Indoor Environmental Quality (IEQ) Assessment in Information Resource Centre (IRC) of Universiti Teknologi PETRONAS (UTP)

by

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Dissertation submitted in partial fulfilment of

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CERTIFICATION OF APPROVAL

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BACHELOR OF ENGINEERING (Hons)

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Approved by,

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(Dr Mohd Faris Bin Khamidi)

UNIVERSITI TEKNOLOGI PETRONAS

TRONOH, PERAK

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CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

NUR ATIAH NABILAH BINTI AB MURAD

ABSTRACT

Green Building is the key component in achieving sustainable development in a country and at the same time it reduces the global warming and climate change effects. Malaysia is not an exception country in moving forward to develop green buildings and encourage the reduction of resource usage and increasing the energy efficiency. In order to achieve that, detail assessment criteria of Green Building Index need to be evaluated for a building to be certified as a green building and one of the important criteria is Indoor Environmental Quality (IEQ). This study is carried out to assess IEQ in Information Resource Centre (IRC) of Universiti Teknologi PETRONAS. The objectives of this study are to (1) To evaluate the occupants' satisfaction in IRC based on Post Occupancy Evaluation, POE (quantitative survey), (2) To identify the current measurement of Indoor Environmental Quality (IEQ) parameters in IRC, (3) To recommend IEQ improvement for IRC based on (2) and compliance to Green Building's IEQ criteria. POE involves questionnaire survey which reflects the satisfaction level of occupants based on solely what they have perceived and experienced while staying in IRC. Field measurement verified the result of the survey based on current measurement of IEQ parameters, which are : Carbon Dioxide (ppm), Relative Humidity (%), Temperature (^{o}C), Lighting (W/m^2) and Noise Level (dB). These IEQ parameters should comply with MS 1525: 2007 "Code Of Practice on Energy Efficiency and Use Of Renewable Energy for Non-Residential Buildings" and Green Building Index. The result from POE has showed temperature with severity index of 41% as the most dissatisfied parameter perceived by the occupants. Meanwhile, temperature and noise do not comply with the recommended range and prescribed value as set by the standards. On the other hand, Post occupancy comfort has met Environmental Quality (EQ 15) of GBI requirement with more than 80% of occupants have expressed satisfaction with the overall comfort in IRC. Recommendations on the improvement of the non-compliance parameters are identified by installing multiple thermostats in large sections area to control indoor temperature as well as installing sound absorber at the air conditioner blower. Improvements of IEQ will lead to the betterment of IRC building's performance in moving forward to be certified as a green building.

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ABBREVIATION

ASHRAE – American Society of Heating, Refrigerating and Air-conditioning Engineers

dB - Decibels

cfm - cubic feet per minute

HVAC - Heating, Ventilation, and Air Conditioning

IAQ –Indoor Air Quality

IEQ – Indoor Environmental Quality

IOM - Institute of Medicine

IRC – Information Resource Centre

ISO - International Standards Organization

IPCC - Intergovernmental Panel on Climate Change

NHMRC - National Health and Medical Research Centre

NIOSH - National Institute for Occupational Safety and Health

UNEP – United Nations Environment Program

OSHA - Occupational Safety and Health Administration

USEPA - United States Environment Protection Agency

UTP – Universiti Teknologi PETRONAS

PM – Particulate Matters

POE – Post OccupancyEvaluation

ppb – parts per billion

ppm – parts per million

SBS - Sick Building Syndrome

VOC - Volatile Organic Compounds

WCED - World Commission on Environment and Development

WHO - World Health Organization

CHAPTER 1

INTRODUCTION

1.1 BACKGROUND OF STUDY

Nowadays, many buildings have been constructed or reconstructed in order to achieve sustainable development as to reduce the effect of global warming and climate change to the occupants. With the aim towards sustainable development, Indoor Environmental Quality is a key component in the evaluation for meeting the concept of green building. Normally in past research, people tend to neglect how important indoor environment quality in a building. Most designers and builders are disconnected from the project after construction, preventing them from the appropriate feedback loop to improve design and construction practices with good indoor environmental quality.

Indoor Environmental Quality (IEQ) simply refers to the quality of environment, overall comfort of a building's interior and the comfort and the health of its occupants. IEQ is closely linked to the environmental issues which are global warming and climate change, providing both influence the indoor environmental quality of a building. The impact of global warming and climate change on indoor environments and thereby on the health of people who live, work, study, or play indoors have received relatively little attention. Buildings that were designed to adapt under the old climatic conditions may not effectively work under the new climatic conditions thus affect the occupants. Institute of Medicine (IOM) found out that health problems are generated and impair the ability of occupants to work and learn with the poor indoor environmental quality, new problems are instigated, existing indoor environmental problems get worse but new opportunities are defined to enhance public health while mitigating or adapting to alteration in indoor environmental quality induced by climate change. As concluded by IOM, indoor environmental quality literally gets affected by climate change, authorize attention and action.

Imbalance of IEQ can contribute to Sick Building Syndrome (SBS) and can initiate a lot of illnesses to the occupants. SBS is a situation in which occupants experience acute health and comforts effects that seem to be linked to time spent in a building, but specific illness or cause are undefined. According to World Health Organization (WHO, 1984), 30% of new and renovated buildings worldwide are linked to the SBS symptoms. This is due to the buildings are inconsistently operated or maintained with its original designs or prescribed operating procedures. Obviously, IEQ deserves more attention for every building before, during and after construction.

According to National Institute for Occupational Safety and Health (NIOSH), indoor environmental is considered as centre of public health too because occupants spend most of their time indoors and they might have health conditions or symptoms from exposures to contaminants in the buildings where they work, and they will feel better when they are not in the building . Based on the prior investigation done by NIOSH, the origin of indoor environmental contaminants is within the building or dragged from outdoor. Variety of contaminants (in gases form and particles) from office machines, cleaning products, construction activities, carpets and furnishings, perfumes, cigarette smoke, water-damaged building materials, microbial growth (fungal/mold and bacterial), insects and outdoor pollutants may give exposure to the occupants.

Good indoor environment should be achieved in order for a building to be sustainable or green. Instead of design or redesign buildings, every component performance in the buildings that leads to the poor indoor environment should be improved. Those components that need to be paid a lot of attentions are indoor air quality, ventilation, thermal comfort, temperature, humidity, wind flow, lighting comfort and noise that will be discussed further in the next chapter.

In this study, assessing the Indoor Environmental Quality of Information Resource Centre (IRC), Universiti Teknologi PETRONAS is the main focus. Being the information resource as well as complements the needs of students, library is one of the important assets at High Institution Level. It is very important to evaluate IEQ in IRC to ensure the staffs and students good performances and health. IRC may have been known as one of the centers of attraction of UTP, but no matter how resplendent its design and interior are, a poorly designed indoor environment can literally affect occupants health, performance and productivity.

1.2 PROBLEM STATEMENT

The quality of indoor environmental should be concerned more by the government and authority in Malaysia. The health effects that come from the poor indoor environment have became serious challenge in both urban and rural areas in Malaysia. Microbial, chemical and building-physical components in indoor environments that have been exposed to the occupants can lead to various health symptoms, ranging from discomfort to clinical disease.

Adherence to make occupants in a building free from any discomfort or clinical disease, IEQ assessment should be done in a building. It is very important to know the current level or measures of IEQ components inside a building, and by that, any improvements in the building systems can be implemented. The measures taken to improve the indoor environment may be excessive and capital intensive, but there is no guarantee that occupants' bad health will completely healed after the improvements have been applied. So, it is better to prevent indoor environment from getting any worse before too late.

In this case study, it is highly appropriate to do IEQ assessment in IRC as it is the centre of information and resource for UTP students. Poor IEQ might lead them to be less productive in doing assignments or study, and so do the staffs in performing their works as well as contribute to bad health. So, by having IEQ assessment, components of IEQ that lead to the poor indoor environment are considered and the measures can be taken into action. Besides that, good IEQ can certify IRC to become one of the green buildings in UTP.

1.3 OBJECTIVE OF STUDY

The objectives of this study are as follows :

1. To evaluate the occupants' satisfaction in IRC based on Post Occupancy Evaluation, POE (quantitative survey).
2. To identify the current measurement of Indoor Environmental Quality (IEQ) parameters in Information Resource Centre (IRC), Universiti Teknologi PETRONAS (UTP).
3. To recommend IEQ improvement for IRC based on (2) and compliance to Green Building's IEQ criteria.

1.4 SCOPE OF STUDY

The study focuses on the Indoor Environmental Quality of Information Centre (IRC), Universiti Teknologi PETRONAS. This study will involve the data collection of occupants' satisfaction in IRC. Besides that, the information regarding occupants' health too will be collected to determine if spending time in IRC can lead to various health symptoms. General questions about the importance of sustainable development and the environmental problems, which are global warming and climate change awareness also will be asked to require information how well those knowledge being perceived by the random occupants. The questionnaires will be distributed to the users (lecturers and students) and IRC staffs, and then will be analyzed. Besides that, field measurement will be conducted too to get the current readings and measurements of the components of IEQ and compared with the IEQ guidelines provided by Green Building Index and MS 1525:2007.

Research and data analysis must be conducted meticulously in order to achieve the objectives of the study. The phase of installing or designing system to improve IEQ in IRC is beyond the scope of the study to be completed within the estimated time. Instead, the data that has been analyzed appropriately can be used to recommend the improvement of IEQ in IRC if there is any dissatisfaction expressed by occupants and IEQ components do not comply with the standards.

1.5 FEASIBILITY OF STUDY

The study is conducted as to represent local satisfaction and comfort of IRC staffs and users (lecturers and students) regarding the current environment inside IRC due to the impact from the surroundings. Besides that, this study too investigates the current measurements of the indoor environmental quality components in IRC. From that, if the results obtained are incompliance with Green Building Index and MS 1525:2007, improvement of mechanical or electrical components can be implemented to ensure they are properly operating and consistently undergoing maintenance such as ventilation systems, air cleaners and lighting source as to improve indoor environment inside IRC and help enhancing the quality of indoor air by controlling the pollutant sources. Thus, the findings of this study are expected to gain staffs and users feedback as well as identify and evaluate the current IRC indoor environment so that further improvement can be done by UTP management. These are very significant to provide satisfaction and comfort for the staffs and users spending their times in IRC in the future and at the same time preventing them from experiencing discomfort and health symptoms.

CHAPTER 2

LITERATURE REVIEW

2.1 GLOBAL WARMING ISSUE

Global warming is an environmental issue that should not be taken lightly by community nowadays. It is now a common term used to describe the rise in average global temperature of the world caused by greenhouse effects and due to this phenomenon, there is an increase in the volume of the water level (Enzinemark, 2010). Human activities such as burning of fossil fuels and deforestation produce greenhouse gases which are the primary cause of the global warming. Without the greenhouse effect, the Earth's mean temperature would be about 33 °C lower.

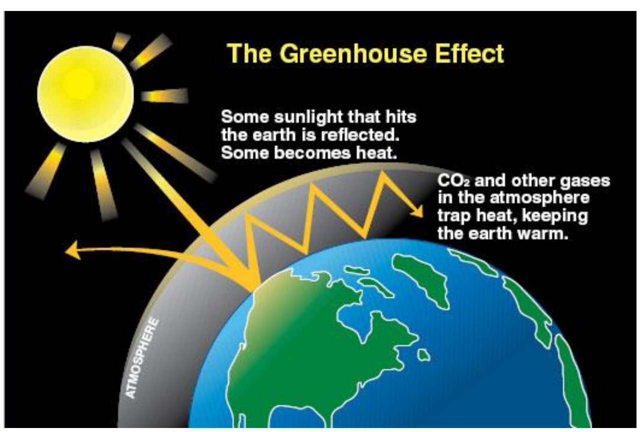


Figure 2.1 : The Greenhouse Effect

(Source : www.globalwarminginmalaysia.blogspot.com, 2011)

Ranging from 0.99 – 3.44 °C per 100 years has shown that there is significant rise of the mean annual temperature and in the past 30 years, global warming in Malaysia kept trending (Wai et al. 2005). The study done by Wai et al. (2005) shows that the mean temperature in Malaysia is expected to rise between 0.6 – 4.5 °C in 2060. Tangang (2007) has asserted that the threats of the global warming should make Malaysians be more prepared as there will be gradual rise in temperature, environment disastrous such as flood, drought and storm and shift in climate patterns.

