Indoor Air Quality measurement in Hong Kong

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IAQ Certification Scheme
Sick Building Syndrome (SBS)
or
Building Related Illness (BRI)
Sick Building Syndrome (SBS)

- Irritation and itching eyes
- Nose and throat irritation
- Runny or congested nose
- Other flu-like symptoms
- Chest tightness
- Itchy skin occasionally with the development of rash
- Headaches
- Poor concentration
- Irritability
Guide on IAQ Certification Scheme

The GN applies to all buildings or totally enclosed areas served with mechanical ventilation system for human comfort except:

1. Domestic building
2. Medical building
3. Industrial building
Key Features of the IAQ Certification Scheme

• 2 Level Excellent or Good Class
• Voluntary for annual certification
• Certificate valid for 5 years for renewal full certification
• In between the 4 years recertification for CO$_2$ and RSP
• Building owner maintain post certification IAQ
<table>
<thead>
<tr>
<th>Parameter</th>
<th>Unit</th>
<th>Excellent Class</th>
<th>Good Class</th>
</tr>
</thead>
<tbody>
<tr>
<td>Room Temperature</td>
<td>°C</td>
<td>20 to &lt; 25.5&lt;sup&gt;b&lt;/sup&gt;</td>
<td>&lt; 25.5&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>Relative Humidity</td>
<td>%</td>
<td>40 to &lt; 70&lt;sup&gt;c&lt;/sup&gt;</td>
<td>&lt; 70</td>
</tr>
<tr>
<td>Air movement</td>
<td>m/s</td>
<td>&lt; 0.2</td>
<td>&lt; 0.3</td>
</tr>
<tr>
<td>Carbon Dioxide (CO&lt;sub&gt;2&lt;/sub&gt;)</td>
<td>ppmv</td>
<td>&lt; 800&lt;sup&gt;d&lt;/sup&gt;</td>
<td>&lt; 1,000&lt;sup&gt;e&lt;/sup&gt;</td>
</tr>
<tr>
<td>Carbon Monoxide (CO)</td>
<td>µg/m³</td>
<td>&lt; 2,000&lt;sup&gt;f&lt;/sup&gt;</td>
<td>&lt; 10,000&lt;sup&gt;g&lt;/sup&gt;</td>
</tr>
<tr>
<td>Respirable Suspended Particulates (PM&lt;sub&gt;10&lt;/sub&gt;)</td>
<td>µg/m³</td>
<td>&lt; 20&lt;sup&gt;f&lt;/sup&gt;</td>
<td>&lt; 180&lt;sup&gt;h&lt;/sup&gt;</td>
</tr>
<tr>
<td>Nitrogen Dioxide (NO&lt;sub&gt;2&lt;/sub&gt;)</td>
<td>µg/m³</td>
<td>&lt; 40&lt;sup&gt;g&lt;/sup&gt;</td>
<td>&lt; 150&lt;sup&gt;h&lt;/sup&gt;</td>
</tr>
<tr>
<td>Ozone (O&lt;sub&gt;3&lt;/sub&gt;)</td>
<td>µg/m³</td>
<td>&lt; 50&lt;sup&gt;f&lt;/sup&gt;</td>
<td>&lt; 120&lt;sup&gt;g&lt;/sup&gt;</td>
</tr>
<tr>
<td>Formaldehyde (HCHO)</td>
<td>µg/m³</td>
<td>&lt; 30&lt;sup&gt;f&lt;/sup&gt;</td>
<td>&lt; 100&lt;sup&gt;f,g&lt;/sup&gt;</td>
</tr>
<tr>
<td>Total Volatile Organic Compounds (TVOC)</td>
<td>µg/m³</td>
<td>&lt; 200&lt;sup&gt;f&lt;/sup&gt;</td>
<td>&lt; 600&lt;sup&gt;f&lt;/sup&gt;</td>
</tr>
<tr>
<td>Radon (Rn)</td>
<td>Bq/m³</td>
<td>&lt; 150&lt;sup&gt;i&lt;/sup&gt;</td>
<td>&lt; 200&lt;sup&gt;f&lt;/sup&gt;</td>
</tr>
<tr>
<td>Airborne Bacteria</td>
<td>cfu/m³</td>
<td>&lt; 500&lt;sup&gt;jk&lt;/sup&gt;</td>
<td>&lt; 1,000&lt;sup&gt;jk&lt;/sup&gt;</td>
</tr>
</tbody>
</table>
12 IAQ Parameters

