Section: IAQ Management

Certification Course for
Green Mark Facilities Manager

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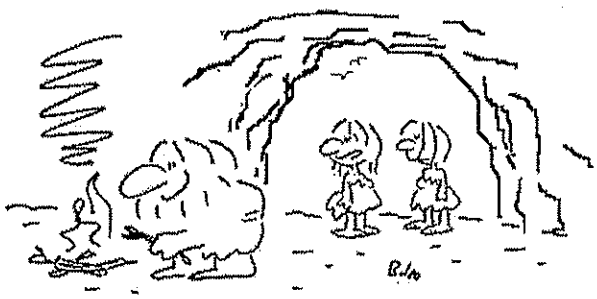
CONTENT

1. Background on Indoor Air Quality – its relevance to health, productivity, regulation and Green Mark
2. Monitoring parameters of the SS554:2009 Indoor Air Quality for Air-Conditioned Spaces and prescribed levels
3. Setting up and maintaining an effective IAQ management program
4. Practical IAQ measures during facility alterations and additions works - pre-construction, construction, before and during occupancy
5. Common IAQ problems & their remediation

PART 1: IAQ BACKGROUND

IAQ Awareness & Beginnings

- Birth of IAQ



"Oh-oh — I have a feeling *that* invention is going to lead to *cooking.*"

Definition of IAQ

- IAQ = Indoor Air Quality
  - "Indoor Air"
    - Air which is within an enclosed space
  - "Quality"
    - degree to which a set of characteristics (i.e. inherent distinguishing features) fulfills requirements (i.e. needs or expectations that are stated, generally implied or obligatory)

- ISO9000:2005, s3.1.1

IAQ: How it came about

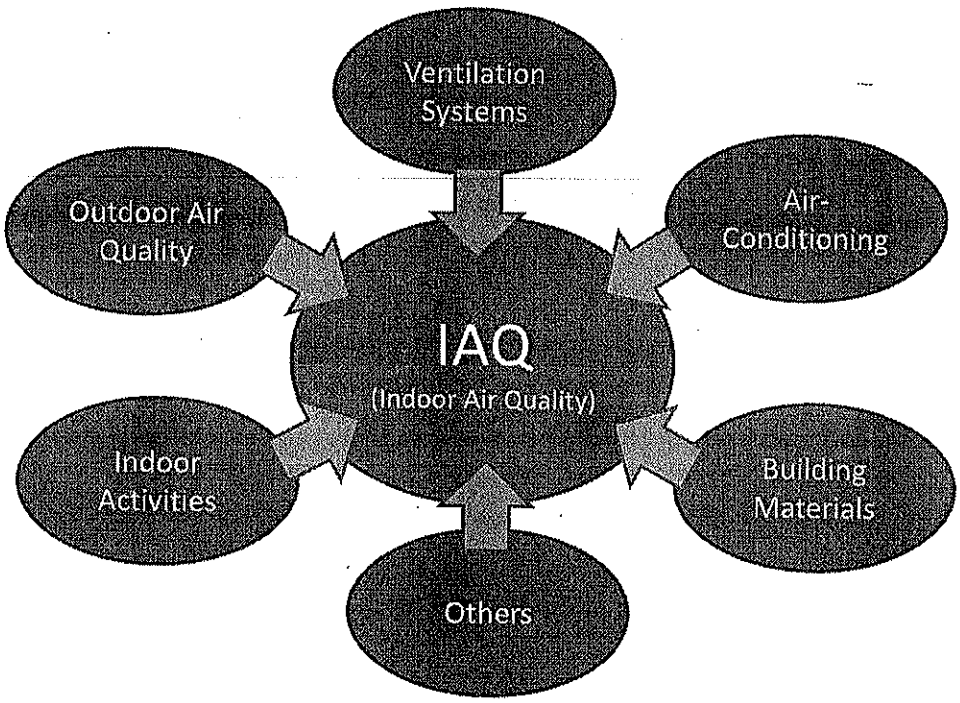
- The basic indoor dwelling provided (and still provides) a more stable and therefore comfortable environment for its inhabitants.
- But as the Indoor Condition Progressed:
  - Buildings become larger and more complex, requiring increased ventilation
  - Air conditioning provided thermal comfort to occupants and allowed for even larger and more complex buildings to be designed and built
  - Energy crises (1973-1974 and subsequent) induced waste-reducing and cost-control measures which included tighter insulation, use of more efficient systems and also reduction in fresh-air intake
  - Advancement of chemical technology gave (and continues to give) rise to new building materials, fittings and furnishings for use indoors

IAQ: How it came about

- Resultant Effects on the Indoor Air
  - Increased rate and overall accumulation of indoor air pollutants
  - Introduction of new pollutants
  - Increased humidity encouraging the proliferation of microorganisms

- Changes in temperature and contents of indoor air were subsequently identified to be responsible for causing or exacerbating adverse effects on human health and well-being.

IAQ: Factors Affecting IAQ



Effects of Poor IAQ

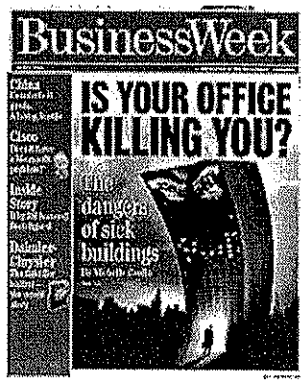
- Triggering of Allergies
  - Breathing difficulty, eye irritation, infections (e.g. sore eyes, sinusitis, etc.)
- Infectious disease
  - Legionaire's Disease, Tuberculosis, Flu, etc.
- Poor Health & Well-Being
  - Feeling 'lethargic' or 'unwell', aches and pains, etc.
- Other Medical Conditions/Complications



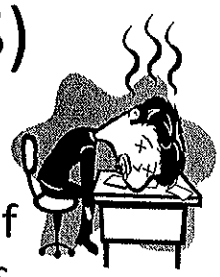
EXPOSURES NORMALLY GREATER DUE TO CONCENTRATION EFFECTS

Characterized Heath Conditions associated with IAQ

- Sick Building Syndrome (SBS)
- Building Related Illnesses (BRI)
  - Legionnaire's disease
  - Pontiac fever
  - Multiple Chemical Sensitivity (due to bldg materials)
  - Hypersensitivity pneumonitis
- Others
  - Flu, Tuberculosis, SARS, etc



Sick Building Syndrome (SBS)



- Definition:
  - "situation in which a substantial proportion of occupants of a building experience symptoms associated with acute discomfort that are relieved upon leaving the premises."

    - Ooi & Goh, Int J. Epidemiology, 26(6) 1997

- Estimated losses (US): US$ 10-20B Annually

Probable causes of SBS

- Separate studies associate SBS symptoms with different characteristics of buildings and indoor environments:
  - Air-conditioning
  - Lower ventilation rates and higher carbon dioxide concentrations
  - Higher air temperature
  - Concentrations of certain VOCs
  - Excess dirt and moisture in HVAC systems
  - Moisture problems in buildings

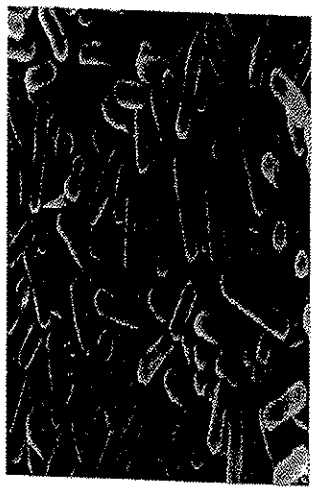
BRI: Legionnaires Disease



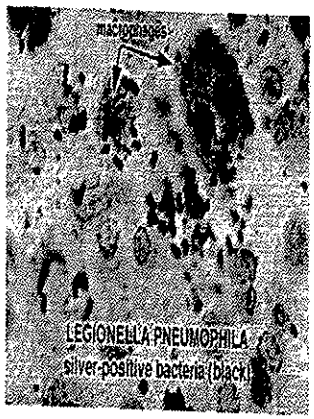
- A type of community-acquired pneumonia
- First recognized when pneumonia outbreak occurred at 58th American Legion convention (1976):
  - >200 infected; 34 died
- Multiple infection sources associated with cooling towers, humidifiers, inadequate hot water showers in hosting hotels.
- Symptoms: Bacterial pneumonia developing over 2-10 days; High fever with chills, non-productive cough, breathing difficulty, vomiting, diarrhoea, abdominal pain.
- Mortality Rate: 5-10% with antibiotic treatment, ~80% without