Awareness of the need energy efficient usage as to maintain Indoor Air Quality has been increased due to the growing concerns of global warming issue. The design, operation and consistent maintenance of heating, ventilation and air conditioning systems are the measures that can be implemented to ensure those systems used in most efficient manner.

2.2 CLIMATE CHANGE

Climate change is another environmental issue that needs to have our eyes on closely. United States Environmental Protection Agency, EPA (2012) states that climate change refers to any significant alteration in the measures of climate, which are the main changes in temperature, precipitation, or wind patterns, and other effects that last over decades period or longer. Intergovernmental Panel on Climate Change, IPCC (2007) has concluded in its Fourth Assessment Report (AR4) that the warming of the climate system is unambiguous and the increment in anthropogenic greenhouse gas concentrations preferably causes the significant observed increase in global mean temperature since the mid 20th century. Different emission scenarios give different rates of greenhouse gases emission into the atmosphere. Drier weather in midcontinent areas, sea level rise, more severe storms, and northward migration of vector borne tropical diseases and climate-sensitive species are the common predicted effects of climate change (IPCC, 1990).

Wyman (2012) states that climate change and global warming are closely related and sometimes the terms are used interchangeably. The rise of global temperatures is referred as global warming while climate change involves other more specific kinds of changes, such as rainfall patterns, storms and droughts, growing seasons, humidity and sea level, and these climate changes are caused by global warming (Wyman, 2012). Different regions around the world experience different specific changes, thus instead of warmer, a few areas might get cooler. Moreover, local plants, animals and people are uniquely affected.

There are two fundamental ways of indoor environmental quality influenced by climate change, which are by direct and indirect response. For direct response, the growth of mold, bacteria and building dampness as result from the frequent or stern hurricanes caused by climate change may increase indoor air quality problems (Chew 2006, Rao 2007, Rabito 2010). Indirect response is defined as concentrations of indoor air contaminants may increase due to the measures taken to reduce the emissions of greenhouse gases. For example, greenhouse gas emissions are reduced by reducing building's intentional ventilation rates or air sealing an enclosure which can reduce accidental infiltration. However, this measure lowers the total ventilation rate of the building thus increase the concentration of some indoor contaminants, and might get worse since this situation can lead to the excessive high indoor humidity levels during cold weather (Brennan, 2010)

2.2.1 Climate Change Mitigation

Climate change mitigation is action to reduce the effects of global warming, permanently eliminate or reduce the long-term risk and hazards to human life and property as a result of climate change. As defined by IPCC, mitigation is an anthropogenic interference to reduce the roots or enhance the sinks of greenhouse gases. For this alleviation action, innovative technologies and a change in lifestyle positively do not come for free at all.

IPCC has given the examples of climate change mitigation which are the efficiency uses of fossil fuels for industrial processes or electricity generation, switching to solar energy or wind power, improving the insulation of buildings, and expanding forests and other sinks to remove greater amounts of carbon dioxide from the atmosphere. Climate neutrality is a path to mitigation which will help to lessen the possible damage. The funded initiatives of climate mitigation too have become part of ‘Rancangan Malaysia Kesembilan’ (RMK9).

There are some opportunities provided for mitigation of climate change in the buildings sector. Globally by 2020, approximately 30% of all buildings-related CO_2 emissions can be avoided at a net benefit. Greatest saving can be achieved by constructing new buildings. Out of the operational costs of standard new buildings, as much as 80% of it can be saved through integrated design principles, and often at no or little extra cost. It is rational to implement hi-efficiency renovation despite it gives out extra cost because it can achieve lots of energy efficiency. Besides that, most of technologies and know-how are widely available as well as net zero energy/emission or even negative energy buildings are dynamically growing (IPCC, 2007).

Clearly, by mitigation, many impacts can be avoided, reduced or delayed. For scenarios in which future atmospheric concentrations of greenhouse gases are stabilized, a small number of impact assessments have been done. Even though these assessments do not consider the incertitude in projected climate under stabilization, they proved that damages are avoided or vulnerabilities and risk reduced for different amounts of emissions reduction.

2.3 SUSTAINABLE DEVELOPMENT

World Commission on Environment and Development (WCED) has developed and incorporated a concept of sustainable development, with the releasing of Brundtland Report in December 1987. It stated that “*Sustainable development is the development that meets the needs of the present without compromising the ability to meet those of future generations*” (Brundtland, 1987). Environment preservation is important in order to ensure the future generations meet their needs. Brundtland (1987) insists that environment and development are inseparable provided environment is where we live and development is the improvement within abode lot.

One of the issues of global concern is campus sustainability. The reference of sustainability in higher education was first made by Stockholm Declaration of 1972 and the interdependency between humanity and the environment has been identified as well as suggesting several ways of achieving environmental sustainability (UNESCO, 1972). Talloires Declaration is the first official statement of a responsibility towards environmental sustainability in teaching, research, operations and outreach at higher institutions with the involvement of 300 universities in over 40 countries (UNESCO, 1990).

Global Higher Education for Sustainability Partnership (GHESP) was initiated by International Association of Universities, the University Leader for a Sustainable Future, Copernicus Campus and United Nations Educational, Scientific and Cultural Organization in order to focus sustainability in higher education. Uniquely, it is an effort to mobilize universities and higher education institutions to encourage sustainable development in response to Chapter 36 of Agenda 21, which was adopted in 1992. Education as the key to boost sustainable development and improves the capacity of the people to voice out environment and development issues are stated in the chapter.

The successful attempt in order to become a sustainable or green campus involve four aspects of the university community which are the administration, academic departments, the university research effort and the local community. Indoor Environmental Quality (IEQ) is one of the driving forces behind this sustainable campus.

2.4 GREEN BUILDINGS

Green building is defined as the environmentally responsible practice of constructing building that uses resource-efficient throughout a building's life cycle from siting to design, construction, operation, maintenance, renovation and deconstruction. Tony Arnel, the Chairman of World Green Building Council states that climate change and sustainable economic development are the challenges that our planet faces and require global solutions. Green buildings is one of the solutions and contribute to environmentally friendly since it can slash greenhouse gases emissions thus reduce the global warming thereby the climate change.

Commonly, green buildings are designed with the objective to reduce the consequences of the built environment on people health and natural environment by using energy, water and other resources efficiently, preserving occupants' health and enhancing employee productivity as well as lessen the waste, pollution and environmental degradation (USEPA, 2009). International research has confirmed that green buildings use less energy, less water thereby produce less waste and a healthy and productive environment are established for occupants. Building's operating cost can be lessen as much as 9%, the building values raised by 7.5% and return investment of 6.6% can be perceived by practicing green building. These show that green buildings not only logical to ecological and environmental sense, but economic too.

2.4.1 Green Building in United States

In United States, the green building movement is initiated from the desire to encourage energy efficiency and environmentally friendly construction practices. United States Green Building Council (USGBC) has developed the Leadership in Energy and Environmental Design (LEED) that provide rating systems for the design, construction and operation of high performance green buildings, homes and residences and have been successfully established in 135 countries. The objective of LEED is to produce knowledgeable building owners and operators on the framework for recognizing and applying practical and measurable green building design, construction, operations and maintenance solutions. According to Inhabitat New York City, the Empire State Building which is the tallest and largest LEED certified building in the US has received a Gold LEED rating in September 2011.

2.4.2 Green Building in Singapore

Singapore Green Building Council (SGBC) is developed to achieve a world-class and sustainable built-environment in Singapore. The main role of SGBC is to encourage green building design, practices and technologies and mobilize environmental sustainability in the building and construction industry. SGBC's certification listed the certified green building products that contribute to the resource-efficient, give consistently better efficiency and lower environmental impacts, provide better indoor environmental quality for a well and prolific workplace in buildings. SGBC has also cooperated with leading organizations such as IBM and Ministry of Education (MOE) to establish "Project Green Insights" as to raise the awareness of energy efficiency in schools.

2.4.3 Green Building in Malaysia

The Green Building Index (GBI) is Malaysia's Industry recognized green rating tool that gives a chance for developers and building owners to design and construct green, sustainable buildings that can establish energy savings, water savings, a healthier indoor environment, better connectivity to public transport and the adoption of recycling and greenery for their projects and lessen the impacts on the environment. Specifically, GBI is established for Malaysian-tropical climate, environmental and development context, cultural and social needs and its objectives are to :

- Establish standard of measurement for buildings to be certified as green buildings.
- Provide better environment for all by encouraging integrated and whole building designs.
- Recognize and reward environmental leadership.
- Reduce the negative environmental impact of the built environment.
- Improve the overall quality of building stock by ensuring new buildings remain relevant in the future and existing buildings are renovated and upgraded.

GBI certification process starts with a certifier appointed by GreenbuildingIndex Sdn. Bhd makes an assessment of the building design. When the constructed building has been examined according to the design, provisional and final certifications are issued. The building is reassessed every three years as to maintain the certification and points will be given for performance above benchmarks and current industry practice. For indoor environmental as one of the assessment criteria, the maximum point allocated is 21 points. IRC should achieve good indoor environment provided with good points from other criteria to certify as green building.

DETAIL ASSESSMENT CRITERIA
SUMMARY OF FINAL SCORE

PART	ITEM	MAXIMUM POINTS	SCORE
1	Energy Efficiency	38	
2	Indoor Environmental Quality	21	
3	Sustainable Site Planning & Management	10	
4	Material & Resources	9	
5	Water Efficiency	12	
6	Innovation	10	
	TOTAL SCORE	100	

Figure 2.2 : Detail Assessment Criteria For Green Building For Non-Residential Existing Building

(Source : GreenbuildingIndex Sdn. Bhd, 2013)

	EQ	INDOOR ENVIRONMENTAL QUALITY		
2	Air Quality			21
	EQ1	Minimum IAQ Performance	1	
	EQ2	Environmental Tobacco Smoke (ETS) Control	1	
	EQ3	Carbon Dioxide Monitoring and Control	1	
	EQ4	Indoor Air Pollutants	2	
	EQ5	Mould Prevention	1	
	Thermal Comfort			
	EQ6	Thermal Comfort: Design & Controllability of Systems	2	
	EQ7	Air Change Effectiveness	1	
	Lighting, Visual & Acoustic Comfort			
	EQ8	Daylighting	2	
	EQ9	Daylight Glare Control	1	
	EQ10	Electric Lighting Levels	1	
	EQ11	High Frequency Ballasts	1	
	EQ12	External Views	2	
	EQ13	Internal Noise Levels	1	
	Verification			
	EQ14	IAQ Before/During Occupancy	2	
	EQ15	Occupancy Comfort Survey: Verification	2	

Figure 2.3: Detail Assessment Criteria for IEQ.

(Source : GreenbuildingIndex Sdn. Bhd, 2013)

GREEN BUILDING INDEX CLASSIFICATION

POINTS	GBI RATING
86 points and above	Platinum
76 to 85 points	Gold
66 to 75 points	Silver
50 to 65 points	Certified

Figure 2.4 : Green Building Index Classification

(Source : GreenbuildingIndex Sdn. Bhd, 2013)

2.5 INDOOR ENVIRONMENTAL QUALITY COMPONENTS

These are the indoor environmental quality components that determine the condition of IEQ in a building and the measures need to be taken into action in order to ensure good IEQ inside a building.

2.5.1 Indoor Air Quality

Indoor Air Quality is now a common term that is closely related to buildings. It refers to the air quality inside and around building and structures, and related to the health and comfort of building occupants. Indoor air is defined by National Health and Medical Research Centre, NHMRC (1992) as air within a building occupied by people of varying states of health for a period of at least one hour. Majority of people are exposed to harmful emission on a daily basis in a building. Approximately people spent 90% of their time indoors. The quality of air comes from the complex interaction of many factors involving the chemistry and motions of the atmosphere, as well as the variety of pollutants from both natural and anthropogenic sources (Isa and Yunus, 2010). Bernheim (1996) stated that the quality of indoor air caused by the linkage of factors such as the outside air, the construction materials, the building envelope, the furnishings and equipment, the ventilation systems and their maintenances, the activities of the occupants, the electric and magnetic fields, and the construction site itself. The author stressed that total indoor air quality is a function of controls including the air source, the activity of occupants, the degree of ventilation and the extent of maintenance to the building.

