

PETRONAS TECHNICAL STANDARDS
HEALTH, SAFETY AND ENVIRONMENT

INDOOR AIR QUALITY ASSESSMENT
(GUIDELINE)

PTS 60.1508

SEPTEMBER 2007



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AMENDMENTS RECORD SHEET

Chap No.	Sect No.	Description	Issue No.	Date	Rev No.	Date	App by: (initial)
All	All	New - PTS 60.1508 Indoor Air Quality Assessment	1	Sept 2007	0	0	IGA

Chap No.	Sect No.	Description	Issue No.	Date	Rev No.	Date	App by: (initial)

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1. BACKGROUND

This PTS on "Indoor Air Quality Assessment" has been developed to assist PETRONAS OPU/JV in the development, implementation and management of an effective Indoor Air Quality program. It sets guidance on how to conduct an Indoor Air Quality (IAQ) assessment with reference to industry standards.

The concern over the IAQ has increases in the last few years as a result of growing scientific evidence, that indicated the air within homes and other buildings can be more seriously polluted than the outdoor air in even the largest and most industrialized cities. The major contributor to the IAQ issues was the introduction of centralized heating, ventilating, and air-conditioning (HVAC) systems that require sophisticated maintenance and more energy-efficient building envelopes, including sealed windows. The furnishing, finishes, and other materials used in buildings contribute to the internal load of air contaminants. As a result of energy and cost minimization, many buildings are under-ventilated, thus chemical emissions are not easily dissipated or removed from the indoors. Additionally, the fact that more people work indoors than in the past, and many spend 90% of their time indoors, contributes to the increase number of IAQ complaints.

In Malaysia, the Department of Occupational Safety and Health (DOSH) has established a Code of Practice (COP) on IAQ in July 2005 with the purpose to serve as a guideline to employers in managing the IAQ issues in their non-industrial indoor work areas. This COP establishes a set of maximum exposure limits for five commonly encountered indoor contaminants (i.e. formaldehyde, total volatile organic compounds, carbon dioxide, carbon monoxide and respirable particulates), and describes a mechanism to assess and control these contaminants. Other international standards and guidelines may also be the main references for IAQ management, especially ones established by the American Industrial Hygiene Association (AIHA), American Conference of Governmental Industrial Hygienists (ACGIH), National Institute for Occupational Safety and Health (NIOSH), U.S. Environmental Protection Agency (EPA), American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE) and the British Occupational Hygiene Society (BOHS).

2. INTRODUCTION TO IAQ

2.1 *Factors contributing to IAQ*

A shift in the way modern commercial buildings are constructed has a significant impact on the indoor air quality (IAQ) and subsequently the health and comfort of occupants. The major contributor to the IAQ issues was the introduction of centralized heating, ventilating, and air-conditioning (HVAC) systems that require sophisticated maintenance and more energy-efficient building envelopes, including sealed windows. The furnishing, finishes, and other materials used in buildings (e.g. carpeting, paints, workstations, furniture, personal products, pesticides, cleaning agents and deodorizers) contribute to the internal load of air contaminants. As a result of energy and cost minimization, many buildings are under-ventilated, thus chemical emissions are not easily dissipated or removed from the indoors¹.

Furthermore, some buildings have a poor smoking policy or facility that can lead to the distribution of certain contaminants from the cigarettes, especially the environmental tobacco smoke (ETS), within the indoor environment.

Additionally, the fact that more people work indoors than in the past, and many spend 90% of their time indoors, contributes to the increase number of IAQ complaints. However, it should be noted that other factors like lighting, noise, ergonomics and work-related stress, can be the real cause of such complaints and not the IAQ as predicted¹.

The factors affecting the IAQ can be summarized into four main sources;

1. Chemical contaminants
 - a. e.g. volatile organic compounds (VOCs) from building materials or furnishing, ozone from outdoor air or office machines (e.g. laser printer), particulate matter, combustion sources or ETS
2. Biological factors
 - a. e.g. microbiological growth in ventilation systems, indoor water leaks or from outdoor sources
3. Physical stressors

- a. e.g. temperature and air flow control problems, relative humidity extremes, high noise levels, lighting or glare issues, and ergonomic problems
- 4. Psychosocial factors
 - a. e.g. crowded working conditions, office politics, personal health or work-related stress

2.2 Health effects of IAQ issues

The terms usually associated with IAQ health effects are Sick Building Syndrome (SBS), Building-Related Illness (BRI) and Mass Psychogenic Illness (MPI).