BRI agent: *Legionella pneumophila*

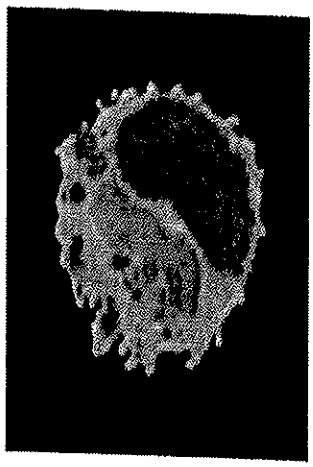
- Named in 1976 after pneumonia outbreak during American Legion convention



- Common in aquatic habitats within temp 20-45 degC



- Can live in other microorganisms



- May infect kidneys and GI tract

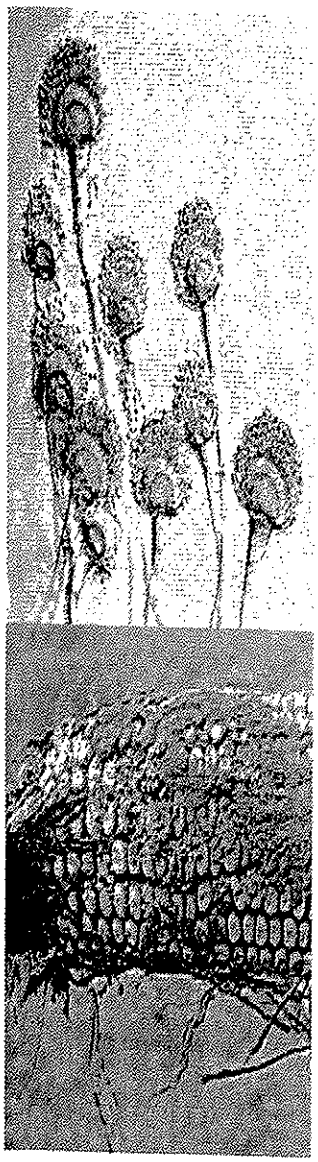
Hypersensitivity Pneumonitis



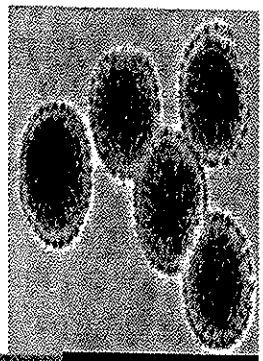
- Also known as "Farmers' Lung"

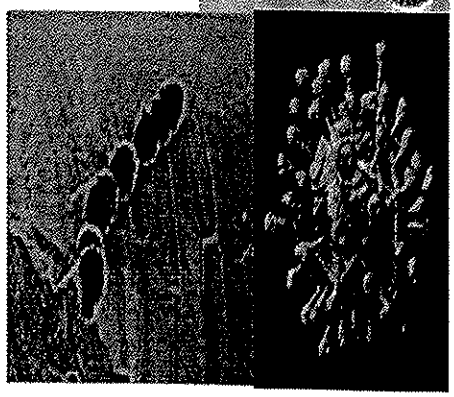
- Symptoms: Fever, cough, chest tightness, fluid in lungs, shortness of breath, fatigue

- Causative Agent(s): Associated with exposure to thermophilic fungi, *Aspergillus spp.*, *Penicillium spp.*, etc

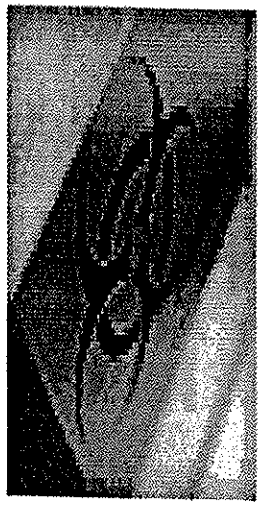


Other Challenges





- Flu, Tuberculosis, SARS



- BIOTERRORISM AGENTS:
  - ANTHRAX (*Bacillus anthracis*)
  - VIRUS (e.g. smallpox, ebola, etc)
  - NERVE GAS (e.g. sarin gas)

HOW DO WE DEAL WITH THESE?

WHAT IS THE CAUSE?

IAQ & Heath Reports

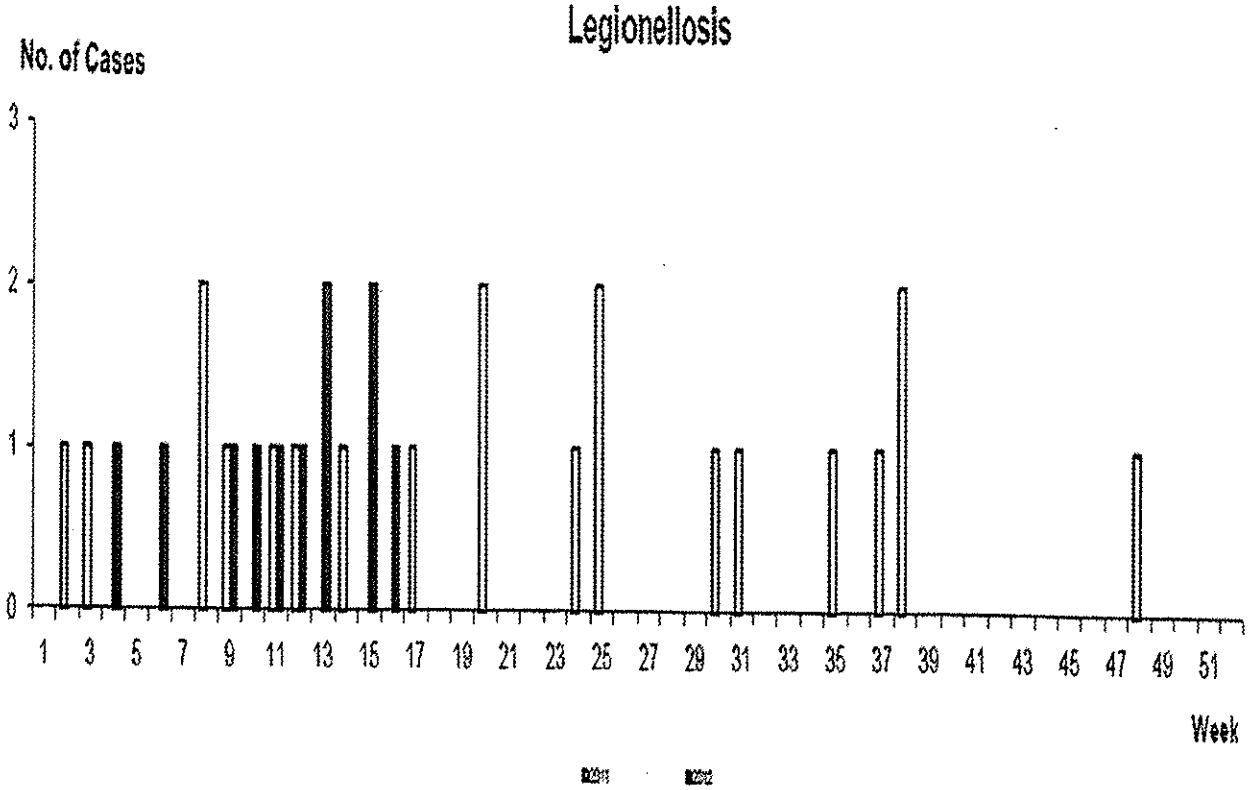


- 1st case of Legionnaires' Disease in Singapore reported in 1986

(Ann Acad Med Singapore. 1986 Oct;15(4):610-6)