It has been proven that quality of indoor air potentially many times worse than that of outdoor air, as result from the various researches. Indoor air is often more polluted as much as 25% than outdoor air, and occasionally more than as much as 100 times according to Environmental Protection Agency (EPA). Inhalation through indoor air causes most of individual's exposure to many air pollutants (WHO, 2000). These include harmful contaminants such as Carbon Monoxide (CO), Carbon Dioxide (CO_2), Nitrogen Dioxide (NO_2), Sulfur Dioxide (SO_2), Radon, Particulate Matter (PM_{10}) and Volatile Organic Compounds (VOC) which will be discussed further. This has suggested that indoor air pollution is one of the top five public health risks.

American Society of Heating, Refrigerating and Air-Conditioning Engineers, ASHRAE 62-2001 have defined acceptable indoor air quality 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 a dissatisfaction*" (ASHRAE & American National Standards Institute., 1999; Robert et al., 1999, p.2). In order to achieve design level of acceptability the components must be specified in terms of the percentage of building occupants and/or visitors expressing satisfaction with perceived indoor air quality.

The concern about indoor air has been paid attention since the last of two or three decades among the public societies, which lead more buildings are constructed or renovated to provide better indoor air quality. Building code has been established to provide standards and guidelines for a building to be constructed or alter the building systems as to protect the health of occupants in indoor or enclosed environment.

2.5.1.1 Carbon Monoxide (CO)

Carbon monoxide consists of one dative and two covalent bonds that connecting one carbon atom to one oxygen atom. It is produced when there is not enough oxygen to produce CO_2 such as operating stove, or an internal combustion engine in an enclosed space. It is colourless, odorless and tasteless but highly toxic. This gas gives the usual reason of fatal air poisoning in many countries (Omaye, 2002) and leads to fetus deterioration of a pregnant woman (Susan, 2007). Symptoms of mild poisoning include headaches, nausea, fatigue and dizziness can occur at concentrations less than 100 ppm. Almost 50% of body's hemoglobin can be converted to carboxyhemoglobin at concentrations as low as 667 ppm (Tikuisis et al., 1992) and this can result in seizure, coma and fatality. Occupational Safety and Health Administration (OSHA) limits long-term workplace exposure levels up to 50 ppm in United States.

2.5.1.2 Carbon Dioxide (CO_2)

Carbon dioxide composed of two oxygen atoms covalently bonded to one carbon atom. It exists in Earth's atmosphere as a trace gas at a concentration of 0.039 percent by volume. It contributes to global warming since it is one of the main greenhouse gases. Somehow it is beneficial despite can give big impact to surrounding as it is used in the food, oil, chemical industry (Pierantozzi, 2001) and in many consumer products need pressurized gas since it is inexpensive and non-flammable.

CO_2 can be harmful to human at high concentration, grossly greater than 50,000 ppm. Jaffar (2008) states that the current threshold limits value (TLV) or maximum concentration of CO_2 is 5000 ppm, which is considered safe for healthy adults for an eight-hour working day. Obviously it would be less for infants, children, the elderly and individuals with cardio-pulmonary health issues. Since respiration come from occupants, CO_2 concentration indoors will be higher than that outdoors. More than 20% of occupants will feel discomfort if concentrations of CO_2 beyond 1000 ppm and due to the discomfort, more CO_2 is produced.

Discomfort felt by occupants might get worsen and many will suffer nausea and headaches when concentrations of CO_2 hit 2000 ppm. As indicator of indoor air quality,

CO_2 of concentration between 300 and 2500 ppm is used. Indoor pollutants that make occupants feel sleepy, get headaches or function at lower activity levels are measured using Carbon Dioxide ppm Level (CDPL). Total indoor CDPL must be reduced to less than 600 ppm to get rid of indoor air quality complaints.

CO_2 is commonly used as to indicate the adequacy of ventilation systems in occupied building since it is produced by human respiration. The National Institute of Occupational Safety and Health (NIOSH) suggests beyond 1000 ppm of indoor air concentrations is a benchmark for inadequate ventilation. ASHRAE recommends that CO_2 concentration inside a space should be lower than 1000 ppm. While in the workplace, OSHA limits the CO_2 concentration up to 5000 ppm for prolonged periods (Jaffar, 2008). NIOSH from United State limits brief exposures up to ten minutes is 30000 ppm and "immediately dangerous to life and health" is considered once CDPL hit 40000 ppm. The consequences that might occupant experience when breathing 50000 ppm for more than half an hour is acute hypercania signs and might get unconscious in only a few minutes while breathing 70000 ppm to 100000 ppm of CO_2.

2.5.1.3 Nitrogen Dioxide (NO_2)

Nitrogen dioxide is produced from the combustion of nitrogen and oxygen at high temperature and highly reactive oxidant and corrosive. Its primary sources indoors from unvented combustion appliances such as gas stoves, vented appliances with defective installations (EPA). It is toxic with reddish-brown in colour and has a sharp characteristic, biting odor and significant air pollutant.

NO_2 irritates the mucosa of the eyes, nose, throat and respiratory tract. It may causes lung impairment and increases the respiratory infections in children. No standards have been agreed upon for nitrogen oxides in indoor air. However, ASHRAE and the USEPA National Ambient Air Quality Standards point out 0.053 ppm as the average 24-hour limit for NO_2 in outdoor air.

2.5.1.4 Sulfur Dioxide (SO_2)

Sulfur dioxide is a toxic highly reactive gas with acrid smell and easily dissolved in water. The main sources of SO_2 emissions come from the combustion of fossil fuel at power plants (73%) and other industrial facilities (20%). More than 65% of SO_2 released to the atmosphere, or beyond 13% tons per year comes from electric utilities especially those that burn coal. It presents in all raw materials such as crude oil, coal and ore or from burn coal to produce heat process. For instances, petroleum refineries, metal processing facilities, cement manufacturing, locomotives, large ships and some non-road diesel equipment burn sulfur fuel and large quantities of SO_2 is emitted to the air.

Exposure to high concentrations of this gas in short time can constrict the bronchi and increase mucous flow, thus making hard to breathe. It becomes more toxic when there is presence of acidic pollutants, liquid or solid aerosols and particulates. To protect health, EPA suggests the annual average standard of 30 ppb and 140 ppb for 24-hours.

2.5.1.5 Radon

Radon is radioactive chemical element with symbol Rn and colourless, odorless and tasteless (EPA, 2010). It remains as a gas under normal conditions that only has radioactive isotopes and hazardous to health. It is responsible to the majority of public exposure to ionizing radiation and estimated to cause many thousands of deaths each year.

Radon produced from the natural breakdown of uranium in soil, rock and water and goes into the air that we breathe. In US, radon can be found all over the place include homes, offices and schools, which gives high indoor radon level. EPA states that radon reduction systems are effective and inexpensive. Up to 99% of radon at home can be reduced, and even very high levels can be reduced to acceptable levels.

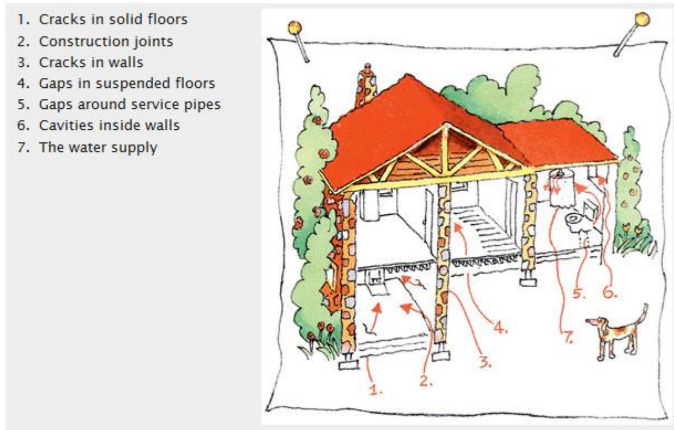


Figure 2.5 : Radon Gets In

(Source : United States Environmental Protection Agency)

2.5.1.6 Particulate Matters (PM_{10})

In the air, there are things that floating and we cannot see most of them. They are particulate matters that give air pollution. They may be classified as primary or secondary, depending on the compounds and processes involved during its formation. Primary PM is emitted at the emissions source in particle form such as construction sites, unpaved roads, fields, smokestacks or fires while secondary PM formed from a series of chemical and physical reactions such as NO_2 and SO_2 that are emitted from power plants, industries and automobiles.

In this study in IRC, only PM_{10} is considered. It stands for particulate matter up to 10 micrometers in size. It is coarser than $PM_{2.5}$ and come from smoke, dirt, dust, farming, roads, mold, spores and pollen. It can give coughing, wheezing, shortness of breath, aggravated asthma, and lung damage.

2.5.1.7 Volatile Organic Compounds (VOCs)

Volatile organic compounds (VOCs) are gases emitted from certain solids or liquids. According to Health Canada, VOCs are classified as organic compounds that have boiling points grossly in the range of 50 to 250 °C (122 to 482 °F). VOCs may come from paints, paint strippers, building materials, furnishings, office equipments (copiers, printers, correction fluids, carbonless copy paper, glue, and permanent markers), wood preservatives, aerosol sprays, cleansers and disinfectants, moth repellents and air fresheners, stored fuels and automotive products, hobby supplies and dry-cleaned clothing. Exposure to VOCs can irritate eye, nose, throat, give headaches, loss of coordination, nausea, deteriorate liver, kidney and central nervous system.

According to United States EPA, concentrations of indoor VOCs are up to ten times higher than outdoors. In homes, studies have found that level of several organics average 2 to 5 times higher indoors than outdoors. The level can be ultimately 1000 times higher background outdoor levels during and several hours instantly after certain activities are done such as paint stripping. Long term exposure to VOCs indoor can lead to Sick Building Syndrome (Wang et al., 2007). Indoors VOCs can be reduced by mean of good ventilation and air-conditioning (Dales et al, 2008)

2.5.2 Ventilation

Ventilation is a process of supplying air to an enclosed space in order to provide high indoor air quality by refreshing, removing or replacing the existing atmosphere. It includes the circulation or air within the building and the demand of clean outdoor air. To put it simpler, ventilation is used to remove contaminant such as fumes, dust or vapor and to provide a healthy and safe working and living environment. Naturally it can be accomplished by opening the windows and doors, or mechanical appliance such as fans or blowers. Usually ventilation was trusted to be the most effective to improve indoor air quality and the higher the ventilation rate, the better the quality of indoor air.

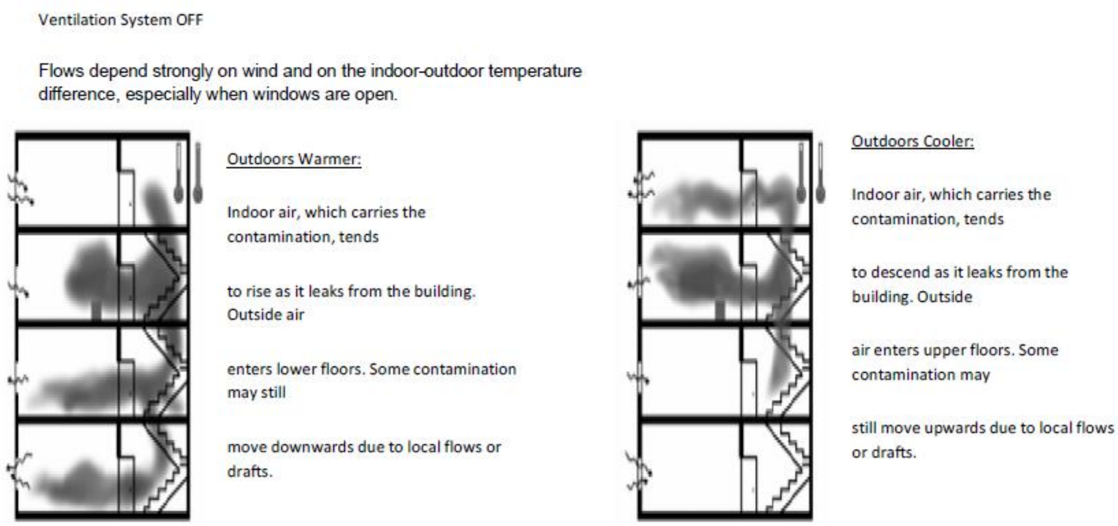


Figure 2.6 : Information For First Respondent For Chemical Release

(Source : Lawrence Berkeley National Laboratory)

However, ventilation in both new and old buildings is frequently inadequate. Typically most of older buildings does not have a mechanical ventilation system or not well-maintained. Fresh air is still not enough to occupy indoor by only entering the means of doors, windows and cracks. Air quality problem is created if new buildings are provided with sealed windows, and only depend solely on mechanical ventilation systems because if the system fails due contamination, air quality may suffer dramatically.