SBS, also known as tight building syndrome, is a set of symptoms affecting a sizeable percentage (usually more than 20% of building occupants) for which no causation can be identified. Symptoms characteristics of SBS seem to be related to mucosal irritation (eyes, nose or throat) or neurotoxicity (headache, lethargy, difficulty in concentrating) and are relieved shortly after leaving the building¹.

BRI, in contrast to SBS, is an IAQ problem with a well-known etiology. BRI is characterized by a distinguishable set of symptoms, often accompanied by physical signs and clinical abnormalities, and might affect only a small number of building occupants. BRI can be confirmed a physician's diagnosis of a specific illness resulting from exposure to specific contaminants identified in a building (such as allergic rhinitis, Legionnaire's disease, hypersensitivity pneumonitis, humidifier fever, or Q-fever)¹.

MPI refers to an apparent epidemic of complaints for which the probable source is social/psychological rather than toxicological. Symptoms might include headache, fatigue, nausea, hyperventilation, and fainting. MPI is characterized by a sudden onset of symptoms, frequently coinciding with an unusual odor, and seems to spread by contact like a contagious disease¹.

3. IAQ STANDARDS

There are a few clear legal standards specifically for typical indoor air contaminants, especially in the U.S. and Canada. In addition to these standards, there are a number of ambient and occupational air quality standards, and consensus standards and guidelines available to assist in interpreting the IAQ assessment results. The assessor may need to refer to these standards or resources to determine the acceptable or “normal” level for indoor air condition (e.g. ventilation) and indoor contaminants (e.g. chemical and biological).

The common references for IAQ standards include:

- i) American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE): ANSI/ASHRAE Standard 62.1-2004: Ventilation for Acceptable Indoor Air Quality
- ii) American Conference of Governmental Industrial Hygienists (ACGIH): Threshold Limit Values (TLVs®)
- iii) American Industrial Hygiene Association (AIHA): Workplace Environmental Exposure Levels (WEELs)
- iv) World Health Organization (WHO): Air Quality Guidelines
- v) American Society of Testing and Materials (ASTM): ASTM Standards on Indoor Air Quality

The Code of Practice (COP) on Indoor Air Quality by the Malaysia’s Department of Occupational Safety and Health (DOSH) has established the maximum exposure limit for five indoor contaminants, which is shown in Table 1.

Table 1: The Maximum Exposure Level of Indoor Air Contaminants

Indoor Air Contaminants	8-hour TWA Concentration Limit	
	ppm	mg/m ³
CO ₂	1000 (C)	
CO	10	
Formaldehyde	0.1	
Respirable particulates		0.15
Total VOCs	3	

C: Ceiling Reference: DOSH Code of Practice on IAQ

Other standards and guidelines are summarized in Table 2. It should be highlighted that the comparison between indoor and outdoor air contaminants level should always be taken into account when evaluating data.