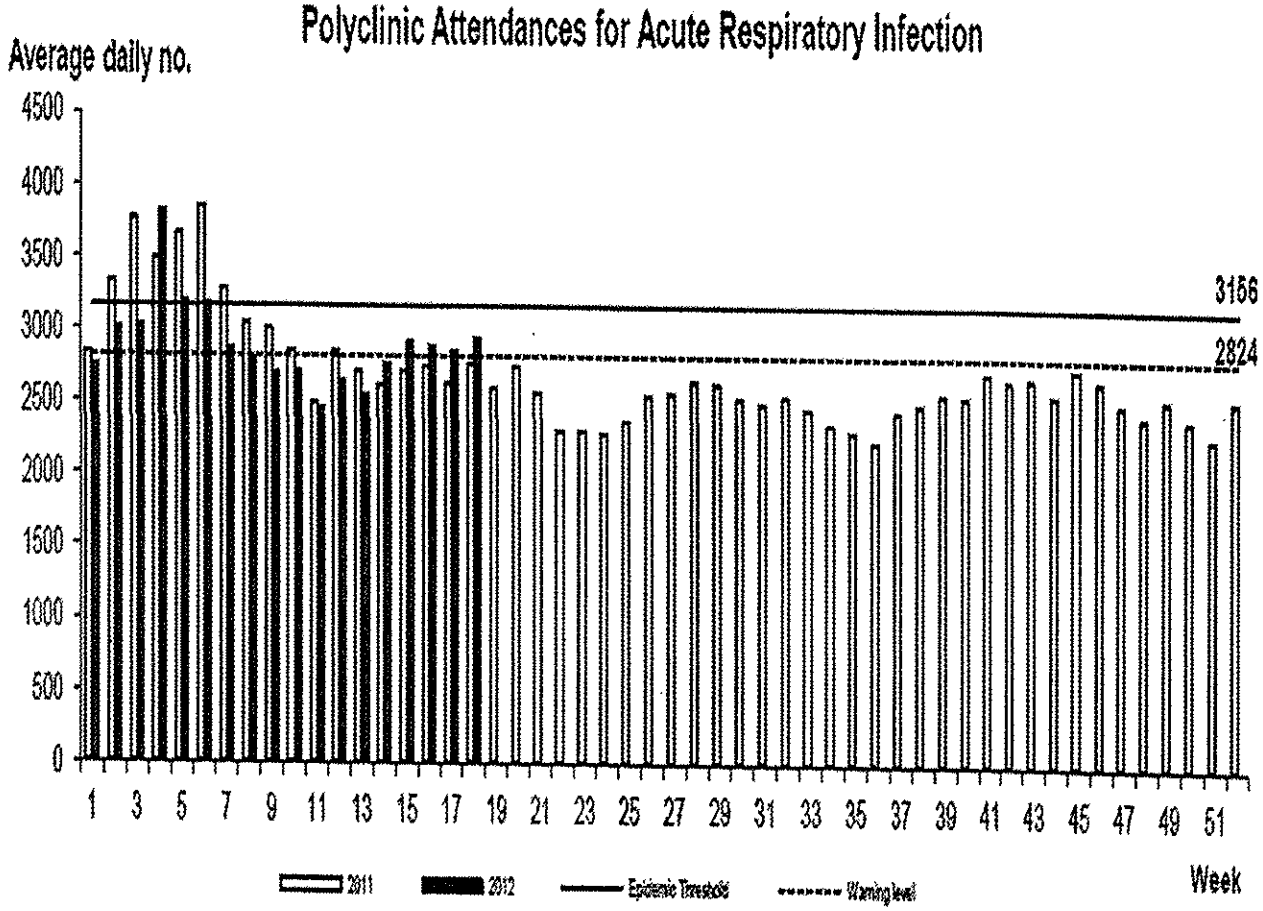
- RECENT: 11 cases of reported infection by *legionella sp.* in 2012 as at wk 18 of 2012.

(SGP MOH Local Infectious Diseases Bulletin)



- C.f. 8 and 21 cases of reported infection by *legionella sp.* in 2011 over same period and total for the year respectively.

Weekly Profile of Respiratory Illness in Singapore as at 05 May 2012



- Profile does not include data from other sources such as hospitals, private clinics and unreported cases.

IAQ & Productivity: Ventilation

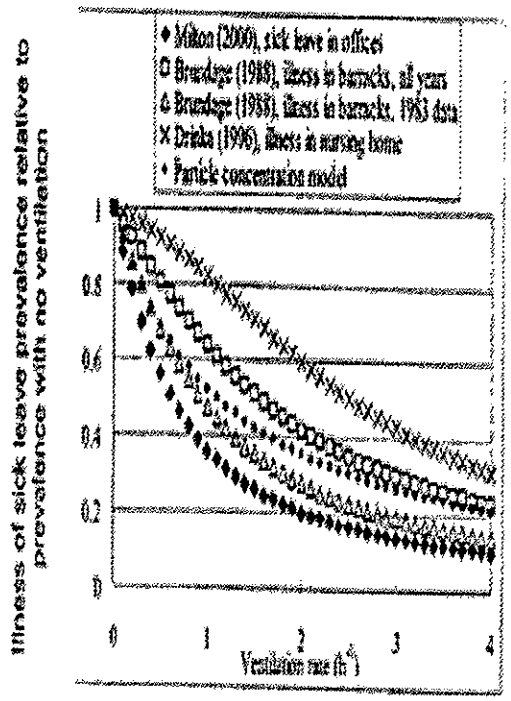


Fig A.1 – Predicted trends in illness of sick leave versus ventilation rate (source: Fisk et al 2003)

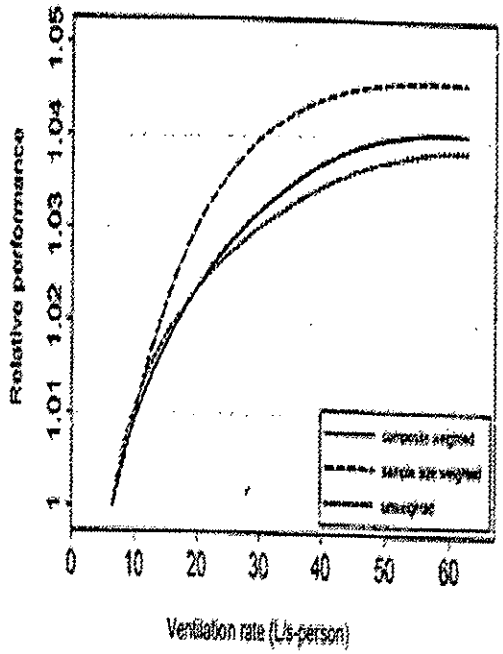


Fig A.2 – Relative performance in relation to the reference value at 6.5 L/s per person versus average ventilation rate (source: Seppanen, OA and Fisk, WJ, 2005)

- Inadequate ventilation increases prevalence of some types of communicable respiratory diseases
- Graph represents estimations based on field data and the application of a theoretical model of airborne transmissions of respiratory infectious

- Ventilation affects productivity
  - Directly by absenteeism from medical leave
  - Indirectly by lower efficiencies
- Trend of increasing performance statistically significant up to 14 L/s-person (95 % confidence interval)
- But high ventilation rates can be costly

Source: Annex A to SS 554 : 2009

IAQ Affects Wealth



- Potential service, maintenance, health and legal costs, losses in productivity and non-tangible losses affect:
  - Designers, Construction companies, Contractors
  - Building owners
  - Employers
  - Building occupants

IAQ: Should we be interested?

