An introduction to Indoor Air Quality (IAQ)

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ASHRAE STD 62.1-2013 Ventilation For Acceptable For Indoor Air Quality

Ventilation is the key to Sustainable IAQ and ASHRAE Standard 62.1 is the most widely used Standard by most Local Authorities and HVAC Engineers in the world.

Minimum IAQ Performance
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.
• The physical and chemical nature of indoor air, as delivered to the breathing zone of building occupants, which produces a complete state of mental, physical and social well-being of the occupants, and not merely the absence of disease or infirmity.

• In commercial buildings, indoor air quality arise when there is insufficient quantity of ventilation air being provided for the amount of air contaminants present in the conditioned space.
Indoor Air Quality

• Good IAQ leads to more productive and happier occupants

• IAQ problems can be costly
  - lost work time
  - lost of use of buildings
  - expensive building/mechanical system repairs
  - legal cost
  - bad publicity
Microbes accounted for nearly $\frac{1}{2}$ of IAQ contamination in a 13-year study:

-Healthy Buildings International (953 Buildings with 147 Million Square Feet)
Indoor Air Pollutants

- Surfaces painted with volatile organic compounds (VOC) paints.

For this kind of product: VOC levels (in g/L) should not exceed:

<table>
<thead>
<tr>
<th>Product</th>
<th>VOC Limit (g/L)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flat Topcoat</td>
<td>50</td>
</tr>
<tr>
<td>Non-Flat Topcoat</td>
<td>100</td>
</tr>
<tr>
<td>Primer or Undercoat</td>
<td>100</td>
</tr>
<tr>
<td>Floor Paint</td>
<td>100</td>
</tr>
<tr>
<td>Anti Corrosive Coating</td>
<td>250</td>
</tr>
<tr>
<td>Reflective Wall Coating</td>
<td>50</td>
</tr>
<tr>
<td>Reflective Roof Coating</td>
<td>100</td>
</tr>
</tbody>
</table>

- Only low VOC carpets and flooring will be used throughout the building.

Green Seal environmental standard:
Factors that increase our exposure to indoor air pollutants

Reduced ventilation rates to conserve energy

• The use of synthetic building materials and furnishings

• The use of chemically formulated personal care products, pesticides, printing inks, and household cleaners.
## Pollutant Sources

### Indoor sources
- Combustion sources
- Building materials and furnishings
- Asbestos-containing insulation
- Household cleaning products
- HVAC systems
- Occupants and activities

### Outdoor sources
- Radon
- Pesticides
- Outdoor air pollution
Sick Building Syndrome

• Illness that occur among occupants as a result of poor indoor environmental quality

• Sometimes used to describe cases in which building occupants experience acute health and comfort effects that are apparently linked to the time they spend in buildings, but in which no specific illness or cause can be identified

• Contributing factors:
  - Insufficient ventilation
  - Low lighting levels and/or flickering light fittings
  - Excessive odours
  - High ambient noise levels
  - Lack of local controls and other factors
Sick Building Syndrome (SBS)

- Symptoms associated with acute discomfort:
  - Headaches, Burning eyes
  - Wheezing, skin rashes
  - Upper respiratory problems
  - Nausea, Fatigue, lung irritation
  - Blurred vision, eye strain
  - Others

- Causes not easily recognizable

- Usually the symptoms disappear when the affected person leaves the ‘mal-functioning’ building and are of short duration
Pollutants Types

Sick building syndrome (SBS)

• Typically inadequate ventilation may be due to insufficient supplies of fresh air, excessive recirculation of air, poorly maintained air handling units (i.e. filters not replace when needed) or a poorly designed and / or installed ductwork system.

• Low light levels are the result of light fittings not being replaced, the wrong type of fitting being used, poor lighting controls and / or insufficient numbers of light fittings being installed. Poor levels of daylighting can have the same effect.
SICK BUILDING SYNDROME

Sick building syndrome (SBS)

• Excessive odours may be due to a poorly designed/installed kitchen ventilation system and inadequate ventilation rates.

• High noise levels may be present due to the proximity of a space to and adjacent busy road and / or a plant room, insufficient sound insulation and lack of sound absorption materials used on wall and ceiling surfaces. No local controls may be available for an occupant not adjacent to an openable window or window or an adjustable thermostat (in many cases local thermostats may be disabled to prevent excessive adjustment by occupants).
SICK BUILDING SYNDROME

External (outdoor) air pollution

• Poor outdoor air quality will have significant impact on indoor air quality. External pollutants include vehicle exhausts, discharges from combustion appliances, industrial process and power station exhausts.