Table 2: Selected Standards and Guidelines for Common Indoor Air Pollutants

Pollutant	Standard (S) or Guideline (G)	Source	Remarks	Common Indoor Levels
CO	9 ppm (S)	EPA	8-hr average outdoor	ND to 4 ppm**
	15 ppm (G)	CPSC	1-hr average indoor	
Formaldehyde	0.04 ppm (G)	Health Canada	8-hr average indoor residential (proposed)	< 0.03 ppm
	0.014 ppm (G)	CA-r	School building materials emission limit	
	0.002 ppm (G)	CA-r	No significant health risk with indefinite exposure	
Nitrogen Dioxide	0.053 ppm (S)	EPA	Annual average outdoor	ND to 0.3ppm**
	0.25 ppm (S)	CA	1-hour average outdoor	
Ozone	0.08 ppm (S)	EPA	8-hr average outdoor	ND to 0.03 ppm
	0.07 ppm (S) (proposed)	CA	8-hr average outdoor	
	0.05 ppm (S)	FDA	Limit on output of indoor medical devices	
Respirable particulates (PM10)	150 µg/m ³ (S)	EPA	24-hr average outdoor	3 to 35 µg/m ³
	50 µg/m ³ (S)	CA	24-hr average outdoor	
Fine particulates (PM2.5)	65 µg/m ³ (S)	EPA	24-hr average outdoor	1 to 25 µg/m ³
	15 µg/m ³ (S)	EPA	Annual average	
	12 µg/m ³ (S)	CA	Annual average	
Radon	4 pCi/L (G)	EPA	Annual average indoor	0.7 to 1.3 pCi/L (homes)
Sulfur Dioxide	0.03 ppm (S)	EPA	Annual average outdoor	**
	0.04 ppm (S)	CA	24-hr average outdoor	
	0.25 ppm (S)	CA	1-hr average outdoor	
Hydrogen Sulfide	0.03 ppm (S)	CA	1-hr average outdoor	-

(Ref: Table 5.2 Reference 1)

ND – none detected using standard sampling methods

EPA – EPA National Ambient Air Quality Standard

CPSC – U.S. Consumer Product Safety Commission

CA – California Ambient Air Quality Standard

CA-r – California Chronic Reference Exposure Level

FDA – U.S. Food and Drug Administration

PM10 – particles with diameters of 10 µm or less

PM2.5 – particles with diameters of 2.5 µm or less

pCi/L – pico-curies/liter

** Depending on fuel sources used indoors, levels are normally less than outdoors, unless significant source exists

The U.S. Environmental Protection Agency (EPA) has carried out a study on typical total VOC concentrations found indoors (normal public and private office buildings). Table 3 summarizes these concentrations. The study should serve as a guideline during the IAQ assessment in terms of determining what is “normal”.

Table 3: Common VOCs Found in Indoor Air (Office)

VOC	Concentration Range (µg/m ³)	VOC	Concentration Range (µg/m ³)
Acetone	7.1 – 220	d-Limonene	0.3 – 140
Toluene	1.6 – 360	Benzene	0.6 – 17
m- & p-Xylenes	0.8 – 96	1,1,1-Trichloroethane	0.6 – 450
n-Undecane	0.6 – 58	Hexanal	0.8 – 12
n-Dodecane	0.5 – 72	2-Butoxyethanol	0.7 – 78
Nonanal	1.2 – 7.9	n-Hexane	0.6 – 21

Ref: Table 5.3 of Reference 1

Microbial sampling results are often interpreted by comparing the microbial types and concentrations that exist outdoors or non-complaint areas, with the types and concentrations found indoors or problem areas. For example, the types of microbial that exist indoors and outdoors should be similar in a building without microbial problems. On the contrary, the dominating presence of a particular microbial indoors and the absence of the same type of microbial outdoors may indicate indoor microbial growth¹.

However, several important factors must be taken into consideration when interpreting the results. It must be noted that there is a natural background of airborne biological agents outdoors and indoors, and that both are highly variable on a daily or even hourly basis. Additionally, poor weather outdoors can limit the concentration found, leading to the false conclusion of amplification indoors. If this condition exists in the assessment areas, it is

advisable to take samples at different weather conditions before any conclusion on the indoor microbial contaminants can be drawn.

Furthermore, the consistent presence of certain fungi, such as *Aspergillus versicolor*, *Stachybotrys chartarum* or various *Penicilium* species at concentrations significantly above background level may indicate that the area has a moisture problem. Again, it is important to compare the samples taken from the problem area with similar samples taken from non-problem or outdoor area².

Comparisons of total bacteria levels indoors versus outdoors may not be as useful as for fungi, since natural bacteria reservoirs exist in both places. Comparisons of the specific types of bacteria present, excluding those of known human origin, can help determine building-related sources². Microbial samples taken from carpet or furniture surfaces (i.e. dust collection) should also be interpreted with great care. Studies have shown that measurements of total culturable fungi exceeding 10^5 cfu/g of dust collected from carpet or furniture surfaces have been correlated with prior water and mold damage⁶.