**Physical Parameters** - *Thermal Comfort*
- Temperature
- Humidity
- Air Movement

**Chemical Parameters**

- **Organic Pollutants** - Volatile Organic Compounds (VOCs)
  - Formaldehyde (HCHO)

- **Combustible Gases** -
  - Carbon Dioxide (CO$_2$)
  - Carbon Monoxide (CO)
  - Nitrogen Dioxide (NO$_2$)

- **Others** -
  - Ozone (O$_3$)
  - Radon (Rn)
  - Respirable Suspended Particulate (PM$_{10}$)

**Biological Contaminants** - Total Airborne Bacteria and Fungi counts
Temperature

Excellent Class: 20-25.5°C

Good Class: less than 25.5°C
Relative Humidity

Excellent Class: 40-70%

Good Class: less than 70%
Q-Trak

Temperature & Relative Humidity Measurement
Air Movement

Excellent Class: less than 0.2 m/s

Good Class: less than 0.3 m/s
Air Flow and Ventilation Measurement

Hot Wire Anemometer
Air Movement

• A certain amount of air movement round the human body is essential for thermal comfort.

• It is also important in dispersing air pollutants. The required level of airflow depends on the air temperature and humidity.

• In the hot and humid summer months, for example, greater air movement can help produce a more comfortable environment.
Air Movement

- Airflow is determined by:
  - Ventilation
  - Convection currents (created by hot air rising and cool air falling) in a room.

- Blocked or unbalanced ventilation systems, or too low pressure levels in ventilation ducts may restrict air movement, producing a "stuffy" atmosphere which makes occupants feel uncomfortable.
Air Movement

- Airflow is also sensitive to:
  - Changes in room occupancy
  - Installation or removal of partition walls
  - Size, quantity and arrangement of office equipment and furniture

- Too much air movement results in draughts and excessive cold.
Formaldehyde (HCHO)

Excellent Class: less than 30 $\mu$g/m$^3$ (24 ppbv)

Good Class: less than 100 $\mu$g/m$^3$ (81 ppbv)
Formaldehyde (HCHO)

- A kind of Volatile Organic Compounds (VOCs)
- Comes from pressed wood products, carpet adhesives, smoking or other incomplete combustion process
- Can be a problem in areas where there are a large amount of carpets and pressed wood furniture

\[
\begin{align*}
\text{Urea} & \quad + \quad \text{Formaldehyde} \\
& \quad \rightarrow \quad \text{Urea-formaldehyde foam}
\end{align*}
\]
Formaldehyde (HCHO)

Can also be formed by burning wood, kerosene, incense or natural gas, by automobiles, and by cigarettes.

Health impacts

- irritating effect to eyes, nose and respiratory system
- sensitization
- a suspected human carcinogen
Air Sampling Strategies

• Active Sampling
• Passive Sampling
Active Sampling

• Actively drawing air through a sorbent filled cartridge or tubes by a personal sampling pumps
HCHO + 2,4-Dinitrophenylhydrazine (DNPH) → [chemical structure]
High Performance Liquid Chromatography (HPLC)

**Conditions**
- Sample: STD 100
- Column: (4.6 x 250mm) TSK ODS 100V
- Eluent: DI ACN:60:40
- Flow rate: 1.0 mL
- Sample Conc.: 0.50mg/L
- Injection: 10 µL
- Temperature: 40°C
- Detector: (360nm) UV Detector
- Software: EMPOWER
Volatile Organic Compounds (VOCs)

Excellent Class: less than 200 $\mu g/m^3$
(87 ppbv)

Good Class: less than 600 $\mu g/m^3$
(261 ppbv)
Volatile Organic Compounds (VOCs)

Classification of Organic Compounds

According to their boiling points,

Organic compounds can be classified as 3 categories:

- Very volatile, 
- Volatile
- Semi-volatile

50-260°C (WHO 1986)
Volatile Organic Compounds (VOCs)

Classification of Organic Compounds

According to their chemical structure/functional group:

- Aliphatic (straight chain)
- Aromatic (compounds with benzene ring)
- Halogenated hydrocarbons (Chlorine atom)
- Oxygenated compounds

Source of VOCs: Petroleum products, perfumes, pesticides, plastics, pigments, paints, adhesives and smoking
Volatile Organic Compounds (VOCs)