- Most of us spend most of our time indoors
- US EPA studies indicate indoor pollutant levels may be many times (2-100) higher than outdoor levels
- IAQ affects short and long-term health, productivity and wealth & reputation
- Some IAQ-related health problems may lead to premature death

IAQ-related Legislation in Singapore

Statutory Requirements (Acts of Parliament)

- Building Maintenance & Strata Management Act 2004
- Environmental Public Health Act (Cap 95)
- Workplace Safety & Health Act 2006 (Cap 354A)
- Clean Air Act (1970)

Subsidiary Legislative Requirements (Rules & Regulations from Ministries)

- Building Control Regulations 2003 Ed
- Building Control (Environmental Sustainability) Regulations 2008 Ed
- Environmental Public Health (Cooling Towers & Water Fountains) Regulations 2000 Ed
- Smoking (Prohibition in Certain Places) Notification 2007 Ed

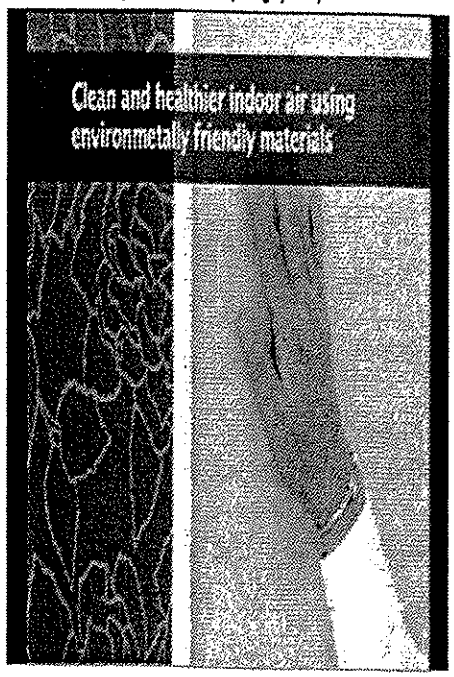
IAQ in BCA's Green Mark (GM)

- 2 GM schemes relevant to this course (BCA-GMFM 2010)
  - Non-Residential Existing Building
  - Office Interior

BCA GREEN MARK

- Relevant IAQ references
  - SS554 Code of Practice for Indoor Air Quality for Air-conditioned Buildings
  - Guidelines for Good Indoor Air Quality in Office Premises

Green Building Green Mark (Singapore)



IAQ for BCA Green Mark (Office Interior Scheme v1-0)

- 4-1 IAQ Performance (8 Pts)
  - Aim:
    - Encourage and recognize good IAQ to ensure comfort and well-being of office occupants
  - Requirements:
    - Perform IAQ audit once every 3 years (5pts)
    - Develop an active IAQ management program (1pt)
    - CO2 monitoring to ensure delivery of sufficient/minimum outside air requirements (2pts)

- 4-2 Indoor Air Pollutants (5 pts)
  - Aim:
    - Minimise airborne contaminants, mainly from inside sources to promote a healthy indoor environment.
  - Requirements:
    - Use and purchase of sustainable and environmentally-friendly products (4pts)
    - Setting of sustainable and environmentally-friendly procurement and purchasing policy (1pts)

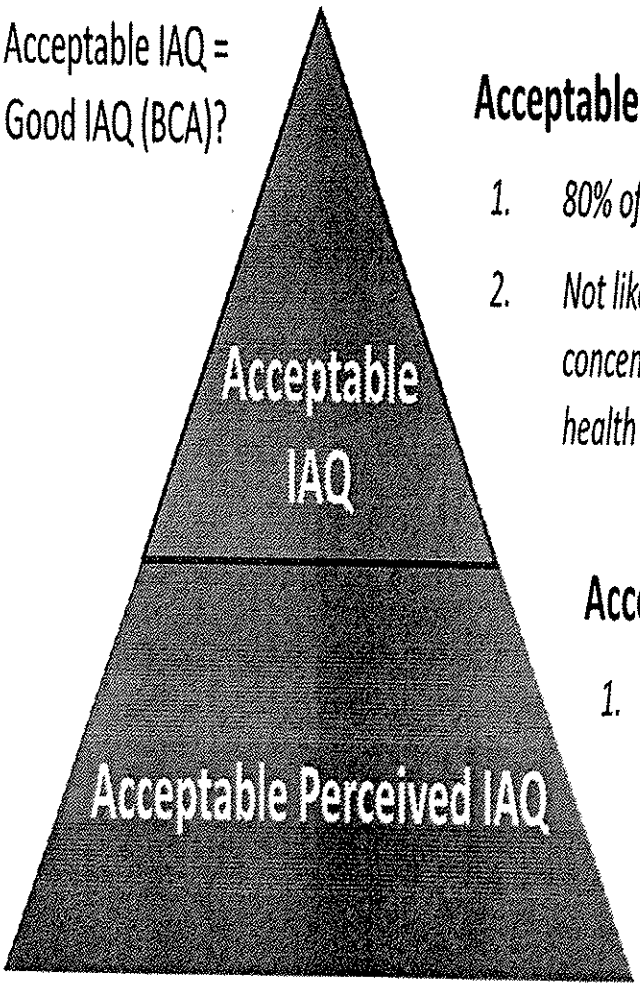
- Total Points : 13 pts

Scope of the COP SS 554 : 2009

- Covers **all air-conditioned premises where air-conditioning is used intermittently or continuously**, EXCEPT:
  - Residential premises
  - Factory production areas
  - Hospitals
  - Polyclinics
  - Laboratories

SS554:2009 Definitions of IAQ

Acceptable IAQ = Good IAQ (BCA)?



Acceptable IAQ

1. *80% of occupants express no dissatisfaction*
2. *Not likely to be known contaminants at concentrations to exposures that pose a significant health risk (s3.1)*

Acceptable perceived IAQ

1. *80% of occupants express no dissatisfaction on the basis of odour and sensory irritation (necessary but not sufficient to meet the acceptable IAQ) (s3.2)*

Therefore, since the purpose of COP SS 554 : 2009 is to specify acceptable IAQ to minimize health risks, air sampling/testing is required and included in an IAQ audit

SS554:2009 References

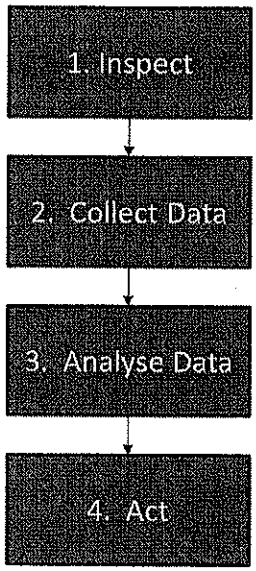
Ref./Standard No.	Title
ANSI/ASHRAE 55	Thermal environmental conditions for human occupancy
ANSI/ASHRAE 62.1	Ventilation for Acceptable Indoor Air Quality
ANSI/ASHRAE 129	Measuring air change effectiveness
ISO 7730	Ergonomics of the thermal environment – Analytical determination and interpretation of thermal comfort using calculation of the PMV and PPD indices and local thermal comfort criteria
ISO 12569	Thermal performance of buildings – Determination of air change in buildings – Tracer gas dilution method
ISO 16000	Indoor air (Sampling strategy)
ISO 16017	Indoor, ambient & workplace air – Sampling and analysis of volatile organic compounds by sorbent tube / thermal desorption / capillary gas chromatography
ISO 16702	Workplace air quality – Determination of total organic isocyanate groups in air using 1-(2-methoxyphenyl) piperazine and liquid chromatography
ISO 16814	Building environment design – Indoor air quality – Methods of expressing the quality of indoor air for human occupancy
SS 553	Code of practice for air-conditioning and mechanical ventilation in buildings

When to Test?

