Review on Indoor Environmental Quality Parameters Towards Healthier Green Buildings in Malaysia

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Abstract

This paper presents the review of indoor environmental quality parameters in various guidelines and green rating tools namely; Guidelines on Indoor Environmental Quality for Government Office, Guideline for Performance Evaluation and Office Building's Rating, Green Building Index (GBI), Green Real Estate (GreenRE), Green Mark and Building Research Establishment Environment Assessment Method(BREEAM). The review process was done by comparing theparameters existing in these guidelines and green rating tools. Further review has been done on the selected green rating tools across several green policies on indoor environmental quality. Standard references for the parameters isalso identified. Previous studies that have been conducted regarding indoor environmental quality level in several buildings are also been reviewed.With the insights drawn from the comparative review, suggestions on ways to improve indoor environmental quality parameters and assessments are made that may facilitate its implementation. The outcome of the study provides a deep understanding in indoor environment quality parameters and assessments. With the outcome of this study, it may helpsinimprovingassessment in indoor environmental qualitytowards healthier green buildings in Malaysia.

Keywords: assessment parameters, indoor environmental quality, green building, green rating tool, guidelines, sustainability

1.0 Introduction

Malaysian Government is commitedincarrying outsustainable development through decades ofinvolvement in international and regional programs for sustainability. It started when Malaysia attendsthe 1972 United Nation's Stockholm Conference on Human Environment in Sweden (Taib, F., 1997).Then in 1992, Malaysia attended the first Earth Summit held in Rio de Janeiro, Braziland agreed to adopt a program in creating sustainable development known as Agenda21. In 1989, Malaysia hosted the Commonwealth Heads of Government Meeting (CHOGM) whereLangkawi Declaration was drafted. In the declaration, all Commonwealth countries agreed to protect and preserve the environment. Malaysia took part in the UN Framework Convention on Climate Change in 1992 and signedtheKyoto Protocol in 1997. Malaysia has also attended the UN's Climate Change Conference in 2009 known as COP15 in Copenhagen, Denmark and pledgeduponreducing carbon emission up to 40% in terms of emission intensity of gross domestic product (GDP) by 2020 compared with its 2005 levels. The continuous commitment in sustainability is translated into the formation of National Green Technology Policy,emerged in 2009.It was launched by Prime Minister, Dato' Sri MohdNajib bin Abdul Razakas one of the approach that aims to be a driver to accelerate the national economy and promote sustainable development. Financially, the Government allocates RM 3.5 billion through Green Technology Financing Scheme (GTFS) in form of soft loan for local companies to start their business in the green technology industry to increase domestic direct investment (DDI) and research & development in the area of green technology namely; energy, water & waste management, transportation and building sector (National Green Technology Policy, 2009).

Green technology (GT) in the building sectorsets in construction, management, maintenance and demolition of buildings. Three goals have been established;short, mid and long term goals for GT in Malaysia encompassed into three Malaysian Plan; 10th, 11th and 12th respectively. One of key goals for GT in construction sector in 2010 is to establish and apply green rating system based on carbon footprint calculation for township and community. The 10th Malaysia Plan (2011 – 2015) assignson widespreading the availability and recognition of GT products, appliances, equipments and systems in local market. This includes award and recognition for greenbuilding.In achieving this national mission, buildings shall comply with green design features that contribute to energy performance and simultaneously accomplish user comfort (Rashid, Y. R. et al., 2011). This aim is a collective approach from government agencies such as Ministry of Green, Technology and Water,

Standard and Industrial Research Institute of Malaysia (SIRIM), Ministry of Natural Resources & Environment and Ministry of Housing & Local Authority with cooperation from the professional bodies namely Malaysian Institute of Architects and Association of Consultant Engineer Malaysia.Malaysia's first green rating tool, the Green Building Index (GBI) was developed by Malaysian Architect Association and Association of Consulting Engineers Malaysia in 2009. It is a voluntary system to assess and evaluate buildings, range from residential to non-residential, existing to new construction. Green Real Estate (GreenRE) has been developed by Real Estate & Housing Developers' Association in 2013 attempts to form a new set of assessment tool for real estate. Currently, the GreenRE has three components of assessment according to building typesnamely; Existing Non-Residential Building, Non-Residential Building and Residential Building.In line with the Malaysian Plan, the Ministry of Work through Public Work Department (PWD) has produced its sustainable plan towards achieving the goals that focuses on green government building initiatives for new and existing buildings. A master document has been developed namely; Manual for Total Asset Management in the Total Asset Management Policy. The manual consists of a guideline namely; Guideline for Performance Evaluation and Office Building's Rating. The guideline comprehends the Immovable Asset Management System Procedure or *TatacaraPengurusanAsetTakAlih* (TPATA) where it outlines five parameters for the performance evaluation; one of it is sustainability. Corresponding to the guideline, PWD has also developed a rating tool to rate Government's buildings namely;PenarafanHijau- JKR (pH). The tool executed Phase 1 for new construction building in 2012 and currently extend the framework in Phase 2 for existing building.