Fundamental VOC Emission Processes

- Evaporation
- Desorption
- Diffusion within a material

<table>
<thead>
<tr>
<th>Materials</th>
<th>Decade Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wet (Paints, Adhesives)</td>
<td>First few hours</td>
</tr>
<tr>
<td>Dry (Building materials)</td>
<td>Months</td>
</tr>
</tbody>
</table>
### Volatile Organic Compounds (VOCs)

<table>
<thead>
<tr>
<th>Pollutants</th>
<th>Indoor Sources</th>
</tr>
</thead>
<tbody>
<tr>
<td>Benzene, Ethylbenzene, Toluene, Xylenes</td>
<td>ETS, solvents, paints, fax machine, computer terminals, adhesives, floor tile adhesives, styrenefoam</td>
</tr>
<tr>
<td>Carbon Tetrachloride ($\text{CCl}_4$)</td>
<td>Solvents, refrigerant, fire extinguishers, grease solvents</td>
</tr>
<tr>
<td>Tetrachloroethylene ($\text{Cl}_2\text{C}=\text{CCl}_2$)</td>
<td>Dry cleaned fabrics, upholstered furniture covering, spot/textile cleaner, fax machines and printers</td>
</tr>
<tr>
<td>Chloroform ($\text{CHCl}_3$)</td>
<td>Solvents, dyes, pesticides, fax machines, computer terminals, printers and chlorinated water</td>
</tr>
<tr>
<td>Dichlorobenzene</td>
<td>Insecticide, dry cleaning agent, deodorant, mod and mildew control and air freshener</td>
</tr>
</tbody>
</table>
Volatile Organic Compounds (VOCs)

Symptoms

- Eye irritation: burning, dry, watery eyes
- Throat irritation: dry throat
- Respiratory problems: shortness of breath; asthma
- Headaches; poor concentration; dizziness, tiredness, irritability.
Tobacco smoke is composed of:

More than 4,500 compounds have been identified in both vapour and particulate phases

Volatile Organic Compounds (VOCs)

Environmental Tobacco Smoke (ETS)

Tobacco smoke is composed of:

Main Stream (MS) : Smoke exhaled by smokers

Side Stream (SS) : Smoke released directly from burning cigarette
<table>
<thead>
<tr>
<th>acetaldehyde</th>
<th>dibenzo(a,i)pyrene</th>
<th>N-nitroso-di-n-propylamine</th>
</tr>
</thead>
<tbody>
<tr>
<td>acrylonitrile</td>
<td>dibenzo(a,e)pyrene</td>
<td>N-nitrosopyrrrolidine</td>
</tr>
<tr>
<td>arsenic</td>
<td>dibenzo(a,l)pyrene</td>
<td>N-nitrosodi-n-butylamine</td>
</tr>
<tr>
<td>benz(a)anthracene</td>
<td>dibenzo(a,h)pyrene</td>
<td>ortho-toluidine</td>
</tr>
<tr>
<td>benzene</td>
<td>formaldehyde</td>
<td>styrene</td>
</tr>
<tr>
<td>benzo(a)pyrene</td>
<td>hydrazine</td>
<td>urethane</td>
</tr>
<tr>
<td>benzo(b)fluoranthene</td>
<td>indeno(1,2,3,-cd)pyrene</td>
<td>vinyl chloride</td>
</tr>
<tr>
<td>benzo(k)fluoranthene</td>
<td>lead</td>
<td>1,1-dimethylhydrazine</td>
</tr>
<tr>
<td>cadmium</td>
<td>nickel</td>
<td>2-nitropropane</td>
</tr>
<tr>
<td>chromium VI</td>
<td>N-nitrosodiethanolamine</td>
<td>2-napthylamine</td>
</tr>
<tr>
<td>DDT</td>
<td>N-nitrosodiethylamine</td>
<td>4-(methylnitrosamino)-1-(3-pyridyl)-1-butanone [NNK]</td>
</tr>
<tr>
<td>dibenz(a,h)acridine</td>
<td>N'-nitrosodimethylamine</td>
<td>4-aminobiphenyl</td>
</tr>
<tr>
<td>dibenz(a,j)acridine</td>
<td>N'nitrosonornicotine</td>
<td>5-methychrysene</td>
</tr>
<tr>
<td>dibenz(a,h)anthracene</td>
<td>N-nitrosopiperidine</td>
<td>7H-dibenzo(c,g)carbazole</td>
</tr>
</tbody>
</table>
Volatile Organic Compounds (VOCs)

Photo-ionization detectors (PID) device

ppbRAE

Certificate of Calibration

Model
FCR240
Serial Number
101599

This instrument has been calibrated using calibration gases and procedures which are traceable to NIST. Test and calibration data is on file with the manufacturer.