Health risks from unhealthy air are typically originated from low efficiency or inadequate ventilation. Pollution can be accumulated indoors when there is poor indoor ventilation and sometimes hitting higher concentrations than outdoors. In IRC, staffs tend to spend majority of their working time indoors as well as students probably spend such a long time there to study, finding resources, conduct researches and group discussion thus it is important to check ventilation in IRC. The significant task of ventilation is to keep the level of pollutants in buildings at an acceptably low level (ASHRAE, 2000). ASHRAE 62.1-2007 specifies that minimum ventilation rate person in library is 5 cubic feet per minute (cfm) of outdoor air. Usually, adequate outdoor air has a CO_2 concentration of 325 ppm – 375 ppm. Doubling of the outdoor CO_2 level is considered to be an indicator of indoor air quality.

2.5.3 Thermal Comfort

According to International Standards Organization (ISO 7730), thermal comfort refers to condition of people expressing satisfaction with the thermal environment where they live in. Maintaining ASHRAE standard of thermal comfort for occupants of buildings or other enclosures is one of the significant goals of Heating, Ventilation, and Air Conditioning (HVAC) design engineers. Any thermal discomfort can lead to SBS.

Indoor comforts levels are determined by the thermal environments that are considered together with other factors such as air quality, light and noise. Thermal comfort is closely related to the thermal balance of human body. This balance is influenced by two factors which are environmental parameters such as air temperature, air velocity and humidity and personal parameters such as activity level or metabolic rate and clothing thermal resistance. These factors give complexity of evaluating thermal comfort.

Generally, human body has greater sensitivity to temperature, so the thermal sensation is relatively slow compared to the cold sensation (Jaffar, 2008). The sweat won't evaporate if indoor humidity is too high, and it will affect the heat dissipation rate and the skin surface temperature thereby gives discomfort to occupants. Heat transfer in the buildings too affected by indoor air environments.

Thermal parameters should be extensively analyzed since different combination of parameters influence people differently. ASHRAE define the valid Effective Temperature (ET) as the temperature with the same effect as an imaginary sealed environment whose relative humidity is 50%. This index includes radiation, convection and evaporation at the same time, which in turn meets the extensive adoption. Standard Effective Temperature (SET) is another index defining thermal comfort but it could be tedious and unpractical since its analysis needs computer help (Jaffar, 2008).

2.5.4 Humidity

Humidity is simply vaporized water in the air, while relative humidity refers to the percentage of water vapor in the air at specific temperature, compared to the amount of water vapor the air is capable of holding at that temperature. Too high or too low of relative humidity can cause problems to building, occupants' health and comfort. Humidity is the key component that leads to the occupants' satisfaction staying in a building. The rate of perspiration evaporates on human skin is lower under humid conditions compared that in under dry condition. We feel warmer in high humidity compared in low humidity provided having same temperature since humans perceive the rate of heat transfer from the body rather than temperature itself (Scharringhausen, 2002).

In building using the means of HVAC, maintaining the relative humidity at a comfortable range is very important, this is optimum enough to give comfort and avoid problems associated with very dry air. Condensation can occur on furniture when relative humidity approaches 100%, which will cause mold, corrosion, decay and other moisture-related impairment. If humidity is too low, it can causes static electricity, dry skin and hair, itching and chapping. It also can give respiratory illness and cold and increasing the occupants' discomfort.

The relative humidity level for occupied space to be designed is limited to be 65% or less for mechanical systems with dehumidification capability (ASHRAE, 2010). ASHRAE with Standard 62.1 has no humidity limitations for other mechanical system types or where spaces are not served by mechanical systems.

2.5.5 Temperature

Temperature defined as physical quantity that measure hotness and coldness on a numerical scale (Maxwell, 1871).For comfort purpose, the uniformity of temperature is very important. Temperature stratification occurred due to convection, the tendency of light, warm air to rise and heavier, cooler air to sink. Temperature near the ceiling can be several degrees hotter than that floor level if ventilation improperly mixes air. However, discomfort can be created in some climate zone due to the moisture problem generated by uninsulated floors over unheated spaces even if air is properly mixed. Furthermore, even thermostat setting and the measured air temperature are within the comfort range, radiant heat transfer still can cause people located near very hot or very cold surfaces to be uncomfortable.

According to Lawrence Berkeley National Laboratory, it has been found that students performed better in thermally conditioned classrooms than in classrooms without heating or cooling based on the several studies conducted. Too high temperature will give poor indoor environmental quality in a building thus will affect the occupants’ performances.

Experiment has been done in late 1960 where six groups each with six students were brought to a climate-controlled chamber ranging from 62°F to 92°F at Kansas State University to simulate school work. From the result, two performances indicators were affected by temperature, one of them is error rate which was highest at 62°F and lowest (about 20% lower) at 80°F. The other indicator is the time required to complete the assignment that showed students worked most slowly at 80°F, and effective (about 10% faster) at 68°F. Similar studies have been done by David Wyon and colleagues in actual classrooms, and the result showed reading speed, reading comprehension, and multiplication performance of school children to be poorer with temperatures of 81-86°F, compared to a temperature of 68°F. In one study, the decrements in reading speed and reading comprehension at 81°F (compared to 68°F) were as much as 30%. So, it is very important to determine good temperature in a library as one of the study spot so that students can perform and study well.

ASHRAE Standard 55-2010 establishes a range of temperature and humidity levels that are considered comfortable by 80% or more of the test subjects, requiring that systems designed to control humidity must be able to maintain a dew-point temperature of 16.8°C (62.2°F).

2.5.6 Air Movement / Wind Flow

Another important component of indoor environments is air movement because it commonly moves across the building envelope and has potential to affect the quality of indoor air impressively. Circulation is air that is moving circularly within a building.

According to Victoria Sustainable Energy Authority, diminution of uncontrolled air leakage as well as the installation of controllable ventilation can control air movement and they are fundamental to minimize the need for complementary heating and cooling. Comfort can be enhanced and almost 20% is saved on heating and cooling cost. Infiltration is air movement between the building's conditioned-air envelope interior and its outside, such as exterior, crawlspace, loft or unheated basement provided air is moving into the conditioned space while exfiltration refers air is moving out from conditioned space. Both of them can lead to air leakage.

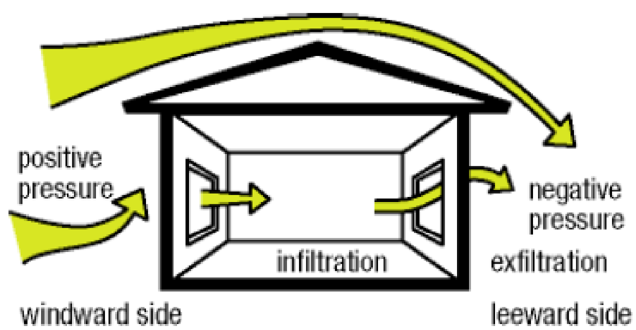


Figure 2.7 : Infiltration and Exfiltration.

(Source : Victoria Sustainable Energy Authority)

Wind effect building can be explained through outdoor air movement. High pressure area is developed next to the upwind external wall and roof surfaces when wind blows against a building, making the other side (internal) of this wall experiences low air pressure. So, the air on the upwind side will be sucked into the building. Air that flows next to the walls and roof (laminar flow) cannot turn sharply enough to stick to the downwind side of the building when air moves beyond the building, thus generating a vacuum on the downwind side. The conditioned air is sucked by this vacuum out of the building and can cause unnecessary heat loss or gain depend either it is heating or cooling season. Make-up air is provided to replace the exhausted air by the mean of ventilation. However, redundant moisture or heat or lack of heat maybe created by uncontrolled make-up.

2.5.7 Lighting Comfort

Good quality lighting is defined since the end of 1990s to balance the needs of humans, economic and environmental issues and architectural design (Bellia et al., 2011). Environmental lighting undoubtedly influences occupants' performance, productivity and health, with positive results. Occupants might face consequences of performances, safety and health when exposed to insufficient or inappropriate lighting. Lighting conditions may be insufficient for those having uncorrected vision as stated by National Research Council. According to the committee too, depression and sleep are influenced by circadian system which may be affected by lighting.

Despite being captivating by the idea of designing and using light as a health measure, there are questions need to be answered before considering the idea of changing lighting practice (Boyce, 2006). Those questions are if the lighting practice, lighting practitioners and designers ready for a change, and if not, what is missing to be ready. Despite new parameters like "Useful Daylight Illuminances" has been introduced, in most cases daylight which is often present at office during work time is still evaluated by means of a 'daylight factor' approach (Nabil, 2006). But from recent researches, as for its energy saving potential purpose, daylighting is taken into account.

Fenestration provides sufficient natural lighting to improve the quality of indoor environment. By considering daylight, building performance can be enhanced according to the fenestration definition. This process consider light and heat from the sun, as well as ventilating stale air which make it vital for a building to be well functioned (U.S Department of Energy, DOE & Public Technology, 1996).

2.5.8 Noise

Noise is invisible and may not seem as harmful as the contamination of air or water, but it is a pollution that affects human health and can contribute to a general impairment of environmental quality. Human or animal life may be interfered by the excessive noise. Outdoor noise come from machines and transportation systems, motor vehicles, aircrafts and trains (Hogan and Latshaw, 1973) and it can interrupt occupants inside a building. While indoor noise also caused by machines, building activities, music performances, loudly played radio and other electronic gadgets.

The difference between sound and noise is often subjective and it depends on the individual definition. However, exposing to high sound levels can lead to serious range of harm severity, from being extremely annoying to being extremely painful and hazardous. The World Health Organization (WHO) has suggested that annoyance, sleep disturbance, interference with communication, and hearing loss caused by noise can influence human health and well-being (UNEP, 1996).

House occupants will be badly affected by the noise interference from adjacent activities and other external source such as traffic noise and this demands special mitigation (The City of San Diego General Plan, 2006). This shows that noise annoyance should not be taken lightly and it is a matter of fact that needs to pay more attention. People do not realize the amount of noise they need to perceive inside a building that lead them to ignore the associative noise as it does not deserve any attention, or a required aspect of modern life (Kenny, 2006).

Four fundamental ways that can control noise are reducing noise at the source, block the path of noise, increase the path-length and protect the recipient. Generally, the effective control method is to reduce the noise levels at the source, which is appropriately most favourable to be applied in IRC. It has been recognized that exposure to levels of noise exceeding safe limits can deteriorate the hearing, but recently WHO published new researches relating linking exposure to excess noise (anything over 50 decibels), to high blood pressure, stroke and even heart attack.

Permitted noise levels and standard safe limit has been determined for various noise levels exposure. Beyond this 'safe' time by keep exposing over a period of a year will lead to hearing loss.

Ambient Noise Levels dB Zone	**Day-time**	**Night-time**
Silent Zone	50	40
Residential Zone	55	45
Commercial Zone	65	55
Industrial Zone	70	70

Table 2.1 : Ambient Permitted Noise Levels

(Source : www.environmentandpeople.org)

Duration	**dB**
8 hours	90
4 hours	93
2 hours	96
1 hour	99
30 minutes	102
15 minutes	105
7 minutes	108
4 minutes	111
2 minutes	114
1 minute	117
30 seconds	120
Instantaneous rupture of membrane	150

Table 2.2 : Safe Limit Exposure

(Source : www.environmentandpeople.org)

2.6 INDOOR ENVIRONMENTAL QUALITY GUIDELINES

In order to evaluate the indoor environmental quality, its components must be complying with MS 1525: 2007 "Code Of Practice on Energy Efficiency and Use Of Renewable Energy for Non-Residential Buildings" and Green Building Index. Instead of standardizing components to determine good IEQ, MS 1525 : 2007 also is used to provide guidelines for the design features of building to achieve high energy efficiency. This code too consider new office buildings, commercial complexes, government buildings, hotels with more than about 50 rooms, hospitals with more than about 50 beds, institutional buildings, high tech factories colleges and universities and among others.