A number ofgreen rating tools such as UK's BREEAM, USA's LEED and Singapore's Green Mark are precedented before Malaysia established own green rating tools.The Building Research Establishment Environment Assessment Method (BREEAM) is one of the world's leading and most widely used environmental assessment method for buildings. It was launched in the United Kingdom in 1990. The Leadership in Energy and Environmental Design (LEED) was developed in 1998 in the United States (US) and being sponsored by the United State Green Building Council. The GreenMark in Singapore was the first green rating tools in South East Asia country, developed by Building and Construction Authorityin January 2005.

2.0 Background Of The Study

Malaysia ranksin 51of 178 countries in Environment Performance Index (EPI) in 2014 with air quality scores 90.54 points (Athanasoglou, S. et al., 2014). In term of air quality performance, Malaysia ranks among top performance benchmark in the issue. The air quality subject in the index isrepresented byair pollution and household air quality categories. According to the report, the air quality has been included in Environmental Performance Index because of poor air quality contributes to acute lower respiratory infections and other diseases such as cancer which significantly affect the human health. The study in Global Burden of Disease due to Asthma in 2014 estimated 334 million people have asthma and it is the 14th most important disorder in the world (The Global Asthma Report, 2014). In Malaysia it is estimated that about 1.5 million people of all ages suffer from asthma (Lung Foundation of Malaysia Website, 2015). In theWorld Health Organization data published in May 2014 reveals asthma deaths in Malaysia reached 1642 or 1.27% of total deaths and adjusted Death Rate is 8.22 per 100 000 of population ranks Malaysia in 58 in the world (www.worldlifeexpectancy.com).According to The Global Asthma Report (2014), environmental factors are much more likely than genetic factors to have caused the large increase in the numbers of people in the world with asthma. In China, indoor environmental quality is suspected to be at least part of the cause of the increasing prevalence of childhood asthma and allergy (Zhang, M., et al., 2013). In this sense, indoor environmental quality (IEQ) is one of the key criteria in green rating toolsthat need to be studied in order to improve the quality of human health.

Human behavior and daily activities are depend on climatic factor (Trenberth, K. E., et al., 2000). According to Yip, et al.(2004), peoplespend most of their time indoor rather than at the outdoor. It is highly observed in hot and humid climate region such as Malaysia.Most office-basedworkers spend on average eight to ten hours a day indoor at work. They are exposed to various sources of indoor pollutants such as molds and bacteria, cigarette smokes, carbon monoxide from vehicles at nearby road, chemicals released from furnishing materials, chemical fumes from paints and solvents. Depend on building and room location, they are potentially expose to sound pollution from nearby traffic, on-going construction and running machines.Building orientation and building envelope subsequently cause excessive heat and glare received from the sun that may offer discomfort. All of these factors contributes to the disruption of indoor environment that may reduce occupants' efficiency and work productivity. It may also cause headaches and respiratory problems; the symptom known as sick building syndrome.These facts are based on several studies that have been conducted to evaluate level of indoor environmental quality in workplacesand its affect toworker's productivity and their health. According to

Mahbob, N. S., et al. (2011), poor IEQ will not only affected physical health of the building occupants but also psychological health. Workers will be more stressful if their feel uncomfortable with the atmosphere and environment in the office despite of the nature of work itself. Characteristics of buildings and indoor environments significantly influence the occurrence of communicable respiratory illness, allergy and asthma symptoms, sick building symptoms and worker performance (Fisk, W. J., 2000). According to Wargocki, P. et al., (2000) indoor air quality should be maintained at a high level to promote human comfort, health and productivity.

The main objective of the study is to review indoor environmental quality assessment parameters for non-residential buildings especially office-type. The study begins with comparative review of two guidelines developed by Malaysian Public Work Department to identify the parameters within the authority concern. The guidelines are chosen to be reviewed in order to capture overview on IEQ parameters measured in government buildings. Further review has been done in two local green rating tools namely; GBI and Green RE and two international green rating tools namely; Green Mark and BREEAM. Theoutcome of this review is to obtain deep insights on the IEQ parameters for rating purposein local and international perspectives. The previous studies on the level of IEQ parameters in buildings are reviewed to find issues regarding IEQ assessment, parameter and implementation. With the understanding drawn from the comparative review, suggestions on ways of improving IEQ parameters are made.