Calibration Date
October 14, 2008

Approved by

RAE Systems Inc.
Certified Reference isobutylene (TVOC) at 10 ppm
Photo-ionization Detector

\[ R + h\nu \rightarrow R^+ + e^- \]
Carbon Monoxide (CO)

Excellent Class: less than 2000 µg/m³
(1.7ppmv)

Good Class: less than 10000 µg/m³
(8.7ppmv)
Carbon Monoxide (CO)

- By-product of incomplete combustion process
- From heavy traffic
- Can bring more CO to the indoor environment if the ambient air is dirty
- Fresh air supply point must be located away from car parks or other traffic sources
- Extremely toxic and can kill if the level is too high as it takes away the oxygen transportation sites in blood
CO Electrochemical Cell
Carbon Dioxide (CO$_2$)

Excellent Class: less than 800 ppmv

Good Class: less than 1000 ppmv
Carbon Dioxide ($\text{CO}_2$)

- A surrogate gas for bio-effluent from the building occupants
- In ambient air, the level is around 400 ppm
- In indoor environment, a level of 1000 ppm has been used as an indicator for ventilation adequacy
- Health impacts:
  - not a toxic gas and no known health impact if the level is not too high. Industrial standards are from 5000 to 30000 ppm
CO2 NDIR Detector
I/O ratio of CO2

Apart from the health issue,

• An indicator of the ventilation condition
• Each person: CO2 exhalation rate: 0.3L/min
• I/O ratio close to 1, implies good ventilation
Nitrogen Dioxide (NO$_2$)

Excellent Class: less than 40 $\mu$g/m$^3$ (21 ppbv)

Good Class: less than 150 $\mu$g/m$^3$ (80 ppbv)
Nitrogen Dioxide (NO$_2$)

- Comes from incomplete combustion process, either indoors or outdoors
- Can be high in kitchen environment or in area close to heavy traffic
- Cannot be removed by traditional filtration systems
- Health impacts:
  - causes irritation to eyes & respiratory system
Ozone \((O_3)\)

Excellent Class: less than 50 \(\mu g/m^3\)
(25 ppbv)

Good Class: less than 120 \(\mu g/m^3\)
(61 ppbv)
Ozone \((O_3)\)

- Can be produced by equipment that utilizes ultra-violet light or high voltage and causes ionization of air.
- Office equipments such as photocopiers, laser printers and ionizers can produce ozone.

\[
O_2 + h\nu \rightarrow 2O + 2O_2 \rightarrow 2O_3
\]
Ozone \((O_3)\)

- Very reactive and not tend to accumulate in the indoor environment
- Can only be found in substantial concentration near the source.

Influence on Health:

- Cause serious damage to lung if inhaled in high concentration
- Irritates the eyes and respiratory tract
Ozone \((O_3)\)

- It can be a very powerful cleaning tool for indoor air pollutants such as smoking.
- Air purifiers or Personal air purifiers (PAP) for de-odorizing.
UV light emitter for checking Ozone meter
Radon \((\text{Rn})\)

Excellent Class: less than 150 Bq/m\(^3\)

Good Class: less than 200 Bq/m\(^3\)
A radioactive gas that has no taste, smell nor color
It is formed when radium (Ra-226) found in soils and rocks, particularly granite. (Ra-226) is the source of gaseous Rn-222 emission.

\[ ^{226}\text{Ra} \rightarrow ^{222}\text{Rn} \rightarrow ^{218}\text{Po} \rightarrow ^{214}\text{Bi} \rightarrow ^{210}\text{Pb} \]
Radon (Rn)

- Comes from soil gas entry and building materials emission
- High radon level when HVAC system is off and when a large amount of granite decoration materials exist
- Health effects:
  - When radon or its decay products are inhaled, some will be deposited in lung and will continue to emit radiation
  - Cause lung cancer in underground miners and it is the second main cause of lung cancer
“Control of Radon Concentration in New Buildings” to set out:

- The radon concentration limit for protection of the public health
- Factors to be considered for the design of new ventilation systems and building and mitigation measures
- The measurement protocols.
Respirable Suspended Particulate (RSP)