IEQ Parameters	MS 1525 : 2007	Green Building Index (GBI)
Carbon Dioxide (CO_2)		CO_2 < 1000 ppm
Relative Humidity	55% - 70%	
Indoor Temperature	23 °C - 26 °C	
Lighting	< 15 W/m^2	
Noise Comfort		< 40 dBAeq
Air movement	0.15 to 0.50 meters per second (m/s)	

Table 2.3 : Guidelines for Indoor Environmental Quality (IEQ) Parameters in Library

(Source : MS 1525 : 2007 and GBI, 2013)

Besides that, the guidelines of maximum concentration for specific indoor air contaminants identified by Singapore's government can be used as reference for IEQ parameters. It is reliable to refer Singapore's guideline since Singapore has a similar climate and conditions alike to Malaysia.

Parameter	Average Time	Limit for acceptable indoor air quality
Carbon Dioxide	8 Hour	1800 mg/m^3 or 1000 ppm
Carbon Monoxide	8 Hour	10 mg/m^3 or 9 ppm
Formaldehyde	8 Hour	120 μg/m^3 or 0.1ppm
Ozone	8 Hour	100 μg/m^3 or 0.5ppm
Recommended maximum concentration for specific classes of contaminants		
Suspended particulates matter *		150 μg/m^3
Volatile organic compounds **		3 ppm
Total Bacterial counts		500 CFU ***/m^3
Total Fungus counts		500 CFU/m^3
• ** Respirable particles with aerodynamic diameter less than 10 mm sample with a size selective devices.* • *** Total photoionisable compounds, reference to toluene.* • **** Colony forming units*		
Guidelines values for specific physical parameters		
Parameter		Range for acceptable indoor air quality
Air temperature		22.5 – 25°C
Relative Humidity		≤ 70%
Air movement *(at work station within occupied zone)*		≤ 0.25 m/s

Table 2.4 : Guidelines for Maximum Concentration of Specific Indoor Air Contaminants

(Source : Institute of Environment and Epidemiology, 1996)

2.7 INDOOR ENVIRONMENTAL QUALITY CASE STUDY

2.7.1 Indoor Environmental Quality on Dense Academic Building, Universiti Tun Hussein Onn Malaysia.

This study focused on identifying the frameworks in the assessment of IEQ in the context of academic buildings at institutions of higher education, which are temperature, humidity, noise comfort, indoor air quality (CO_2), air movement and lighting. The assessment has considered two factors, the level of IEQ and level of occupants' satisfaction in the academic buildings (Sulaiman et al., 2013). The data analyzed are compared with Malaysia Standard MS 1525 : 2007.

From the result, the average temperature of G3 lecture complex is 23ºC, which mean in good condition as the standard set by MS 1525 for non-residential building should be between 23ºC - 26ºC. As for relative humidity, it is set to be in range of 55% - 70%. However, the total average relative humidity in G3 lecture complex higher than the standard, which is 73%. For the noise intensity, 76.4 dB is recorded, which beyond the prescribed standard of 50 – 70 dB.

For lighting, MS 1525 set the standard to be 300 – 500 lux, but the result show the lighting is 251 lux lower than standard. The air movement of G3 lecture complex is at speed of 0.4 meters per seconds (m/s), and still in the range of the standard, 0.15 m/s – 0.5 m/s. The air quality is good since the concentration of CO_2 is 513 ppm, which below the prescribed value of 1000 ppm. So, some measures need to be taken to improve IEQ in G3 lecture complex, such as change the lighting, reduce the noise source and improve the ventilation.

2.7.2 Indoor Environmental Quality in Hellenic Hospital Operating Rooms, Greece.

IEQ in Operating Rooms (OR) contributes a major challenge for the proper design and operation of an energy efficient hospital. This assessment was performed during the audits of 18 ORs at nine major Hellenic Hospitals and participated by 557 medical personnel in an occupational survey, providing data for a subjective assessment of IEQ in the audited ORs (Dascalaki et al., 2009).

Thermal comfort with indoor temperature is consistently higher in ORs with indoor environmental controls (IEC), providing the average 43% compared to 29% without IEC in ORs. For indoor humidity, thermal satisfaction ranging respectively 59% and 61% in facilities with and without humidifier in air handling units (AHUs) and the proper design and operation of ventilation system raise to 72% personnel satisfaction. Lack of lighting intensity gives problem to 1/3 of personnel, but greater concern should be given to surgeons who having insufficient operating table lighting. Because of the poor space layout, it leads to high noise levels and having lowest noise satisfaction level with average of 17%. Indoor air quality is poor too because ventilation rates are inadequate.

Overall, result found out that personnel reported an average of 2.24 work-related symptoms each, and 67.2% of respondents reported at least one. Women suffer more health symptoms more than men. Personnel that perceive satisfactory indoor comfort conditions (temperature, humidity, ventilation, light and noise) suffered average of 1.18 symptoms per person while for satisfactory indoor air quality the average complaints are 0.99. Both satisfactoriness reduces the average number of health complaints to 0.64 symptoms per person and improves working conditions.

2.8 POST OCCUPANCY EVALUATION (POE)

Post occupancy Evaluation simply refers to the process of gaining feedback from the occupants on a building performance. It has been summarized by British Council for Offices that feedbacks of the workplace performance in upholding organization and individual end-user requirements are gained through POE (Oseland, 2007). From POE, the current building performance can be identified and poor performance can affect occupant well being and work performance. The building occupants as well as its owners and operators' needs, perceptions and anticipations are gained and taken into account in assessing POE (Wolfgang, 2002). For instance, building performance is set as benchmark on how well the building can serve to satisfy the occupants while staying inside it.

Commonly, POE consists of different quantitative and qualitative measures. Lighting, acoustics, temperature, humidity, amount and distribution of space are various aspect of quantifiable building performance. The space surrounding such as the attraction of the touching, hearing and smelling sense as well as visual perception for instance colour are covered by qualitative views. Any current building's problems can be surfaced and addressed by conducting POE and those problems can be further rectified. Besides that, outcomes are obtained and advantageous to be used in improving the design and future projects acquisition. POE also can serve as benchmark for other building to compare across projects. Based on GBI (EQ 15), POE must achieve 80% of occupants' satisfaction while staying in a building under IEQ assessment.

CHAPTER 3

METHODOLOGY

3.1 METHODOLOGY

The methodology of the study involves research process, scientific measurement, questionnaire distribution, data interpretation process and evaluation. Appropriate research design and methodology will help to achieve the objectives of study by clearly show the method of data acquisition and data analysis to generate information. In the research process, information regarding green building and IEQ are gathered to enhance the understanding in this study.

To fulfill the objective of this study, Post Occupancy Evaluation is conducted by preparing the questionnaires and they are distributed to the IRC staffs and users. For scientific measurement, the preliminary investigation will be done by observing IRC building plan to get the whole idea of IRC design and whole environment of building space which will be used for advanced search later. Besides that, rough ideas of the mechanical and electrical system too are pictured to get the overall idea of electrical and mechanical system in IRC such as ventilation, lighting and other components. Scientific measurement too involves field measurement at certain period of time, and performed using special equipments to get the current measurement of each IEQ parameter.

The data obtained from Post Occupancy Evaluation and field measurement are then analyzed and interpreted. Then, data evaluation is done and the current level field measurement components are compared with MS 1525 : 2007 and GBI Tools.

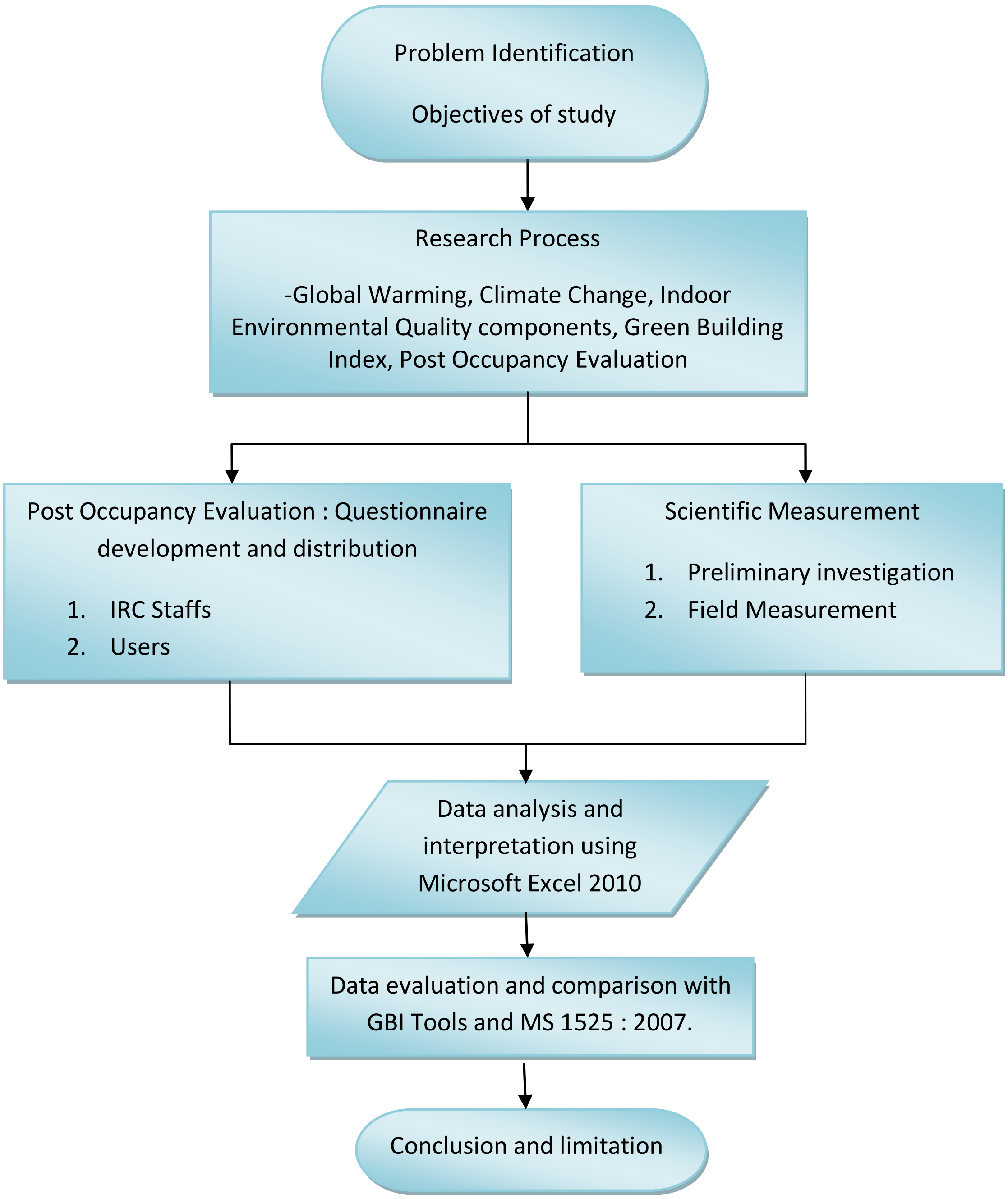


Figure 3.1 : Proposed Methodology

3.1.1 Post Occupancy Evaluation (Questionnaire Survey)

One of the objectives of the study can be achieved by adopting this approach. The questionnaire is developed and distributed to the IRC staffs and users, which are lecturers and students. There are slightly differences in questionnaire provided for staffs and users (See Appendix A). The questionnaire consist of four sections, which are :

- Section A : Demographic
- Section B : Health Condition
- Section C : IRC Observation
- Section D : Knowledge and Opinions

The questionnaires are created using Google Documents and distributed to the staffs and users through email. The respondents' responses are accessible to view since it offers statistics and chart view for all responses. Besides that, questionnaires hardcopy are distributed too in order to gain more respondents considering the responds from the online survey are not favourable and then the questionnaire distributed are collected and were key-ed in by the author herself in the Google Documents. Then, the responses are further analyzed using Microsoft Excel 2010 to deeply interpret and generate information and the results obtained are related with the literatures that have been reviewed beforehand. This is important to achieve the feasibility and objectives of this study.