3.0 Indoor Environmental Quality Assessments

Most of green rating tools worldwide recognize IEQ as one of categories to be assessed. However percentage of scores allocate by these green rating tools are vary.Table 1 below shows the percentage of IEQ category distributed infive green rating tools:

Table 1. Percentage of score allocated for the IEQ category in green rating tools

Green rating tool	Score percentage of IEQ category	Manner of score calculation
Malaysia's GBI	21%	Not mandatory
Singapore's GreenMark	17%	Not mandatory
UK's BREEAM	15%	Not mandatory
US's LEED	14%	Not mandatory
Malaysia's GreenRE	5%	Not mandatory

The differences are not only in score marks percentage, the sub-elements covered in the IEQ category in the green rating tools encounter some dissimilarities. Two guidelines and four green rating tools have been compared to review the indoor environmental quality elements and their sub-elements namely; Guidelines on IEQ for Government Office, Guideline for Performance Evaluation and Office Building's Rating, Green Building Index (GBI), Green Real Estate (GreenRE), Green Mark and Building Research Establishment Environment Assessment Method (BREEAM). It is observed that four common elements are exist in all guidelines/rating tools namely; indoor air quality, visual comfort, thermal comfort and acoustic comfort. A few elements only observed in some guidelines/rating tools such as high frequency ballast, house keeping and safety and health.The presence of IEQ elements and sub-elements are compared acrossthese guidelines and green rating tools as shown in Table 2.

From Table 2, it is shown that the guidelines and green rating tools are share common elements, however the sub elements are different. This differences are caused by the factors determine rating methods namely; climate, ecology, construction materials, culture, construction practices, building regulations, infrastructure, historical context, political decisions and geography. For example, due to climatic factor, relative humidity does not comply in UK's BREEAM. The environmental tobacco smoke (ETS) control does not observe in both Government's guidelines due to building regulations of smoking prohibition in all government premises. It is also observed that major differences show in bothGovernment's guidelines despite they have been developed by the same agency. The Guidelines on IEQ For Government Office has been developed comprehensively however at present, the Guideline for Performance Evaluation and Office Buildings's Rating does not cover all elements recognized.

Elements	Sub-elements	Guideline for Performance Evaluation & Office Building's Rating	Guideline on IEQ For Government Office (Edition 1)	GBI	Green RE	Green Mark	BREEAM
Verification	Post Occupancy comfort survey (IAQ)	x	x	√	x	√	x
	Occupancy comfort survey (IAQ)	x	x	√	x	√	x
Safety and Health	Renovation	x	√	x	x	x	x
Housekeeping	Operation & miantenance	x	√	x	x	x	x
	Construction	x	√	x	x	x	x
Indoor Air Quality	Environmental tobacco smoke (ETS) control	x	x	√	x	x	x
	CO Monitoring	x	√	√	x	x	x
	CO2 Monitoring Control	x	√	√	x	x	x
	Radon	x	√	x	x	x	x
	Indoor air quality assessment	x	√	√	x	x	√
	Indoor air pollutants control	x	√	√	√	√	√
	Mould prevention	x	√	√	x	x	x
	Outdoor air performance	x	√	x	x	√	x

Elements	Sub-elements	Guideline for Performance Evaluation & Office Building's Rating	Guideline on IEQ For Government Office (Edition 1)	GBI	Green RE	Green Mark	BREEAM
Acoustic comfort	Reverbaration times	x	x	x	x	√	√
	Sound insulation	x	x	x	x	√	√
	High frequency ballast	x	x	√	√	√	x
	Internal noise levels	√	√	√	√	√	√
Thermal Comfort	Thermal zoning and controls	x	√	x	x	x	√
	Design & controllability of systems	x	x	√	x	√	x
	Air Movement (Ventilation)	√	√	√	x	√	√
	Relative humidity	√	√	x	√	√	x
	Indoor temperature	√	√	x	√	√	x
Visual Comfort	Internal & external lighting levels, zoning & control	x	x	x	x	√	√
	External views	x	√	√	x	x	√
	Daylighting	x	√	√	x	√	√
	Glare	√	√	√	x	√	√
	Illuminance (Artificial lighting)	√	√	√	x	√	√

Table 2. Comparison of presence of elements and sub-elements in indoor environmental quality assessments

According to Todd, J. A. (2002), building environmental systems must reflect national, regional and local differences if they are to be accepted and used.There is no single assessment tool that can be used in every and all circumstances. However, these differences grasp to the principal of the assessment which is the green policy. The comparison of IEQ elements is further reviewed across several green policies in indoor environmental quality.These green policies are adapted from a study by Ahankoob, A., et al (2013). Table 3 below shows the presence of IEQ's green policies in four green rating tools namely; GBI, GreenRE, Green Mark and BREEAM.

