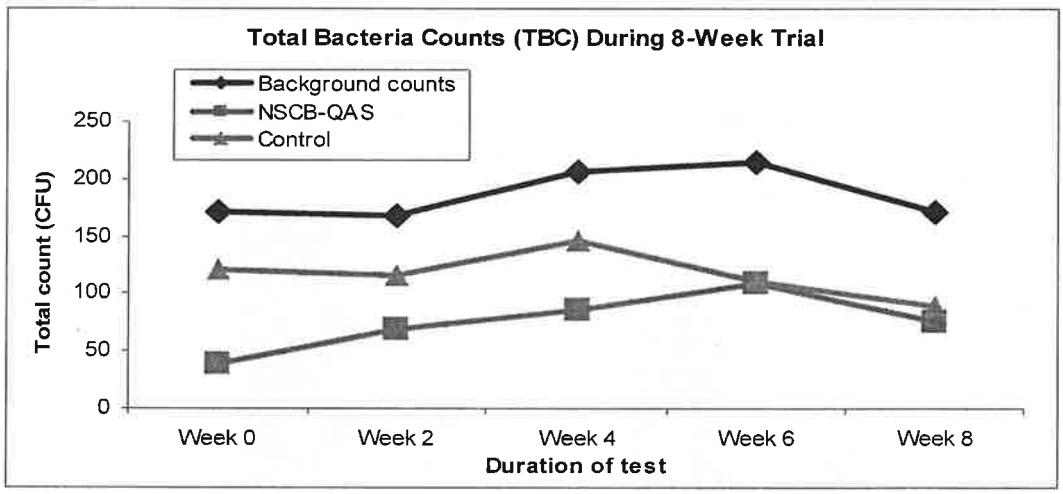
Cut the filter at the central piece
Seal the gap with new filter



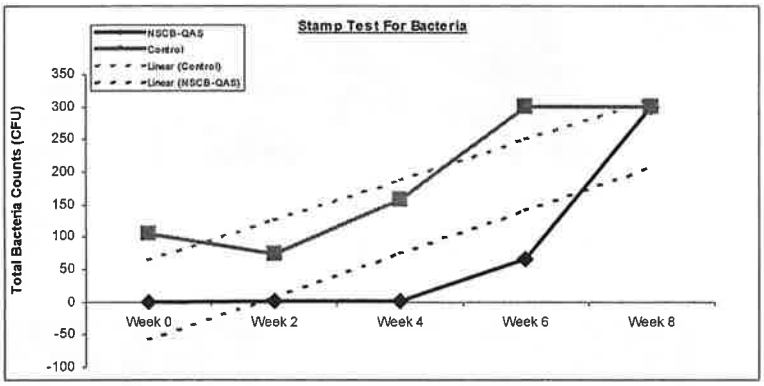
Air sampling conducted using wind tunnel