3.1.2 Field Measurement

Another objective can be fulfilled by conducting field measurement in IRC to obtain the current measurement of IEQ parameters and thereby to identify if they comply with GBI and MS 1525 : 2007. Hereby are the tools and equipments used to conduct field measurement :

Equipments	Functions
 AMI 300 Multifunction	Interchangeable Optional Probes to measure Carbon dioxide (CO_2), relative humidity and temperature.

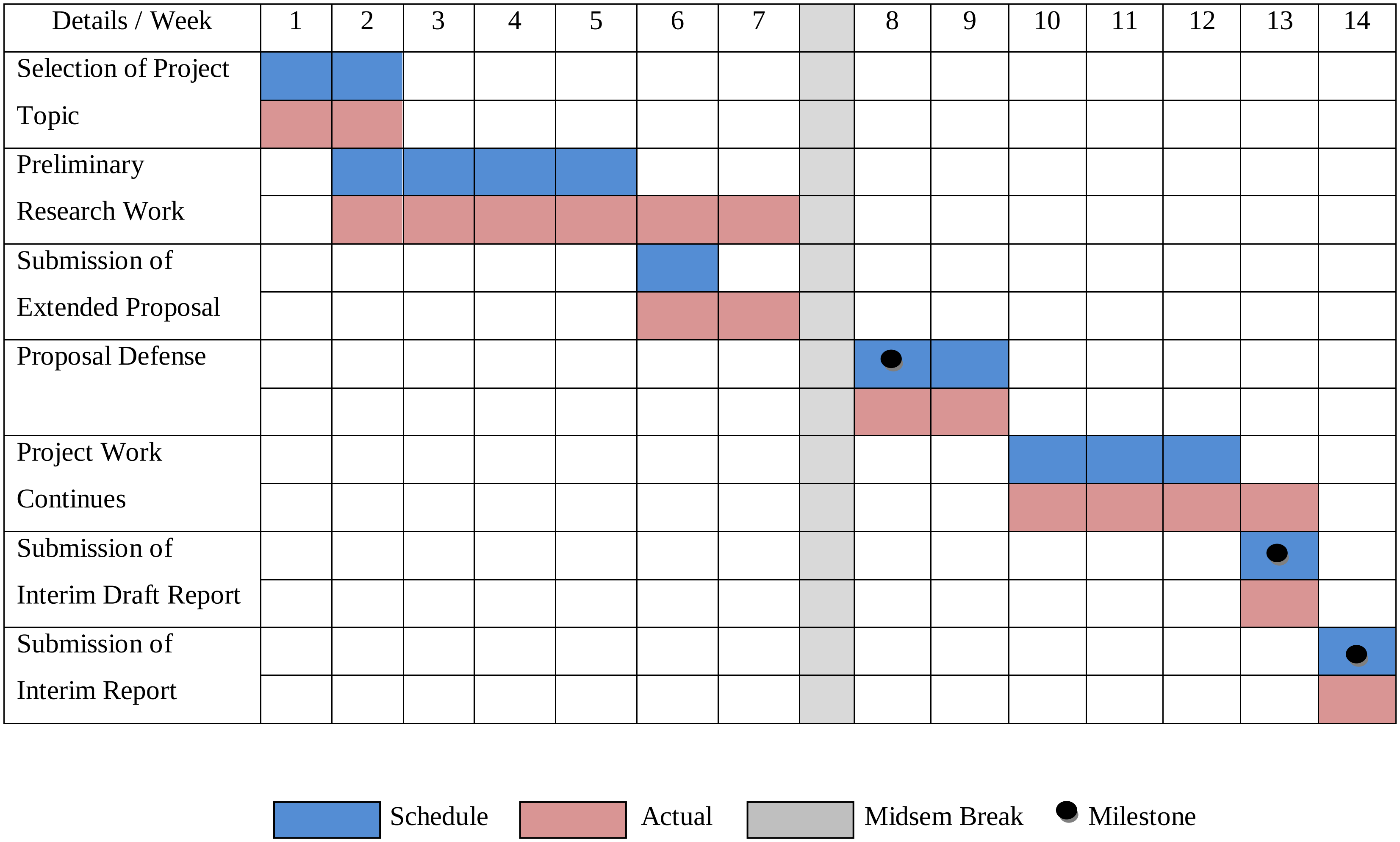
 Sound Level Meter	To measure sound pressure level.
 Solarimeter	To measure the lighting power.

Table 3.1 : Field Measurement Equipments and Their Functions

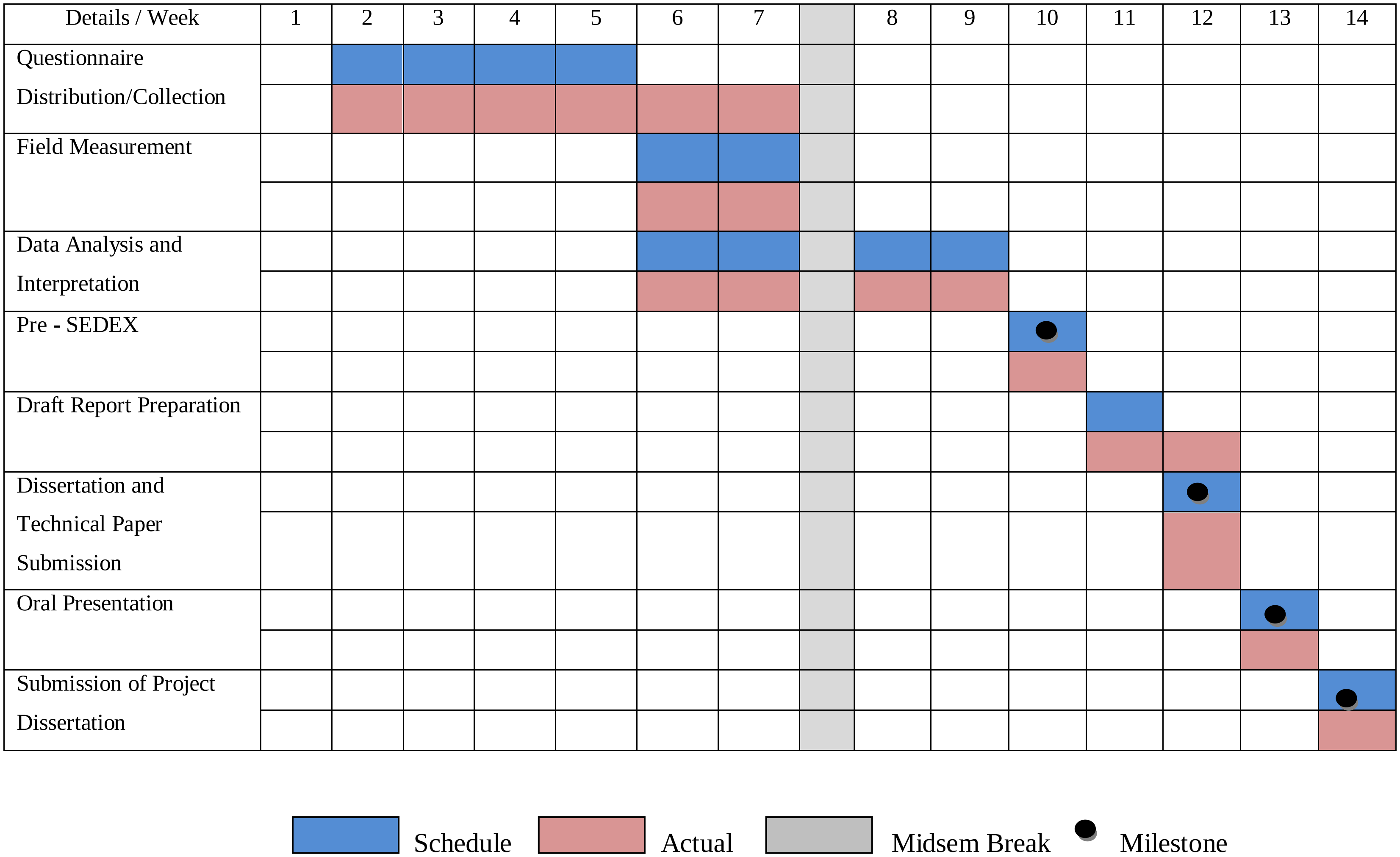
For AMI 300 Multifunction, it has ±0.5 ºC and ±0.6% accuracy for temperature and relative humidity, respectively. All equipments are calibrated beforehand according to manufacturer's specification before conducting field measurement. These equipments are set to read about 1.2 m above the floor level.

Based on Malaysian Industry Code of Practice on Indoor Air Quality 2010, measurement of IEQ parameters are preferable to be conducted on an 8-hour basis unless otherwise specified. Surrogate measurement in which intermittent measurement strategy based on average half-hour measurements can be conducted instead if it is not practical to conduct 8 hour continuous measurement due to the time constraint. This surrogate measurement is more applicable since the equipments used to measure the specified parameters are manually functioned instead of being provided with the real-time monitor with a data logging device which automatically record the measurements for at least every 5 minutes interval. These parameters are measured at selected sampling locations in IRC based on the guidelines from Malaysian Industry Code of Practice on Indoor Air Quality 2010 and carried out from 10.00 am to 4.00 pm.

3. 2 GANTT CHART (FINAL YEAR PROJECT 1)



3. 3 GANTT CHART (FINAL YEAR PROJECT 2)



CHAPTER 4

RESULT AND DISCUSSION

4.1 INTRODUCTION

This chapter consists of the analyzed data that has been acquired from the distributed questionnaire. The perception and opinion of the staffs and users of Information Resource Center (IRC) are obtained through the questionnaire in order to accomplish the second objective of this study, which is to evaluate the occupants' satisfaction in IRC. The data for each questionnaire are automatically analyzed by Google document and furthered analyzed using Microsoft Excel 2010. Besides that, this chapter comprises field measurement results for the defined parameters which are Carbon Dioxide (CO_2) level, relative humidity, temperature, lighting and noise and they are further interpreted. These current measurements thereby are compared with the standard set by MS 1525 : 2007 and GBI to identify if they comply with those standards.

4.2 DATA ANALYSIS (POST OCCUPANCY EVALUATION)

There are 101 respondents that have responded to the questionnaire, comprises of 93 users in which 49 or 53% of them are male and the remaining is female. While for IRC staffs there are 8 respondents have responded with 7 or 88% of them are female. As much as 20 hardcopy questionnaires have been distributed and only 3 staffs responded to the survey within the time frame given. Same goes to users in which 50 questionnaires were distributed and 41 were collectible.

Gender	IRC Staffs		Users	
Male	1	13%	49	53%
Female	7	88%	44	47%

Table 4.1 : Respondents' Gender Data

The questionnaire consists of 4 sections which are Section A : Demographic, Section B : Health Condition, Section C : IRC Observation and Section D : Knowledge and Opinions.

Section C and D involved 5-point scale based on Likert scale with variable end anchors, in which responses are chosen along a range, providing respondents to specify their level of opinions (agreement, disagreement, satisfaction, dissatisfaction, etc) in a series of statements (Burns, 2008). The end anchors termed negative feedback in which respondents express their negative opinions as disagree or discomfort while responses towards the positive end are defined as positive feedback.