- Testing Frequency for Green Mark is once every 3 years
- Frequency consistent with the recommendations in:
  - SS 554 Code of Practice for indoor air quality for air-conditioned buildings
  - Workplace Safety and Health (Risk Management) Regulations, 2006

Testing/Air Sampling in the IAQ audit

4-STEP AUDIT



- Inspect premises and ACMV system
- Conduct Ground Activities
  - **Conduct air sampling/testing**
  - Obtain feedback from occupants
- Check if results from air sampling are within acceptable limits, and if majority score for acceptable IAQ is obtained. Where requirements are not met, identify and investigate possible causes
- Perform remediation activities where necessary and monitor results towards compliance to acceptable limits

Recommended IAQ Test Parameters: Table 1, SS 554 : 2009

Recommended IAQ Parameters	Acceptable Limit*
Thermal Comfort	
•Operative temperature	24-26 degC
•Relative humidity	< 65 % -new bldgs , <70%-existing bldgs
•Air Movement	0.1-0.3 m/s
Chemical Contaminants	
•Carbon dioxide (CO2)	700 ppm > outdoor
•Carbon monoxide (CO)	9 ppm
•Formaldehyde	120 ug/m3 or 0.1 ppm
•Total volatile organic compounds (TVOCs) photoionisable at 10.6eV	3000 ppb
Particulate matter	
•Respirable suspended particles (10um, median 4um)	50 ug/m3
Biological Contaminants	
•Total viable bacterial count	500 cfu/m3
•Total viable mould count	500 cfu/m3

* Refer to test methodologies recognized in the SS 554 : 2009

Compare: ENV Guidelines for Good IAQ in Office Premises, 1996

PARAMETER	ACCEPTABLE LIMIT	REMARKS
Carbon dioxide	1000 ppm (1800 mg/m3)	
Carbon monoxide	9 ppm (10 mg/m3)	
Formaldehyde	0.1ppm (120 ug/m3)	
Ozone	0.05 ppm (100 ug/m3)	
Suspended particulates	150 ug/m3	Sizes ≤ 10um (PM10)
Volatile Organic Cmpds	3 ppm	Photoionisable toluene reference
Total bacteria counts	500 CFU/m3	Colony forming units
Total Fungal counts	500 CFU/m3	" " "
Air temperature	22.5-25.5 deg C	
Relative Humidity	≤ 70%	
Air movement	≤ 0.25 m/s	At workstation area

Operative Temperature, t_o

- Operative temp. (t_o) is average of air temp.(t_a) and mean radiant temp (t_r)

$$t_o = \frac{(t_a + t_r)}{2}$$

And: $t_r = t_g + 2.44 \times V^{0.5}(t_g - t_a)$

Where:
t_g = Globe temp in degC
V = air speed in m/s

How Much Testing?

- SS 554 : 2009, Table 3 – Sampling requirements for indoor environments

No of Occupied Floors	% of Occupied Floors to be Sampled*	Remarks
< 5	80 %	
5 – 10	70 %	* Result rounded up to
11 – 20	60 %	determine number of
21 – 30	12 flrs or 50%, whichever higher	floors to sample.
31 – 40	15 flrs or 40%, whichever higher	Selection of floors to
41 – 50	16 flrs or 35%, whichever higher	be sampled is random
> 50	18 flrs or 30%, whichever higher	

- For each floor, at least 1 sampling point per area serviced by separate AHU, FCU or any air-conditioning or air distribution system.
- **PLUS** at least 2 samples taken at entrance to building or at the location of outdoor air intake.

Where to Test & How Long?

- Indoor air sampling at each point
  - At area with highest occupant density
  - At center of room or occupied zone
  - 75-120 cm from floor
  - As close as possible to breathing zone of occupants
  - Generally made continuously over 8-hours. If not practical or possible, a strategy to obtain the average results of 30mins x 4 time slots, or timings based on professional judgment of a competent person is acceptable

Who to Test?

- Air sampling may be conducted by a competent person who has attended and met the requirements of an IAQ course conducted by a training provider recognized by cognizant authorities.
- Laboratories used for sampling or analysis should be SAC-SINGLAS accredited for respective tests.
- Use of calibrated testing instruments required.

Targeted IAQ Test Parameters: Table 2, SS 554 : 2009

Recommended IAQ Parameters	Acceptable Limit	Remarks
PM 2.5	35 ug/m3	
Ultra-fine particles	-N/A-	For source tracing
Nitrogen dioxide	100 ug/m3	
Ozone	0.1 ppm	
Radon	150 Bq/m3	
Asbestos	0.01 fibre/cc	
Nicotine	Not Detectable	
Pathogenic Bacteria	-N/A-	To confirm presence & identity
Pathogenic mould	-N/A-	To confirm presence & identity
Semi VOCs (SVOC) & VOCs	Respective PEL	

Notes on Table 2, SS 554 : 2009

- To be tested when:
  - A potential source is suspected
  - Complaint cannot be traced to IAQ problems, noise, lighting and work stressors (SS514 Code of Practice for Office Ergonomics)

Notes on IAQ Tests

- Air sampling/testing may be useful when:
  - It is part of an overall evaluation
  - When the data is interpretable
  - When the data has a descriptive component that helps to illustrate its place in the overall evaluation

Building Occupant Feedback

- Seek confidential feedback on health-related aspects or experiences while indoors in the building with demographics and work conditions.
- Annex J to SS 554 : 2009 serves as a sample confidential questionnaire for building occupants covering:
  - Personal information
  - Environmental conditions
  - Nature of occupation
  - Health complaints
- Alternative questionnaires better suited to the situation or characteristics of the building may be acceptable

SS 554 : 2009 S1 Note 2

- Meeting the requirements of this Code might not achieve the acceptable indoor air quality for everyone in all air conditioned buildings, due to one of the following reasons:
  - The diversity of sources and contaminants in indoor air;
  - Many other factors that may affect occupant perception and acceptance of indoor air quality, such as air temperature, humidity, noise, lighting and psychological stress;
  - The wide range of susceptibility and preferences in the population;
  - Outdoor air brought into the building may be unacceptable or may not be adequately cleaned.

Therefore, compliance to the code does not ensure acceptable IAQ for 100% of the building occupants.

PART 3: SETTING UP YOUR IAQ PROGRAM

Why Setting Up an IAQ program is Important

- Sets a basic platform or organization-level standard for IAQ in the building
- Enables continuity/sustainability
- Consistent with the ideology of Quality
  - "Success can result from implementing and maintaining a management system that is designed to continually improve performance while addressing the needs of all interested parties." ISO9000:2005, s0.2.

Setting-up an IAQ program

1. Appoint an IAQ Manager
2. Develop and IAQ profile of the building
3. Address existing and potential IAQ problems
4. Develop and implement plans for specific activities
5. Educate facilities management (FM) personnel about IAQ management
6. Communicate with occupants about their role in maintaining acceptable IAQ
7. Establish procedures for responding to IAQ complaints

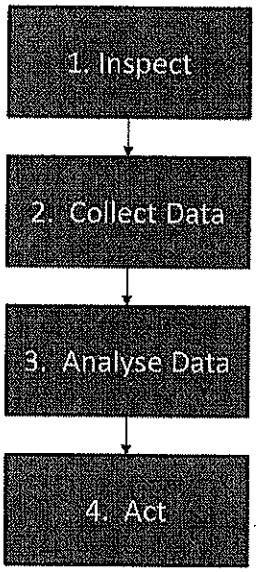
Appointment: IAQ manager



- Establishes and manages the IAQ program
- Have good understanding of the building's structure and function and relevant experience in managing IAQ; have access to building plans
- Have authority or influence to enact measures or remedies to attain, retain or regain IAQ to an acceptable level
- Responsibilities relevant to IAQ:
  - establish lines of communication with tenants, occupants and management
  - Review and coordinate internal and external activities that affect IAQ
  - Ensure operational and/or preventive maintenance activities are scheduled and performed
  - Review contracted services (cleaning services, pest control) for potential effects on IAQ
  - Ensure that IAQ audit is conducted as required
  - Respond to IAQ complaints or concerns and provide follow-up status information till resolution