• Fungal spores and pollen from vegetation may also cause air quality problems. Vehicle exhausts include CO, CO$_2$, NO$_x$ and SO$_2$, particulates (especially from diesel engines) and VOCs (e.g. from petrol and oil).
Motorists passed a highway toll gate covered by thick haze in Kuala Lumpur, Malaysia, Thursday, Aug. 11, 2005. The ominous haze that has shrouded parts of Southeast Asia this month is just one visible element of a much larger problem that is choking hundreds of thousands to death every year across the region, the World Health Organization said. (AP Photo/Andy Wong)
Pollutants Types

**External (outdoor) air pollution**

- Ozone is generated by the action of sunlight on nitrous oxides (present in vehicle exhausts).
- Power station release the same pollutants to vehicles, but are usually located in rural or semi-rural areas, so the impact of their pollutants is much reduced.
- In urban areas, traffic is a significant contributor to external pollution, with additional pollutant emissions coming from building exhausts and industrial processes.
• **Building-Related Illness (BRI)** is a term referring to illness brought on by exposure to the building air, where symptoms of diagnosable illness are identified and can be directly attributed to environmental agents in the air.
Building Related Illness (BRI)

- Diseases:
  - Legionnaire’s disease
  - Hypersensitive pneumonitis
  - Allergic rhinitis
  - Humidifier fever
  - Asthma
  - Mycotoxin intoxication
  - Endotoxin intoxication

- Needs immediate attention

- Characterized by clinical signs

- Much more serious than SBS: prolonged recovery time
What is a Legionnaires’ Disease?

- Respiratory disease
- Bacteria – Legionella pneumophilia
- Found in any aquatic environment, outbreaks have been traced to water systems including domestic water system (tanks, showers), Cooling towers, humidiers, evaporative condensers, whirlpool/spas, decorative fountains, fire sprinklers systems.
What is a Legionnaires’ Disease?

- **Legionella pneumophila** became a recognised public health concern in 1976 after 34 people died and 221 people became ill following the Legionnaires’ convention in Philadelphia, US.

- Legionella also causes Pontiac fever

- Documented cases of Legionella traveling hundreds of feet.
<table>
<thead>
<tr>
<th>Year</th>
<th>Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>1999</td>
<td>Flower show in Netherlands</td>
</tr>
<tr>
<td>2000</td>
<td>Aquarium opening in Melbourne, Australia</td>
</tr>
<tr>
<td>2001</td>
<td>Communities of Murcia, Spain</td>
</tr>
<tr>
<td>2002</td>
<td>Barrow-in-Furness, England</td>
</tr>
<tr>
<td>2003</td>
<td>Hereford, England</td>
</tr>
<tr>
<td>2004</td>
<td>Pas-de-Calais, France</td>
</tr>
</tbody>
</table>
• **Sept. 2012** – Montreal: A Legionnaire’s disease outbreak in Quebec City has killed 10 people since late July, health authorities in the French speaking Canadian city said. A total of 165 people have so far been diagnosed with the disease. Health authorities suspect improper maintenance of air conditioning systems are at fault for the outbreak – AFP

• Source: The Sun,
Sign and Symptoms of Legionnaires’ Disease

- Usually begins with a headache, pain in the muscles and a general feeling un-wellness.
- High fever (up to 40°-40.5 deg C or about 104-105 deg.F) and shaking chills.
- Nausea, vomiting and diarrhea may occur
- Dry cough with muscle aches may occur
- 5 -15% of known cases have been fatal
Water Cooled Chiller System

- Airside Loop (AHU & Air Duct)
- Chilled Water Loop (CHWP, Piping & Cooling Coil)
- Refrigeration Loop (Water-cooled Chiller)
- Condenser Water Loop (CWP, Piping & Cooling Tower)
Counter-flow Tower

Cross-flow Tower
Water Chiller and Cooling Tower

- Cooling tower
- Pump
- Control valve
- Bypass pipe
- Water-cooled condenser
Legionnaire Disease

Dissemination from a cooling tower by drift and exposure to the contaminated water
Locate OA intakes

Example:
Drift from cooling tower with clean-looking, treated basin causes Legionnaires’ Disease in 3 workers from neighboring building (~330 ft)

Photos copyright Janet Stout, Special Pathogens Laboratory
**Objective of Water Treatment**

- Minimize microbial growth.
- Minimize scale and corrosion.
- Minimize sediment / deposition of solids (organic or inorganic) on heat transfer surfaces.

**Effective water treatment program allows:**

- More efficient operation due to lower fouling
- Longer system life due to decreased corrosion
- Safer operation of the system due to the reduced chances of microbial exposure to the public.
Reduced Air Flow

Scale and trash will reduce air flow.
## How to Prevent Legionnaires’ Disease?