4.2.1 Analysis Using Severity Index

The 5-point scale surveys in Section C are then analyzed further using severity index. Relative index ranking technique is a non-parametric technique used to analyze structured questionnaire feedback data involving serial measurement of attitudes and widely used by construction management researchers (Olomolaiye et al., 1987; Idrus, 2001). Severity index analysis is one form of this technique which uses weighted percentage scores to compare the relative importance of the criteria and ranking under study. Firstly, frequencies of responses are determined and thereby severity indices can be calculated by using this formula

$$\textbf{Severity Index (I)} = [\, \Sigma\, a_i \,.\, x_i \,] / [\, 5\, \Sigma\, x_i \,] \times 100\%$$

x_i = variable expressing the frequency of the response for i where i = 1, 2, 3, 4, 5

ai = constant expressing weight given to i

x5 = frequency of ‘very high extend’ response and corresponding to a5 = 5

x4 = frequency of ‘high’ response and corresponding to a4 = 4

x3 = frequency of ‘moderate’ response and corresponding to a3 = 3

x2 = frequency of ‘low’ response and corresponding to a2 = 2

x1 = frequency of ‘very low’ response and corresponding to a1 = 1

Severity boundary lines = Σ SI / n

where n = number of element or criteria involved

For example :

Question : ***Is the air inside IRC fresh or stale?***

Rating scale		Respondents	Severity Index
Stale	1	1	1 x 1 = 1
	2	18	2 x 18 = 36
	3	43	3 x 43 = 129
	4	31	4 x 31 = 124
Fresh	5	8	5 x 8 = 40
			Total = 330
			Severity index = 330 x 100 / (5 x 101) = 65.35%

Table 4.2 : Severity Index Calculation Example

The priority of the criteria in the study that has been defined by the respondents beforehand can be identified from this severity analysis. Criteria will be ranked topmost for highest severity index (%) while criteria with the least severity index (%) will be ranked at the bottom. The formula above is used to obtain the ranks of different criteria in which the 5-point scale for each criterion was transformed to relative importance indices. This severity index analysis enables the researcher to cross-compare the relative importance of the criteria perceived by the respondents. Therefore, severity indices are calculated from the numerical scores of each criterion by the formula shown and hence the relative ranking of the criteria can be determined. Air quality, temperature, lighting and noise responses are the parameters used to analyze the result of the survey.

4.2.2 Section A : Demographic

This section for users' questionnaire basically acquired the demographic information of the respondents, comprising gender, their frequency going to IRC, preferable location, the time spent and the equipments used, if any in IRC. Differ from users, there are additional questions provided for IRC staffs (see Appendix A). There are 93 users responded to this survey and most of them spent their time in IRC at reading area, with 63% or 59 respondents (See Appendix B-1).

How long do you spend your time / working hours in IRC?

Time Duration	**Users**		**Staffs**	
	Respondents	**Percentage**	**Respondents**	**Percentage**
Less than 1 hour	10	11%	0	0%
1 – 2 hours	46	49%	0	0%
2 – 4 hours	31	33%	0	0%
4 – 6 hours	5	5%	1	12%
6- 8 hours	1	1%	3	38%
More than 8 hours	0	0%	4	50%

Table 4.3 : Summary of Time Spent in IRC

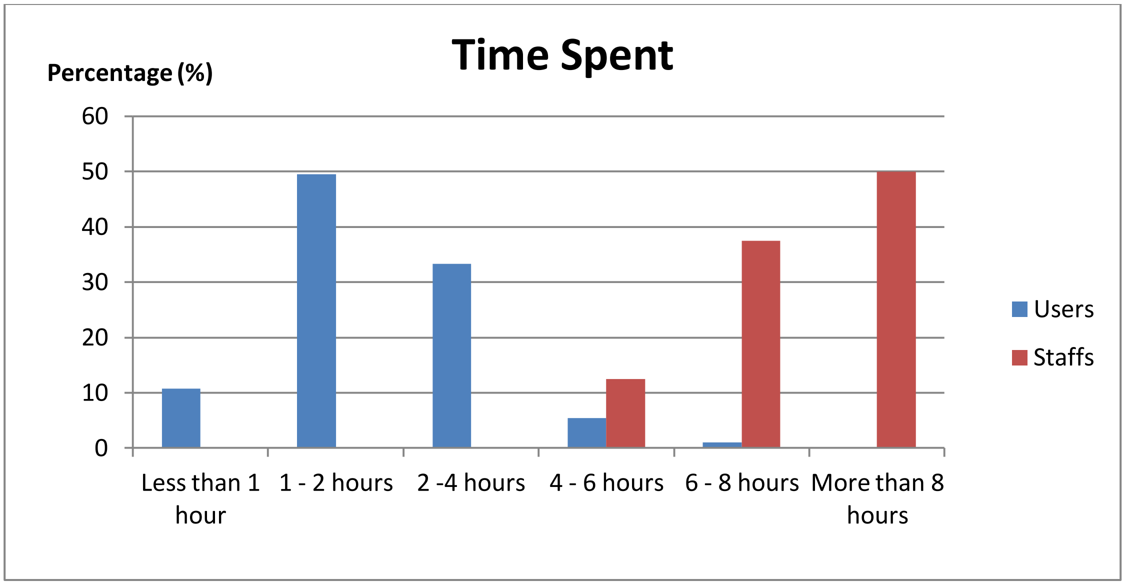


Figure 4.1 : Summary of Time Spent in IRC

Most of the users spent their time in IRC for 1-2 hours, carrying 49% and ahead of those who spent their time for 2-4 hours with 33%. The least percentage of 1% of the users spent their time for 6 – 8 hours. For staffs, most of them spent their working hours in IRC for more than 8 hours. The minimum hours they spent is between 4 – 6 hours, which mean the indoor environment of IRC does matter most to the staffs since they spent more time in IRC compared to the users. This shows that the staff survey is weightier and its results are more reliable to be used for other data analysis.

Do any of your work activities generate dust/particles or odor? (IRC Staffs only)

	Respondents	**Percentage**
Yes	4	50%
No	4	50%

Table 4.4 : Dust/Particles or Odor Generation

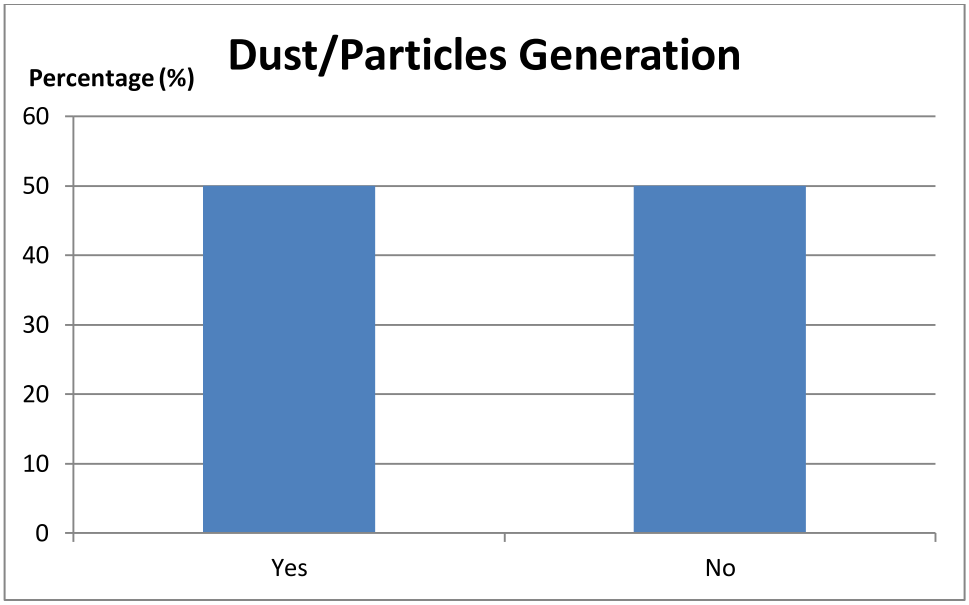


Figure 4.2 : Dust / Particles or Odor Generation

Only staffs are asked if any of their work activities generate dust/particles or odor. There is an equal number of staffs which their work activities do generate dust/particles or odor and does not generate any of it. However, the generation of dust or particles can lead to the presence of Particulate Matters, PM_{10} and the excessive generation thereby can lead to poor indoor air quality.

Do you use any of these equipments in IRC?

Equipments	Staffs	Users	Total
Photocopier	39%	37%	37%
Laser printer	22%	14%	16%
Facsimile	6%	2%	2%
Self-copying (carbonless) paper	6%	7%	7%
Cleanser	6%	0%	1%
Glue	17%	3%	5%
Correction fluid	6%	8%	7%
Other strong smelling chemicals	0%	0%	0%
No	0%	31%	27%

Table 4.5 : Equipment Used by IRC Staffs and Users in IRC

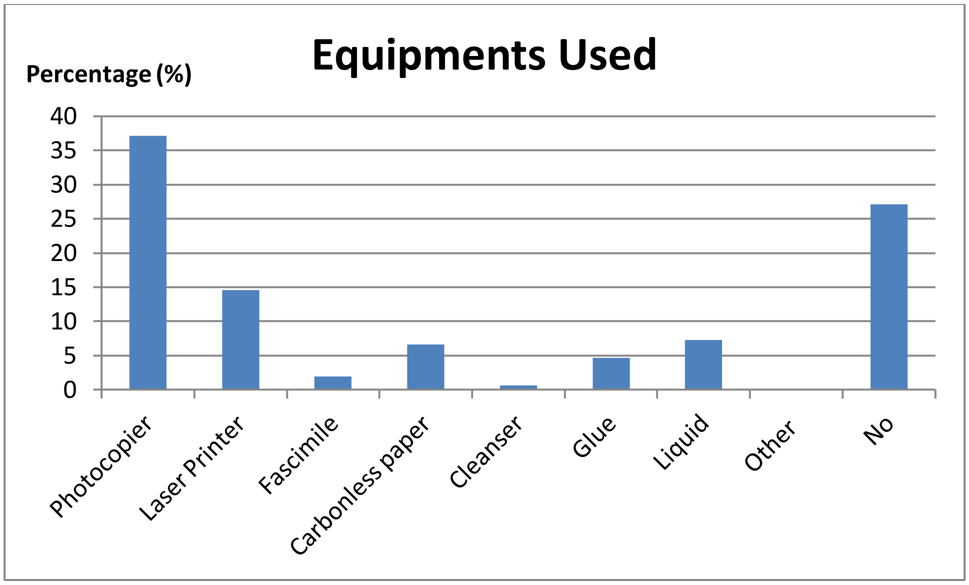


Figure 4.3 : Equipment Used by IRC Staffs and Users in IRC

From the combination analysis, most of the respondents use photocopier in IRC with 37%, and it is 10% ahead to those use none. There is significant number that uses laser printer too in IRC. However, not to mention excessive usage of office equipments can contribute to the presence of Volatile Organic Compounds which may affect indoor air quality.

4.2.3 Section B : Health Condition

This section in questionnaire consists of health condition of respondents in general as well as symptoms they experienced while spending time in IRC. For this result analysis, only symptoms experienced by the staffs are analyzed considering they spent most of their time at work every day, compared to users which most of them rarely go to IRC (See Appendix B-1).

In the LAST FOUR WEEKS AT WORK, did you experience any of the following symptoms?

Symptoms	Percentage	Symptoms	Percentage
Allergy	0%	Blocked nose	4%
Coughing	15%	Dark circle under eyes	4%
Eye irritation	7%	Nose rubbing	4%
Itchy throat	7%	Conjunctivitis	0%
Sneezing	11%	Asthma symptoms	0%
Dry skin	19%	Runny nose	0%
Tightness	4%	Wheezing	0%
Chest dizziness	7%	Teary eyes	4%
Short of breath	4%	Sleepy	0%
Respiratory symptoms	0%	Other	11%

Table 4.6 : Symptoms Experienced by IRC Staffs

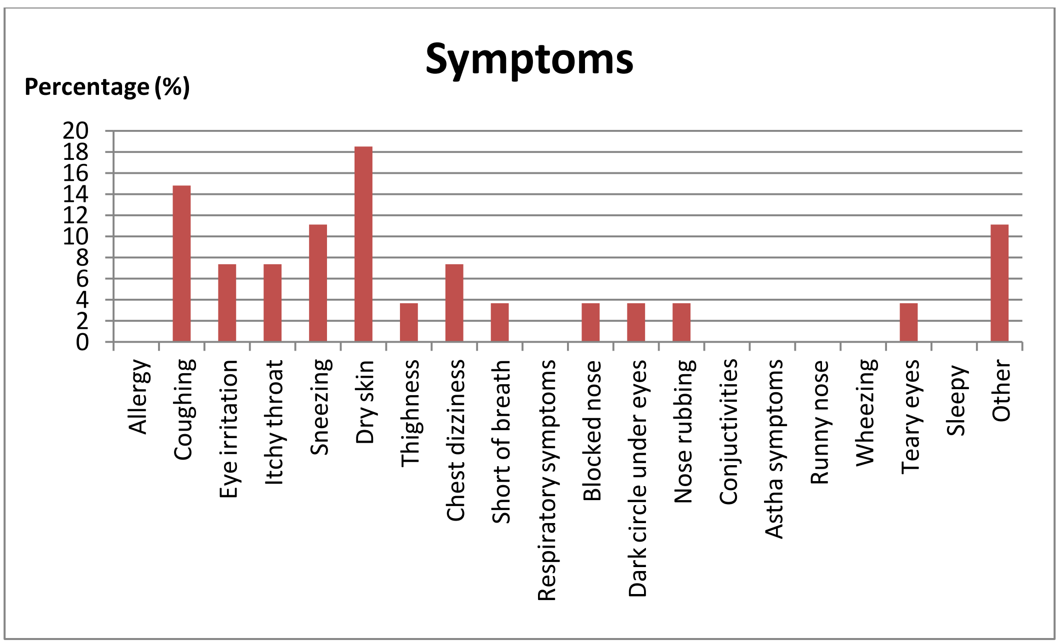


Figure 4.4 : Symptoms Experienced by IRC Staffs

Most of the staffs have opted dry skin and coughing as the dominant symptoms they have experienced at work. It has been stated in the previous chapter the factors that contribute to both dry skin and coughing are due to the low humidity and presence of particulate matter (PM_{10}), respectively. Meanwhile, 11% of the respondents chose sneezing and other options without any symptoms specification. Some of them too experienced itchy throat and chest dizziness which have been discussed earlier from Chapter 2 as result from the exposure of Volatile Organic Compound and Carbon Monoxide. It is important to conduct field measurement to determine the level of these parameters and verify if their current levels are within the range.