IAQ Profile: 4-Step IAQ Audit

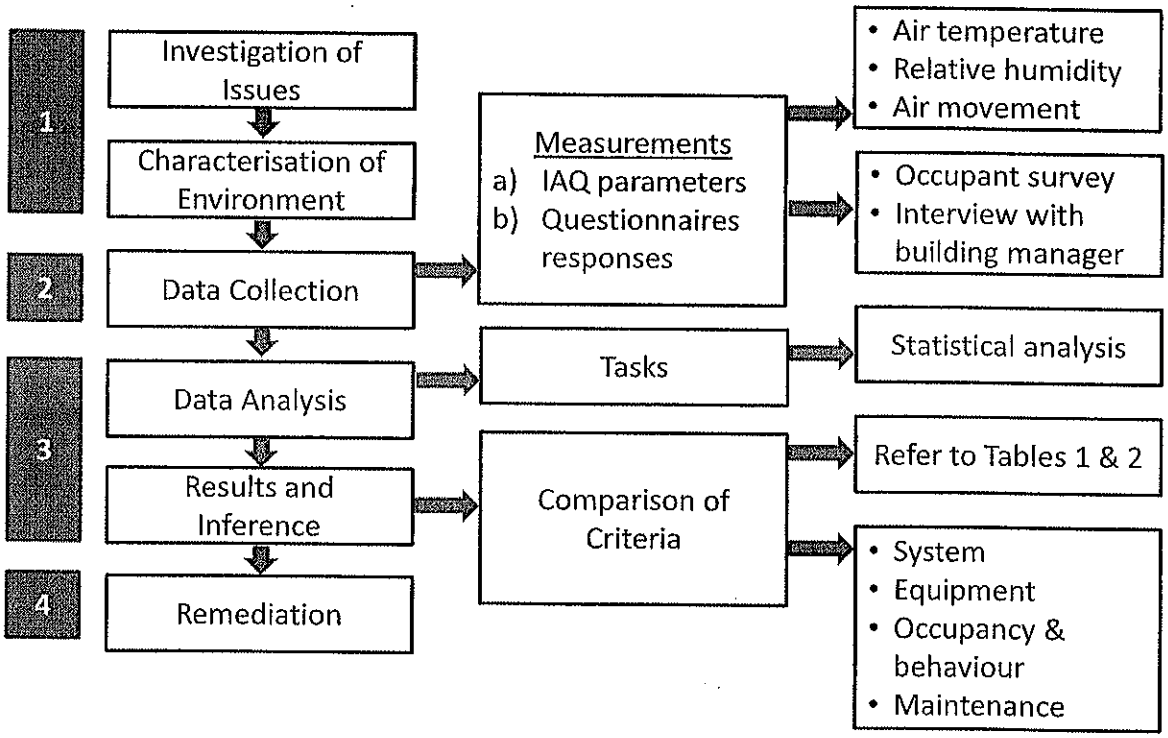
4-STEP AUDIT



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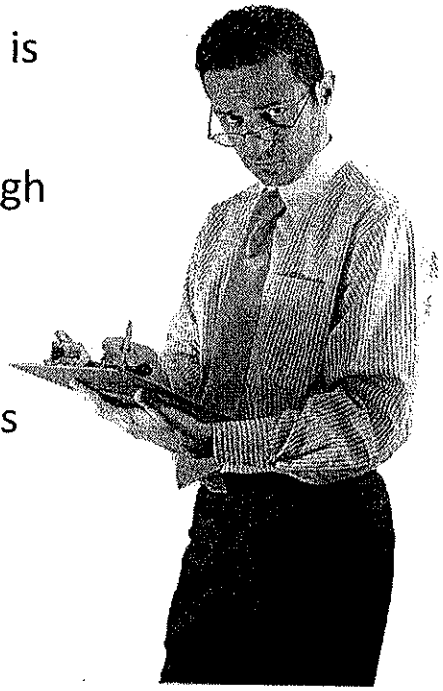
SS 554:2009 Figure 1 – IAQ Audit Methodology

4-STEP IAQ AUDIT



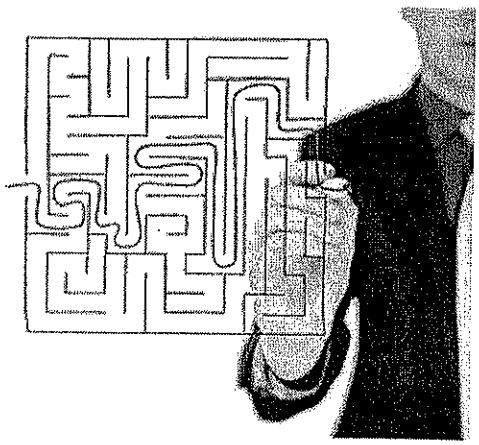
Building (IAQ) Inspection

- The purpose of a building inspection is to identify irregularities
- It is to be performed as a walk-through process together with a checklist, in addition to checks performed during routing maintenance
- Annex I to the SS 554 : 2009 serves as an example and is a basic guide covering:
  - Human comfort levels
  - Potential sources of contamination
  - Ventilation and air conditioning



Plans for Specific Activities

- Renovation works
- Addition and alteration works
- Pest control
- Cleaning & maintenance



Plans for IAQ Education for FM Personnel

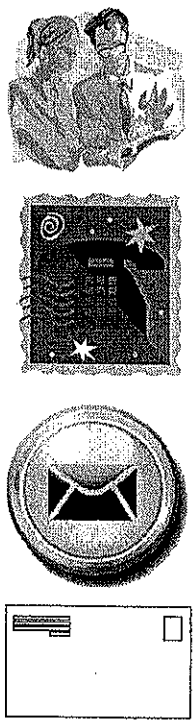
- Identify facilities management personnel whose functions and activities may affect IAQ of the building.

- Equip them with relevant IAQ knowledge



IAQ Communications

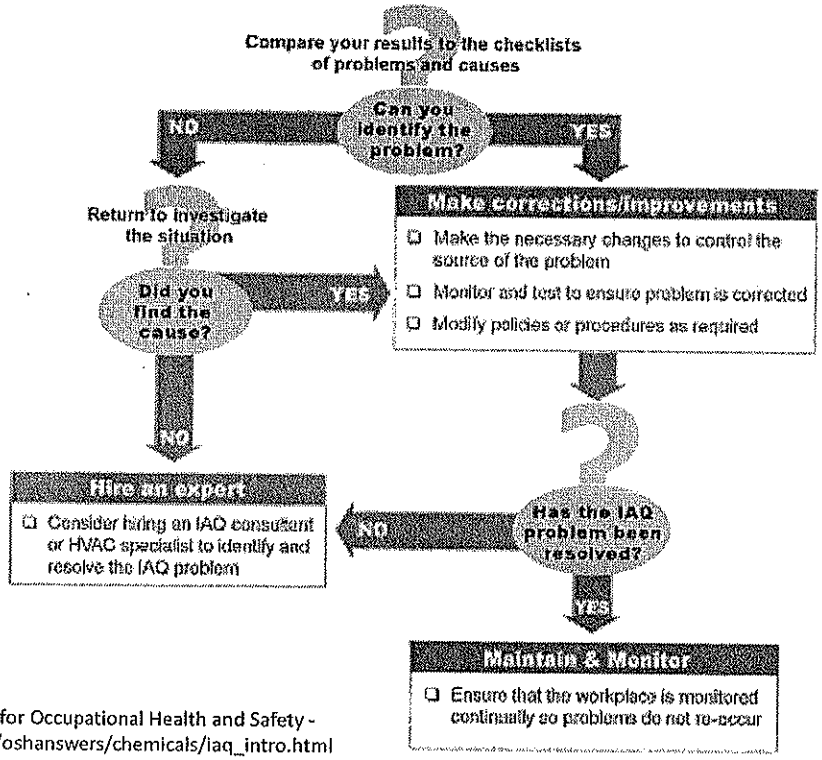
- General information
  - Management's policy statement to provide healthy and safe environment
  - Common policies and practices to promote good IAQ in the building
  - How IAQ complaints are raised are handled.
  - Identification of the IAQ manager and alternative contact person together with contact numbers to call for enquiries
- Notices on ad-hoc activities that may affect IAQ
  - Prior notification of activities in the building that may affect IAQ together with timings and anticipated concerns that may arise and steps taken to lessen such concerns.
- IAQ investigations
  - Information in response to IAQ complaints raised (investigations done, data collected, remedial actions taken and follow-up plans)
  - Information on how specific occupant activities may negatively impact IAQ of the building



Responding to IAQ Complaints

- Establish procedures for recording and responding to IAQ complaints which are made available and notified to facilities management personnel and tenants and/or occupants
- Respond promptly to the person/party making the complaint
- Conduct an IAQ audit towards remediation
- Discuss and consult with appropriate parties as necessary
- Provide timely follow-up communications on progress and status

Plan Remedial Actions to Take



Ref: Canadian Centre for Occupational Health and Safety - http://www.ccohs.ca/oshanswers/chemicals/iaq_intro.html

Common Remedial Actions

- Remove pollution sources
- Substitute for low emitting products whenever possible
- Fix all leaks promptly
- Remove and discard all water-damaged porous materials including ceiling tiles, carpets, fittings and furnishings.