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>a)</td>
<td><strong>Good engineering practices in the operation and maintenance of the system.</strong></td>
</tr>
<tr>
<td></td>
<td>- Cooling towers should be inspected and thoroughly cleaned at least once a year.</td>
</tr>
<tr>
<td>b)</td>
<td><strong>Corroded parts, such as drift eliminators should be replaced.</strong></td>
</tr>
<tr>
<td>c)</td>
<td><strong>Algae and accumulated scale should be removed.</strong></td>
</tr>
<tr>
<td>d)</td>
<td><strong>Cooling towers water should be treated constantly.</strong></td>
</tr>
</tbody>
</table>
Factors affecting comfort and Indoor Air Quality (IAQ)

• Space Temperature
• Relative Humidity
• Air Velocity
• Noise and Acoustic Level
• Ventilation - Supply of Acceptable Air & removal of Unacceptable Air
• Lack of Maintenance of ACMV ( HVAC ) system ( eg. Filters not cleaned or replace regularly )
What are the IAQ Problems in Buildings?

- IAQ during design and construction
- Lack of Commissioning
- Moisture in Building Assemblies
- Poor Outdoor Air Quality
- Moisture and Dirt in Ventilation
- Indoor Contaminant Sources
- Contaminants from Indoor Equipment and Activities
- Inadequate Ventilation Rates
- Ineffective Filtration and Air Cleaning
Minimum IAQ Performance

*EQ1: Minimum IAQ Performance

- Meet the minimum requirements of ventilation rate in ASHRAE Standard 62.1:2007 or the local building code whichever is the more stringent.
Outdoor Air-Ventilation Rates should comply with Third Schedule (By Law 41) Article 12 (1) of Uniform Building By Laws, 1984 (UBBL)
### 11. Room, window, etc., air-conditioning units.

When rooms, windows, or walls air-conditioning units are provided as means of air-conditioning, such units shall be capable of continuously introducing fresh air.

### 12. Fresh air changes.

1. The minimum scale of fresh air ventilation in conjunction with recirculated, filtered, and conditioned air meeting the requirements of ASHRAE STANDARD 62-73 shall be as follows:

<table>
<thead>
<tr>
<th>Type</th>
<th>Minimum Requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Residential building</td>
<td>0.14 cfm per occupant</td>
</tr>
<tr>
<td>Commercial premises</td>
<td>0.14 cfm per occupant</td>
</tr>
<tr>
<td>Factory and Workshop</td>
<td>0.21 cfm per occupant</td>
</tr>
<tr>
<td>School classroom</td>
<td>0.14 cfm per occupant</td>
</tr>
<tr>
<td>Projection room</td>
<td>0.14 cfm per occupant</td>
</tr>
<tr>
<td>Theatre and Auditorium</td>
<td>0.14 cfm per seat</td>
</tr>
<tr>
<td>Canopy</td>
<td>0.28 cfm per occupant</td>
</tr>
<tr>
<td>Building of Public Resort</td>
<td>0.28 cfm per occupant</td>
</tr>
<tr>
<td>Office</td>
<td>0.14 cfm per occupant</td>
</tr>
<tr>
<td>Conference Room</td>
<td>0.28 cfm per occupant</td>
</tr>
<tr>
<td>Hospital wards</td>
<td>0.14 cfm per occupant</td>
</tr>
<tr>
<td>Computer Room</td>
<td>0.14 cfm per occupant</td>
</tr>
<tr>
<td>Hotel rooms</td>
<td>0.14 cfm per occupant</td>
</tr>
</tbody>
</table>

2. The minimum scale of fresh air ventilation in conjunction with the mechanical ventilation systems shall be as follows:

| Basement and garages          | Minimum of 6 air changes per hour |
| Commercial premises (excluding Factory and Workshop) | 0.28 cfm per occupant |
| Factory and Workshop (the design shall be based on the actual requirements) | 0.56 cfm per occupant |
| Project rooms                 | 10 air changes per hour |
| Theatre and Auditorium       | 0.28 cfm per occupant |
| Kitchen                       | 20 air changes per hour |

Note — that all other areas shall meet the minimum requirements of the ASHRAE STANDARD 62-73.
8. Air Conditioning and Mechanical Ventilation (ACMV) System

**Indoor Design Condition**
- Recommended Design DB Temperature: 23 - 26°C (73.4 – 78.8°F)
- Minimum DB Temperature: 22°C
- Recommended Design RH: 55% - 70%
- Recommended Air Movement: 0.15 m/s – 0.50 m/s
- Maximum Air Movement: 0.7 m/s