Excellent Class: less than 20 $\mu g/m^3$

Good Class: less than 180 $\mu g/m^3$
**Respirable Suspended Particulate (RSP)**

- In the form of PM$_{10}$
- Can be treated by a good air filtration system but part of it will still get into the indoor environment
- Both organic and inorganic matters can be attached on it. Health effect is complicated.
- High RSP level in smoking zone where Environmental Tobacco Smoke (ETS) exists
- Use of standalone air cleaning devices
Respirable Suspended Particulate (RSP)

- Combustion particulates (tobacco smoke, emissions from cooking, heating appliances, and incense burning)
- Animal particulates (pollen and insect parts)
- Microbial particulates (bacteria, virus, mould and spores)
- Mineral particulates (asbestos)
- Radioactive particulates
Respirable Suspended Particulate (RSP)

- Health impacts:
  - smoke particles from combustion cause respiratory irritation and infection
  - itching and irritation to the skin, eyes, nasal & upper respiratory system
  - aggravation of existing respiratory or cardiovascular disease
  - lung cancer
Airborne Bacteria and Fungi

Excellent Class: less than 500 cfu/m$^3$

Good Class: less than 1000 cfu/m$^3$
Airborne Bacteria and Fungi

Definition of Bioaerosol

Bioaerosols are airborne particles, large molecules or volatile compounds that are living, containing living organism or are released from a living organism.

Definition quoted from the ACGIH guidebook for the assessment of bioaerosol in the indoor environment
Airborne Bacteria and Fungi

- The size of bioaerosol particles may vary from 0.01 micron to 100 micron

- Similar to ordinary non-viable particle, the behavior of bioaerosols are governed by the principles of gravitation, electromagnetism, turbulence and diffusion
Microbes
They are minute particles of living matter which occur in three main forms generally known as

- Viruses
- Bacteria
- Fungi
Airborne Bacteria and Fungi

Size Comparison

In this diagram, approximately 100,000 of these virions fit within the 100 micron circle representing the pollen.
Bacteria

- High counts of environmental bacterial such as Staphylococcus epidermis, Micrococcus, and Flavobacterium shed from skin flakes indicate inadequate poor ventilation.
- The presence of bacteria in indoor environment does not necessarily imply that human infections.
- Legionella pneumophila, Mycobacterium tuberculosis, and Corynebacterium diphtheria are of IAQ concern.
- Outbreaks of Legionnaires’ disease in the past occurred in buildings that had air-conditioning systems with cooling towers or evaporative condensers.
- Endotoxin present in outer cell wall of gram-negative bacteria is associated with sick building syndrome.
Fungi

- Fungal growth favored by high temperature and high humidity
- Most fungi can induce allergic and asthmatic reactions in human
- Proliferation of fungi can produce VOCs that contributes to mouldy smell
- The VOCs are thought to contribute to SBS
- Examples of toxigenic fungi: Stachybotrys atra, toxigenic Aspergillus, Penicillum aurantiogrisem, Cryptococcus and Histoplasma.
Airborne Bacteria and Fungi

- Problem with poor HVAC system and carpet environment
- Damp environment and still air favor the growth of micro-organisms
- Health impact:
  - health effect is complicated
  - some bacteria can be fatal and some cause allergic effect
Calibration Certificate

Certificate No.: 42532
Page 1 of 1 Pages

Customer: Hong Kong Calibration L.L.C.
Address: 13 Wing Cheuk Ho St., Fo Tan, Sha Tin, N.T.

Certificate No.: 42532
Date of receipt: 27-May-94

Item: Teflon

Description: Viable (Microbial) Particle Sizing Samplers
Manufacturer: Ancare
Model: 1941
Serial No.: 166-040

Test Conditions:
Date of Test: 12-Jan-94
Supply Voltage: (220 ± 10) V, 50 Hz
Ambient Temperature: (22.6 ± 0.8°C)

Test Specifications:
Calibration check according to customer's requirement.
Calibration procedure: V1H

Test Details:
The Flow Rate of U.F.T. = 26.3 l/min

Test Equipment Used:

<table>
<thead>
<tr>
<th>Component</th>
<th>Code No.</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>ST16</td>
<td>54DD-11</td>
<td></td>
</tr>
<tr>
<td>ST19</td>
<td>54DD-11</td>
<td></td>
</tr>
</tbody>
</table>

Date: 27-May-94