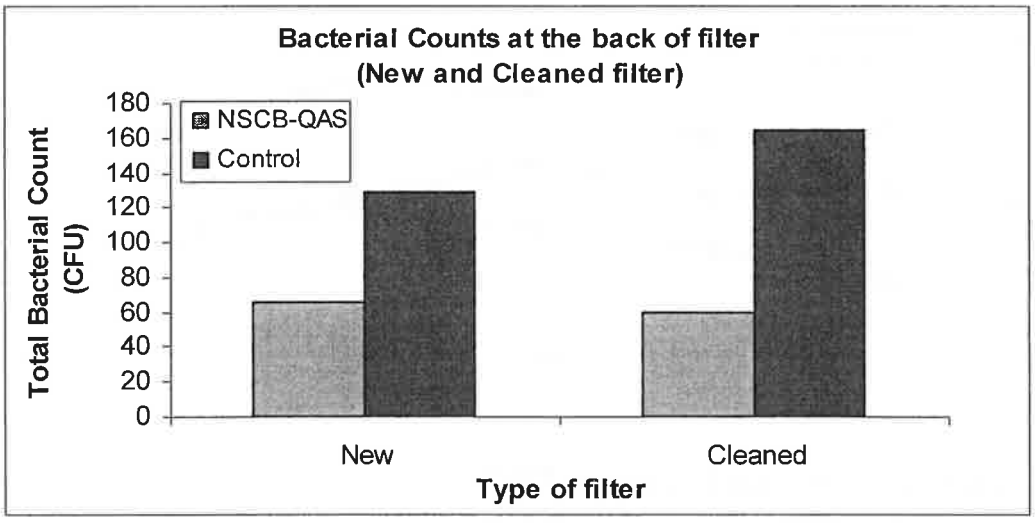


- Unfiltered air has highest TBC.
- Generally, $TBC_{NSCB\text{-}QAS} < TBC_{Control}$
- Between Wk 0-4, gradual increase in TBC regardless of filter.
- Blockage of filters occurred for control at Wk 6 and for NSCB-QAS at Wk 8



- There has been a steady increase in the number of bacterial counts in both filters over the 8-week period.
- Overall, NSCB-QAS treated filter had lower bacterial counts than the control

Restoration of NSCB-QAS efficacy after cleaning



- Bacterial count on NSCB-QAS treated filter was significantly lower than control after cleaning ($p<0.03$)

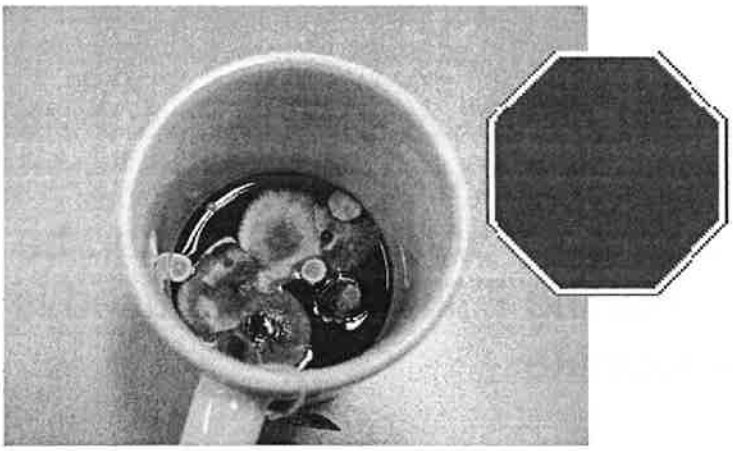
Finding:

- NSCB-QAS treated filter was tested to be effective for 6 weeks
- The efficacy of NSCB-QAS can be restored by cleaning if filter material used is appropriate

Towards Good Building IAQ

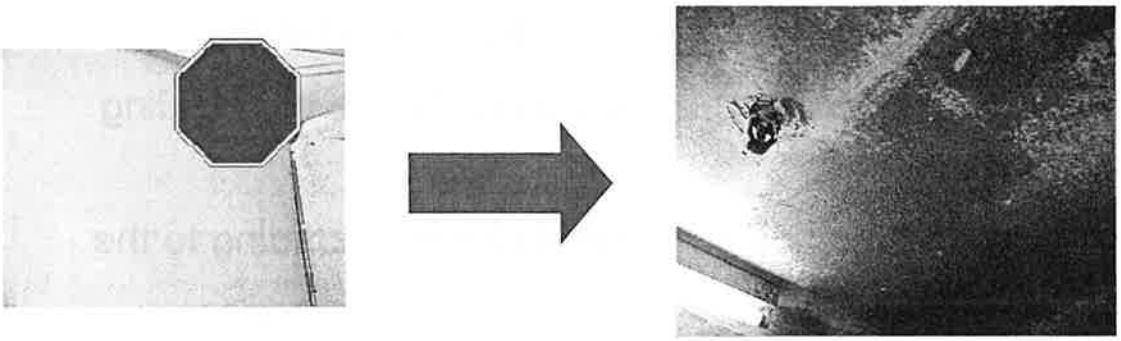
i. Building needs owners with the IAQ awareness and willing to spend money to upkeep good IAQ
ii. Architects to incorporate good IAQ into the building design
iii. The construction firm to build them according to the design
iv. The building management to operate and maintain the building appropriately
v. The building occupant to take initiative to upkeep good IAQ

Occupant's responsibility….



Ensure that no food is stored in the office overnight !

Occupant's responsibility….



Stop the problem before it causes further damages!

Our Environment

Safeguard • Nurture • Cherish

National Environment Agency