**Outdoor Design Conditions**
- Recommended Outdoor Design Conditions DB / WB: 33.3°C / 27.2°C
  ( 92°F/ 81°F )
Industry Code of Practice on Indoor Air Quality 2010
DOSH Malaysia* Ministry of Human Resources
Table 1: List of Indoor Air Contaminants and the Maximum Limits
### Acceptable Range for Specific Physical Parameters – 2010

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Acceptable range</th>
</tr>
</thead>
<tbody>
<tr>
<td>(a) Air temperature</td>
<td>23.0 – 26.0 °C</td>
</tr>
<tr>
<td>(b) Relative humidity</td>
<td>40 – 70%</td>
</tr>
<tr>
<td>(c) Air movement</td>
<td>0.15 – 0.50</td>
</tr>
</tbody>
</table>
### List of Indoor Air Contaminants and acceptable limits

<table>
<thead>
<tr>
<th>Indoor Air Contaminants</th>
<th>Eight-hours time-weighted average airborne concentration</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>ppm</td>
</tr>
<tr>
<td><strong>Chemical contaminants</strong></td>
<td></td>
</tr>
<tr>
<td>(a) Carbon dioxide</td>
<td>C1000</td>
</tr>
<tr>
<td>(b) Carbon monoxide</td>
<td>10</td>
</tr>
<tr>
<td>(c) Formaldehyde</td>
<td>0.1</td>
</tr>
<tr>
<td>(d) Ozone</td>
<td>0.05</td>
</tr>
<tr>
<td>(e) Respirable particulates</td>
<td>-</td>
</tr>
<tr>
<td>(f) Total volatile organic compounds (TVOC)</td>
<td>3</td>
</tr>
<tr>
<td><strong>Biological contaminants</strong></td>
<td></td>
</tr>
<tr>
<td>(a) Total bacterial counts</td>
<td>-</td>
</tr>
<tr>
<td>(b) Total fungal counts</td>
<td>-</td>
</tr>
</tbody>
</table>
CO2 Monitoring and Demand Control Ventilation

Selecting CO2 Criteria for Outdoor Air Monitoring

By Thomas M. Lawrence, Ph.D., P.E., Member ASHRAE

ASHRAE Journal  
ashrae.org  
December 2008
The effect of CO$_2$ on man

- **Main alarm**
  - 8.0%: Convulsions, immediate paralysis and death

- **Pre alarm**
  - 3.0%: Muscular pain, unconsciousness, convulsions and risk of death
  - 1.50%: Shortness of breath and increased heart frequency
  - 0.50%: Hygienic limit value
  - 0.10%: Recommended indoor limit value
  - 0.04%: Fresh air

Convulsions, immediate paralysis and death
Convulsions, immediate paralysis and death
Muscular pain, unconsciousness, convulsions and risk of death
Muscular pain, unconsciousness, convulsions and risk of death
Shortness of breath and increased heart frequency
Shortness of breath and increased heart frequency
Hygienic limit value
Hygienic limit value
Recommended indoor limit value
Recommended indoor limit value
Fresh air
Fresh air
Carbon Dioxide and DCV

- Humans are the main indoor source of CO2.
- Indoor carbon dioxide concentrations can be used to indicate specific and limited aspects of indoor air quality but are not an overall indicator of the quality of indoor air.
- Demand Control Ventilation adjusts ventilation air based on the number of occupants and the ventilation demands that the occupants create.
Typical Installation – AHU Room

- Return Air
- Supply Air
- Fresh Air
- Fresh air damper
- CO2 sensor
- Damper Actuator

AHU Room

AHU

Fresh Air

AHU

Fresh air damper

CO2 sensor
7.) Air Purification Systems

1.) Germicidal UV Lights (UVGI)
2.) Magnetized Air Media Filtration
3.) Cold Plasma Bi-Polar Ionization
4.) Photo-Catalytic Oxidation
5.) Electrostatic Precipitation, EAC (Electronic Air Cleaners)
3b.) Air Cooled Split Units

- Fan Coil Unit
- Warm air (recirculating)
- Cool air
- Outdoor air
- Condensing Unit
Air Cooled Split Units (ACSUs)

Both indoor and outdoor units are housed in robust casings. The outdoor unit is basically the same construction for all the various types of indoor units. The difference lies in the type of indoor unit.

- **Wall Mounted**
- **Floor Standing**
- **Cassette**
- **Ceiling Exposed**
Air Cooled Split Units

Many Business Establishments are housed in Small Premises using ACSUs.
ACSUs Application

Shop Office
ACSUs: Fresh Air Intake?

The wall mounted, floor standing and under ceiling split system has no provision for intake of outdoor air and/or exhaust of stale room air.

Room air is just filtered and re-circulated.
THANK YOU

I. Ng Yong Kong (email: nyk@nyk.com.my) and others.

18th September 2014