Maintaining Good IAQ

- Run the course of the IAQ audit.
- Carry out routine O&M and PM activities as per SS 553 Code of Practice for air conditioning and mechanical ventilation in buildings.
- Inspection methodology of ACMV with respect to IAQ and recommendations of conditions requiring cleaning are provided in Annex F to SS 554 : 2009.
  - This is referenced by and correspond to 'annual maintenance of supply and return air ducts' in section 20.2.4.4 of SS 553:2009
  - Recommends cleanliness inspection for 3 ACMV components:

ACMV component	Inspection Interval
Air Handling Unit	6 months
Supply air ducts	12 months
Return air ducts	12 months

Generate a Master Calendar

E.g. HVAC Maintenance: Air-Conditioning Maintenance Checklist/Calendar

Component	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Refrigerant compressors	m	m	m	m	m	m, A	m	m	m	m	m	m
Chiller condenser	m	m	m	m	m	m, A	m	m	m	m	m	m
Air Handling Units	m	m	m, S	m	m	m, A	m	m	m, S	m	m	m
Fan Coil Units	m	m	m, S	m	m	m	m	m	m, S	m	m	m
Pumps	m	m	m, S	m	m	m	m	m	m, S	m	m	m
Cooling towers	m	m	m	m	m	m	m	m	m	m	m	m
Motors	m	m	m	m	m	m	m	m	m	m	m	m
Chilled water expansion tanks	m	m	m	m	m	m	m	m	m	m	m	m
Supply and return air ducts						A						

KEY: m – monthly checklist; S – six-monthly checklist; A – annual checklist

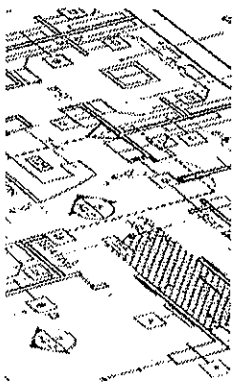
PART 4: REDUCING POLLUTANTS INDOORS DURING A&A WORKS

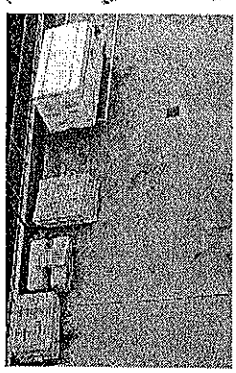
A&A works and IAQ



- A&A works to existing building may adversely affect IAQ from the associated breakdown and/or construction activities
- Typical IAQ contaminants arising from A&A works include:
  - Particulate matter
    - from demolition, fabrication & installation, etc.
  - VOCs
    - from painting, varnishing, new fittings & furnishings, etc.
  - By-product fumes and gases
    - from welding, masonry, carpentry, etc.

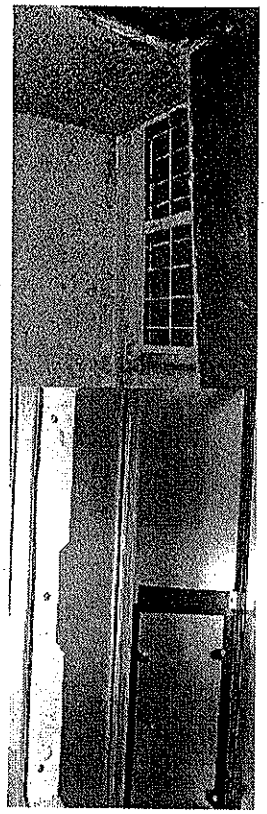
Before and During A&A works





Plan and execute precautions to prevent contamination to the indoor environment:

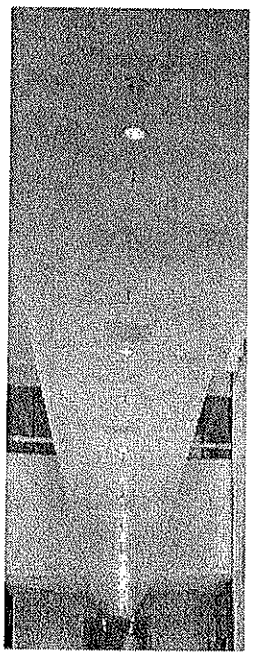
- Select materials and processes that generate the lowest possible emissions
- Plan for as many works as possible (e.g. painting, re-surfacing, carpet installation, etc.) to be done during off hours
- Isolate spaces where A&A works are being carried out
- Prevent existing and new internal surfaces of ductwork from contamination
- Store and protect interior building materials and ACMV components against contamination
- Elect for fabrication and installation methods which generate minimal airborne contaminants



Before Occupation

- Clean air ducts where necessary
- Perform air-purging to remove contaminants
- Ensure that interior surfaces are clean and dust-free
- Re-balance the supply air

After Occupation



- Examine building usage and monitor activities
- Continue/initiate maintenance programs and specific activities
- Administer the IAQ program
- Run the IAQ audit

Summary of Strategies to Control IAQ Pollutants

- Source control
  - Eliminate source(s) of contaminant(s)
  - Substitute source with lower emissions
  - Modify source(s) to reduce emission rates
- Local Pollution Management
  - Segregate (and/or isolate) source(s)
  - Improve local ventilation (e.g. by local exhaust)
  - Use local air cleaning
- Dilution / Exposure control
  - Increase ventilation rates
- Air Cleaning
  - Particulate air cleaners
  - Gas phase air cleaners

Singapore Green Label Scheme

- Products in Singapore that have relatively less undesirable effects on the environment are certified and marked by a Green Label (GL)
- The GL is awarded under the Singapore Green Labeling Scheme (SGLS) which is administered by the Singapore Environment Council (SEC)
- The SEC champions environmental causes in Singapore and aims to "set new sustainability standards for urban development" as one of its objectives
- A list of GL products (low emission paints, etc.) relevant to GM and IAQ may be found from their website (page: http://www.sec.org.sg/awards/greenlabel)

SINGAPORE ENVIRONMENT COUNCIL

Green Label SINGAPORE



PART 5: DISCUSSION - COMMON IAQ PROBLEMS & THEIR SOLUTIONS

Common IAQ-related Complaints

- May be categorized:
  - Related to inadequate air-conditioning and ventilation systems
    - Stuffy
    - Too cold, too warm
  - Related to presence of contaminants
    - Mould
    - Dust
    - Unwanted odours
    - Multiple irritation
    - Others

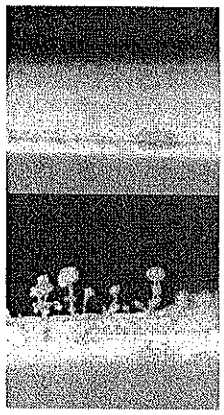
General Strategies to Control IAQ Contaminants

- Source control
  - Eliminate source(s) of contaminant(s)
  - Substitute source with lower emissions
  - Modify source(s) to reduce emission rates
- Local Pollution Management
  - Segregate (and/or isolate) source(s)
  - Improve local ventilation (e.g. by local exhaust)
  - Use local air cleaning
- Dilution / Exposure control
  - Increase ventilation rates
- Air Cleaning
  - Particulate air cleaners
  - Gas phase air cleaners

Problem: Mould (a.k.a. fungi)