4. IAQ ASSESSMENT

4.1 Objectives

The aim of the IAQ assessment is to protect the health and comfort of workers against indoor contaminants (e.g. chemical, biological agents) and inappropriate indoor conditions (e.g. temperature, humidity). In order to achieve this, the IAQ assessment is carried out with the following objectives:

1. To measure the level of contaminants exposed to the occupants as well as the environmental conditions
2. To provide a baseline data for future assessment even though with the absence of staff complaints
3. To inspect the Heating, Ventilating and Air-Conditioning (HVAC) systems to evaluate their adequacy in maintaining the appropriate IAQ

Generally, there are two types of IAQ assessment; baseline IAQ assessment and investigation of an IAQ complaint. Although a workplace does not seem to have an IAQ problem or none of the staffs complain about IAQ-related problems, a baseline IAQ assessment is essential to proactively determine the adequacy of IAQ and relevant controls (e.g. HVAC system) at a workplace before it exaggerates to an actual IAQ problem. Like other occupational hazards, this proactive assessment can reduce or even eliminate the risks caused by poor IAQ.

For both types of assessment, a systematic approach is important in order to gain a complete overview of the IAQ issues and ultimately an accurate assessment. A systematic IAQ assessment covers two main stages: the initial assessment which includes historical information review, initial walk-through survey, HVAC system assessment and the second stage which includes the in-depth studies.

4.2 Instrumentation

The instruments commonly used during an IAQ assessment and their recommended measurement range, as well as the acceptable range for each IAQ parameter are listed in Table 4. Figure 1 shows some of the instrument that may be used during an IAQ assessment.

Table 4: Common IAQ Measurement Techniques

Parameter	Instrument	Range of Measurement	Acceptable Range
Temperature	Thermometer Thermocouple	-1° to 49°C	22.8° to 26.1°C (summer) 20° to 23.9°C (winter)
Relative Humidity	Capacitive Detector Psychrometer	0 to 100% RH	30 – 60% RH
Carbon Monoxide	Electro-chemical sensor Colorimetric tube	1 to 50 ppm	0 to 2 ppm above ambient, < 9 ppm avg.
Carbon dioxide	Infrared Detector Colorimetric tube	200 to 4000 ppm	< 700 ppm above the outdoor level
Airflow	Smoke tube Thermal Anemometer Flow hood	Qualitative Only 10 to 2000 fpm 10 to 2000 cfm	20 – 50 fpm (at the occupant level)
Moisture	Moisture meter	5 to 30% (wood) 0 – 100 (comparative scale)	Comparative

Ref: Table 3.1 Reference 1

Figure 1: Examples of IAQ direct reading equipment



Ref: www.wolfsense.com

4.3 Initial Assessment

4.3.1 Historical Information Review

The acquiring of sufficient background information on the building and its occupants is necessary during the initial stage of IAQ assessment. The information needed may include, but not limited to, the following:

- i) building or floor plans and specifications
- ii) prior IAQ studies
- iii) medical documents
- iv) renovation works details
- v) HVAC specifications
- vi) past and present IAQ complaints
- vii) use of chemicals indoor
- viii) surrounding buildings or facilities
- ix) smoking policies of the facility
- x) history of water leak, flooding, or other conditions suggestive of high humidity, dampness and microbial growth

This information can be obtained before the actual visit to the site by discussing the problems by phone or reviewing documents related to the case. Once on-site, further information gathering can be carried out by interviewing selected occupants and individuals familiar with the history of building's constructions, renovation, operation, maintenance of building's systems, and patterns of past and current occupancy. The checklist provided in Appendix A¹ and the Occupants Interview Form in Appendix B are useful in guiding this process. Specifically for baseline IAQ assessment, the Occupants Interview Form should be distributed to a larger group of workers to view the general profile of the IAQ across a company or site, whereas for a complaint investigation, the form can be used to interview the workers who complaint or other relevant people.