Table 3. Comparison of Indoor Environmental Quality's Green Policies in Green Rating Tools

Green Policies	GBI	GreenRE	GreenMark	BREEAM
Indoor air quality development			√	√
Outdoor air delivery monitoring			√	
Low-emitting materials	√	√	√	√
Indoor chemical and pollutant source control	√	√	√	√
Thermal comfort controllability of systems	√		√	
Thermal comfort monitoring			√	
Daylight and views	√		√	√
Thermal comfort	√	√	√	√
Noise level	√	√	√	√
Increased ventilation	√	√	√	√
Construction indoor air quality managementplan				√

The IEQ elements that have been compared in Table 2display identical elements in Green RE and Green Mark.However based on comparison in Table 3, it is found that GreenRE covers least of green policies in IEQ compare to Green Mark but both have similar compliance to green policies in low-emitting materials, indoor chemical and pollutant source control, thermal comfort, noise level and ventilation. While GBI and GreenRE are having major differences in elements of IEQ however they have five similar green policies namely; low emitting materials, indoor chemical pollutant source control, thermal comfort, noise level and increased ventilation. This is occurbecause ofGBI and Green RE are based in the same country, therefore they are subject to mutual green policies.BREEAM on the other hand, covers most of the green policies however three policies are omitted namely outdoor air delivery monitoring, thermal comfort controllability of systems and thermal comfort monitoring.

4.0 Indoor Environmental Quality Parameters Standard References

The environmental factors that inaugurate indoor environmental quality are grouped into four categories: indoor air quality, acoustics comfort, thermal comfort and visual comfort.In the previous studies, several standards have been adoptedas references to analyse IEQ performance such as the Industry Code of Practice on Indoor Air Quality by Department of Occupational, Safety and Health (DOSH) 2010, Guidelines on IEQ For Government Officeand Malaysian Standard (MS) 1525:2014. Table 4 below shows the IEQ elements, parameters and standard references.

Table 4. Indoor environmental quality parameters standard references in Malaysia

IEQ Elements	IEQ Parameters	Standards	References
Indoor Air Quality	Ventilation Performance Indicator: i. CO2 ii. CO iii.Respirable particulates (PM10) iv. Formaldehyde v. TVOC vi. Bacterial counts vi. Fungal counts	 Ceiling limit: 1000 ppm 10 ppm 0.15 mgm-3 0.1ppm 3 ppm 500 cfu/m3 1000 cfu/m3	Industry Code of Practice on Indoor Air Quality-DOSH 2010
Acoustic Comfort	Internal Noise Level	Open plan office: max 45dBA Individual office: max 40dBA	Guidelines on IEQ For Government Office (based on ASHRAE Chapter 47)
Thermal Comfort	Air Temperature	Room Dry Bulb Temperature: 23-26°C; min: 22°C	MS1525:2014
	Air Speed	Air movement: 0.15-0.50 m/s with maximum 0.7 m/s	MS1525:2014

IEQ Elements	IEQ Parameters	Standards	References
	Humidity	Relative humidity: 55-70% Relative humidity: 40-70%	MS1525:2014 Industry Code of Practice on Indoor Air Quality-DOSH 2010
Visual Comfort	Natural Lighting	Illumination level: 300 lux	MS1525:2014
	Artificial Lighting	Illumination level: 300 lux	MS1525:2014

5.0 Previous Study On Indoor Environmental Quality

Several researches on Indoor Environmental Quality level have been conducted in various types of building. From these studies, understanding in IEQ factors andstrategies on improving IEQ level may help to enhance IEQ parameters.

5.1 Indoor air quality

Due to climatic factor, most of office buildings in Malaysia are fitted out with air conditioning. Air-tight spaces are created to maximize cooling efficiency. This may lead to poor indoor air quality because of inadequate ventilation and indoor air pollutants (Industri Code of Practice on Indoor Air Quality, 2010).According to a study by Spengler, J. D. and Chen, Q. (2000), there are three strategies available to control indoor contaminants; source elimination, local source control and dilution of the indoor contaminants by ventilation. Since the first two have their limitations, ventilation becomes very important for achieving an acceptable level of IAQ.Present of sick building syndrome (SBS), building related illnesses (BRI) and Legionnaire's diseaseamong building users can besymptomaticsindicator of poor IAQ level.