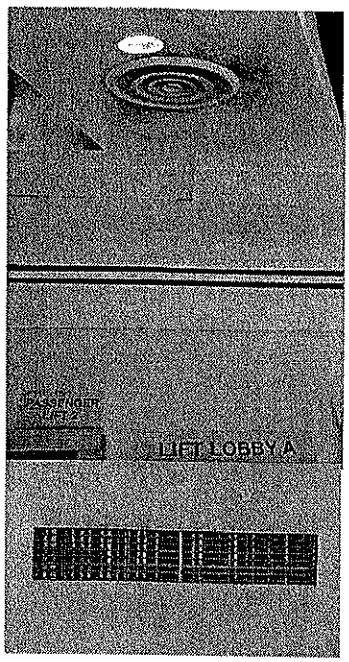
- Background
  - Mould are scientifically known as fungi (singular – fungus)
  - Require oxygen and moisture or high humidity to germinate and develop
- Significance in IAQ
  - Small enough to be airborne and bioactive to cause:
    - Or aggravate allergic reactions and respiratory conditions (e.g. Asthma)
    - Serious lung infection from spore inhalation (hypersensitivity pneumonitis)
  - Germinates readily and grows fast and on a wide selection and minimal quantities of substrates including dust aggregations
  - Depending on the species, fungi may produce toxic metabolic by-products called mycotoxins
- Common indoor spore-forming species are *Cladosporium, Penicillium and Aspergillus*





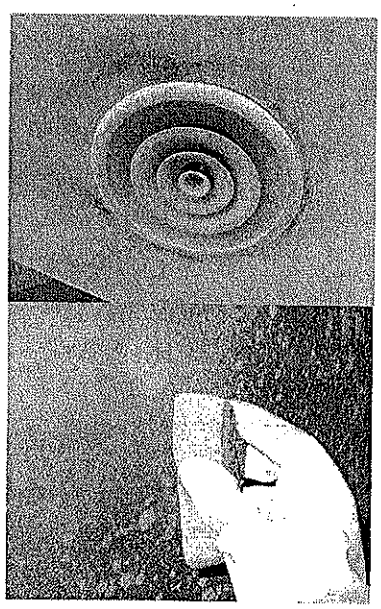
Common Sources of Moisture Indoors

- Condensation from
  - Poorly insulated or damaged insulation of air conditioning components
  - Temperature differential across a barrier (e.g. walls)
  - Cooling equipment such as refrigerators
- Cracks and leaks in
  - Air conditioning components including chilled water pipes, drain pans, etc
  - Roof components such as tiling, waterproofing, drainage gutters, etc.
  - Walls adjacent to wet areas such as toilets, flower beds, etc.
  - Windows, doors, window frames and door frames.
- Items which have prolonged exposure to moisture
  - Carpets
  - Drapes
  - Upholstery
- Over-watered indoor potted plants



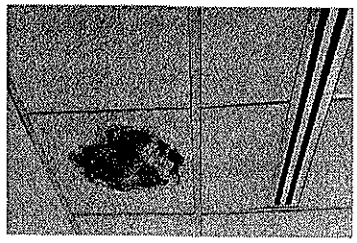
Solution to Mould

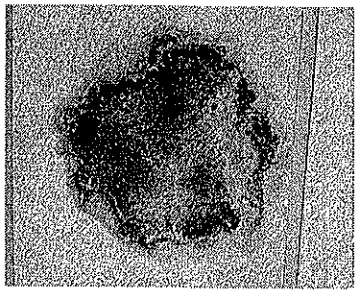
- Assessment of contamination
- Plan for Remediation
- Clean-Up Methods
- Precautions
  - Personal Protection Equipment (PPE)
  - Containment



Prevention of Mould in Buildings

- Inspect for evidence of water damage and growth of visible mould during routine inspections
- Remove water-damaged materials
- Determine the source of moisture and rectify accordingly
- Dry the building surfaces or furnishings
- Remove any other visible mould





Problem: Unwanted Odour

- Background
  - Unwanted odours refer to significant levels of smells which are perceived as objectionable due various reasons:
    - Excessiveness
    - Generally deemed unpleasant
    - Inappropriate for an intended environmental setting
  - May be difficult to solve due to transient occurrence, subjectivity in perception, etc.
- Significance in IAQ
  - Often a cause of discomfort
  - May be a major point of discontent
  - May indicate or suggest a larger IAQ problem

Odour Control

- Identify the source
- Where possible first work on source control strategies
- In addition explore:
  - local pollution management strategies
  - air cleaning options

CASE STUDY: Odour Control in Shopping Centre



BACKGROUND

- A management corporation of existing shopping centre allows a proportion of units to converted for use as F&B outlets.
- After conversion of these units they receive complaints from other tenants as well as shoppers of excessive cooking and food odours from the newly converted F&B outlets.

SOLUTION(S) ??

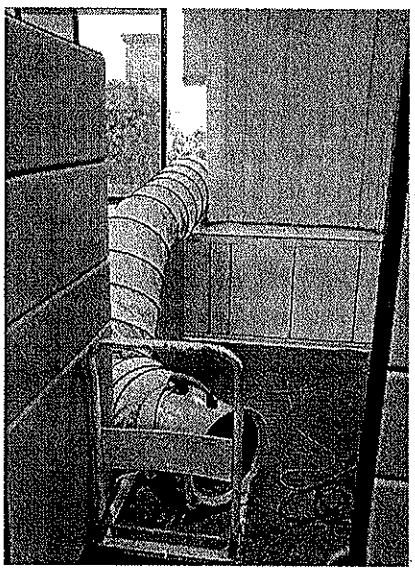
CASE STUDY: VOC reduction in office of manufacturing facility

BACKGROUND

- Employees of a precision manufacturing facility reported to feel unwell due to excessive odour of lubricant in the air.
- Testing by 3rd party laboratory revealed raised levels of VOCs in the air.

SOLUTION(S) ??

CASE STUDY: Multiple Irritation in Office



BACKGROUND

- Employees of an office complain of irritation to the eyes and nose whenever they are in the office.
- When interviewed the source was not known since the problem had existed since occupation nine months ago.
- Testing by 3rd party laboratory revealed raised levels of formaldehyde in the air, although they were within limits.
- Office management tried several methods but with no success.

SOLUTION(S) ??

SUMMARY

General Summary

- There is an increasingly good case for establishing good IAQ in Singapore
- IAQ is relevant in BCAs Green Mark, as long as there are people in buildings
- SS554, the code of practice for IAQ in air-conditioned buildings sets the standard at this time

Summary: SS 554 : 2009

- Serve as base for statutory requirements and enforcement
- Provides background information on IAQ
- Provides basic guidance on setting up an IAQ program, ACMV inspection, filter specs, as well as control of indoor air contaminants
- Provide source references for detailed support information

Towards meeting requirements of SS554 : 2009

- Meet other standards and requirements
  - SS 553 Code of practice for air-conditioning and mechanical ventilation in buildings.
  - ANSI/ASHRAE 62.1 for suggested specification if smoking zones are present.
  - Workplace Safety and Health (Risk Management) Regulations
  - Water fountains and cooling towers

In Reality



- In reality, IAQ problems may need to be fixed (sometimes urgently) even if the requirements of SS 554 : 2009 are met. This is mainly due to potential costs associated with potential liability or loss of opportunities and reputation
- Also, IAQ may be improved for optimal state of human health and well-being indoors but there are practical limits associated to cost
- Individual cost-benefit evaluations may need consideration

IAQ Cause and Effect

FACTORS → **IAQ** → **EFFECTS**

- **PEOPLE**
- **ACTIVITIES**
- **BUILDING MATERIALS**
- **HVAC PERFORMANCE**
  - Outdoor Air Quality
  - System specs & design
  - Maintenance
- **HOUSEKEEPING & MAINTENANCE**

- **POLLUTANTS**
  - Particles
  - Chemical
  - Biological
- **THERMAL COMFORT**
  - Temperature
  - Humidity

- **PEOPLE**
  - Personal Health & Well-being
  - Productivity
- **COMMERCIAL**
  - Profit/Loss
  - Liabilities
  - Reputation

NOTE:

IAQ STARTS WITH PEOPLE AND ENDS WITH PEOPLE

Thank You