5.2 Acoustic comfort

Acoustic comfort in office building is important element that affect productivity. Characteristic of good acoustic is complex and multilayers causing even little modifications in design and work mode resulted poor acoustic performance. A comparison study by Rao et al. (2012) in two Malaysian green buildings has found that acoustical quality even in the green-status buildings are not at par. The study concludes that acoustical quality is easily compromised if building was not carefully design.A study conducted by Din, N. C et al. (2014) compares noise level in three green-status buildings and two conventional buildings found that the background noise level and reverberation time in certain rooms in the green buildings are over acceptable level. It is concluded that green building strategies are not given significant acoustical improvements.A case study by World Global Building Council in a company in Swindon, UK shows that workspace satisfaction has increased 24% after re-arrangement of the office layout been made. Zoning of working area is an approach by improving interior layout where spaces are arranged according to acoustical separation.Green Mark has added provision of communal-private spaces into their assessment in the latest version. Observation oninterior design consideration and furnishing can provide indication of acoustic comfort level during preliminary phase of evaluation.

5.3 Thermal comfort

Thermal comfort affected by several design components such as HVAC system, natural ventilation system, floor and ceiling cooling system, window location and specification, window shades and envelope tightness. In addition, a person's perception of thermal comfort depends on their metabolic rate, clothing, and personal preference. Qahtan et al. (2010) has found that the thermal comfort and air movement in two green buildings in Malaysia are below the MS1525:2007 recommendation.However, relative humidity are satisfied in both buildings.From the studyit is observed that even the green-status buildings could not fully satisfy the IEQ level set by the standard or guideline. Khalil, N. and Husin, H. N., (2009) have investigated thermal comfort, visual comfort and ventilation level in office buildings in Kuala Lumpur by using post occupancy evaluation method. They concludedthat visual comfort, indoor air movement and ventilation are the highest factor in occupants' comfortability. It is suggested that staff to have control on the cooling temperature. It also recommends the buildings to provide ventilation fans and moisture control in order to improve thermal comfort. Therefore, controllability of thermal comfort systemis a criterion need to adopt in IEQ assessment.

5.4 Visual comfort

A study in two green-status buildings in Malaysiaby Qahtan et al. in 2010 has found that lighting is within acceptable range in both buildings however one of the buildings uses 100% natural lighting and cause users less satisfied with brightness and glare. According to Bülow-Hübe (2008) building is to have good IEQ by establish free-glare environments. Khalil, N. et al. (2011) suggests the need of integration between artificial and natural lighting in buildings. Glare and heat are two issues in achieving visual comfort in Malaysian climate, hence the application of devices to control the quantity and quality of sunlight might need to be consider in IEQ assessment.

5.5 Design, operational, maintenance and user factor

According to Fard (2006), physical IEQ factors result mainly from design decisions and building operation procedures.In a research conducted by Ng, B. H. and AkasahZ. A. published in 2013 concludes the maintenance plays an important factor in maintaining the energy-efficient buildings' IEQ performance. They have suggested that building owners, occupants, and people involved at the design stage of the building need to have a healthy communication among them in order to fill the gap between the actual building performance and the intended performance. Post occupancy evaluation is essential in evaluating chemo-physical aspect (such as the indoor environmental quality, indoor air quality and thermal comfort) and users' sensibility & satisfaction (Zakaria&Hamzah, 2007).

6.0 Conclusion And Recommendation

Indoor environmental quality is a very important category in the green rating toolsdue to its direct affect on human health. However, in some green rating tools show relatively small percentage of scoreallocated for IEQ as compare to other categories, suggest that little priority given in the category. Since the IEQ is a public interest which is beyond the willingness of the building industry to manage, therefore the Government should responsible to develop and enforce the IEQ parameters in rating assessment. Furthermore the IEQ category in the green rating tools is not a mandatory category that might cause any building receives green-status by skipping this category. It is recommends that five green policies are integrate in the IEQ assessments in Malaysia namely; indoor air quality development, outdoor air delivery monitoring, thermal comfort controllability of systems, thermal comfort monitoring and construction indoor air quality management plan. In measuring thermal comfort, user's perspective can not be neglected.It is suggested that measurement of IEQ level must be conducted in two areas; physical measurement of environmental factors and user satisfactory level.The user satisfactory level is suggested to be measured by using post occupancy evaluation.

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