4.2.4 Section C : IRC Observation

In this section, it surfaces respondents' observations on the parameters to be assessed in the field measurement. It is very convenient to provide this section as their opinions do matter for building improvement (if any) in order to enhance indoor environment quality and building performance. The data in this section is further analyzed by the mean of Severity Index.

4.2.4.1 Mean Analysis

Parameters	Scale					Mean
	1	2	3	4	5	
Air Quality : Is the air fresh or stale in IRC? (scale is rated from stale to fresh)	1%	18%	42%	31%	8%	3.27
Air Quality : Does the air smell? (scale is rated from smell to no smell)	2%	6%	22%	39%	31%	3.91
Air Quality : How would you rate air humidity in IRC (scale is rated from too humid to too dry)	1%	23%	51%	23%	2%	3.02
Temperature : How would you rate temperature in IRC (scale is rated from too cold to too hot)	22%	52%	24%	2%	0%	2.06
Lighting : How would you rate lighting in IRC (scale is rated from too dim to too bright)	1%	9%	58%	30%	2%	3.23
Noise : Is there any significant distraction from background noise in IRC (scale is	4%	12%	29%	37%	18%	3.53

rated from very significant to not significant)						

Table 4.7: Respondents' Feedbacks on the Parameters Assessment

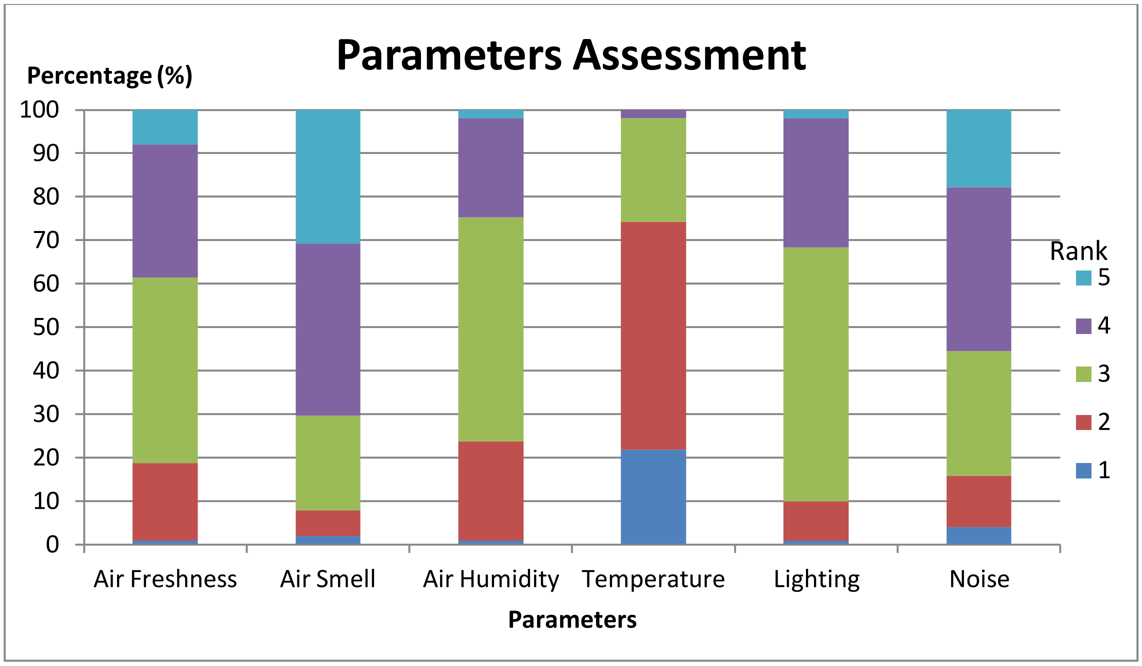


Figure 4.5 : Respondents' Feedbacks on the Parameters Assessment

The figure above summarized the percentage of respondents (combination analysis for both users and IRC staffs) based on the ranking specified for each parameters. For air freshness, about 81% respondents have defined air inside IRC as fresh, and this analysis carried mean of 3.27 which reflects most of them experienced fresh air. About 92% respondents responded positively on the air smell and this can be verified by its mean of 3.91, which indicates majority of them experienced insignificant smell inside IRC. Meanwhile, the mean of humidity is 3.02 and this shows majority of respondents rated air humidity as moderate, which is neither too dry nor too humid. These analyses on air quality show that air perceived by both users and staffs inside IRC is quite satisfactory.

As for temperature, respondents as much as 74% have rated temperature as cold, thus carried mean of 2.06 which signifies most of them experience coldness while staying in IRC. Among IRC staffs, most of them rated temperature as moderate as compared to the users since they already get used to the ambient temperature during working. About 58% respondents have specified lighting as moderate with mean of 3.23, which shows majority of them satisfied with the current lighting, which is not too dim or too bright. While for noise, majority of the respondents with 84% responded positively on the noise inside IRC and this can be verified by its mean of 3.53, and only 16% opposed to this.

4.2.4.2 Severity Index Analysis

<table>
<tr><th rowspan="2">Parameters</th><th colspan="5">Scale</th><th rowspan="2" colspan="2">Severity Index</th><th rowspan="2">Ranking</th></tr>
<tr><th>1
Very low</th><th>2
Low</th><th>3
Moderate</th><th>4
High</th><th>5
Very high</th></tr>
<tr><td>Air freshness</td><td>1</td><td>18</td><td>43</td><td>31</td><td>8</td><td>65%</td><td rowspan="3">68%*</td><td rowspan="3">2</td></tr>
<tr><td>Air smell</td><td>2</td><td>6</td><td>22</td><td>40</td><td>31</td><td>78%</td></tr>
<tr><td>Air humidity</td><td>1</td><td>23</td><td>52</td><td>23</td><td>2</td><td>60%</td></tr>
<tr><td>Temperature</td><td>22</td><td>53</td><td>24</td><td>2</td><td>0</td><td colspan="2">41%</td><td>4</td></tr>
<tr><td>Lighting</td><td>1</td><td>9</td><td>59</td><td>30</td><td>2</td><td colspan="2">65%</td><td>3</td></tr>
<tr><td>Noise</td><td>4</td><td>12</td><td>29</td><td>38</td><td>18</td><td colspan="2">71%</td><td>1</td></tr>
</table>

*Air quality covers air freshness, air smell and air humidity. Hence, severity index for air quality is determined by calculating the severity boundary line of those three components ($SI_{air\ quality}$ = [65+78+60] / 3 = 68%)

Table 4.8 : Overall Severity Index Parameters

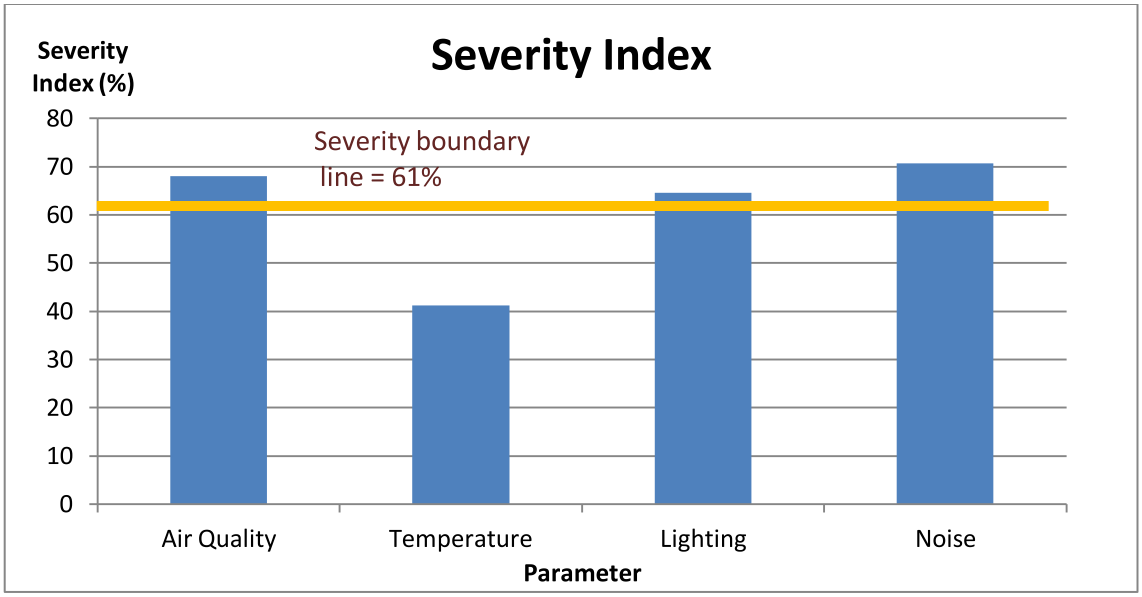


Figure 4.6 : Overall Severity Index Parameter Chart

From the severity indexes calculated for each parameter, noise is ranked as 1, and directly indicates noise has gained most positive feedback by most of the users and staffs in IRC. However, there is still some of respondents rated noise as significant. Air quality is another most satisfied parameter, and this shows respondents felt that they have perceived good air inside IRC. However, based on the severity index boundary line for air quality covering air freshness, air smell and humidity which is 68%, only air smell passed the severity boundary (See Appendix B-5) in which can be concluded air freshness (severity index of 65%) and humidity (severity index of 60%) betterment and improvement inside IRC should not be neglected even though overall air quality quite satisfactory.

Lighting too has met respondents' satisfaction and most of them specified artificial lighting as moderate, in which the amount of light they experience is just good enough for their vision. Moreover, majority of them did not experience a reflection or glare in their field of vision (See Appendix B-5). Most unsatisfactory parameter is temperature, as most of them specified the temperature as cold and too cold. As we can see from the chart, the severity boundary for this overall parameter is 61% which indicates only temperature did not pass this severity boundary, while other parameters passed. Only quarter of respondents are satisfied with the temperature performance, which clearly shows that temperature control or adjustment should be commenced. Thermal comfort which refers to occupants' satisfaction on thermal environment cannot be achieved if the ambient temperature keeps them unsatisfied.

4.2.5 Section D : Knowledge and Opinions

This section is provided to roughly identify respondents' basic knowledge on sustainable development, climate change and green building concept as well as gaining their opinions on IRC indoor environment based on solely what they have experienced and perceived.

4.2.5.1 Knowledge

Scale	**1**	**2**	**3**	**4**	**5**
I do understand sustainable development concept	6%	15%	29%	22%	28%
Climate change is one of the factors that contribute to poor indoor environment in a building.	3%	10%	39%	27%	21%
	Yes		Partially		No
Green building is one of the solutions to reduce global warming and climate change	69%		27%		4%

Where 1 = strongly disagree, 5 = strongly agree

Table 4.9 : Respondents' Basic Knowledge

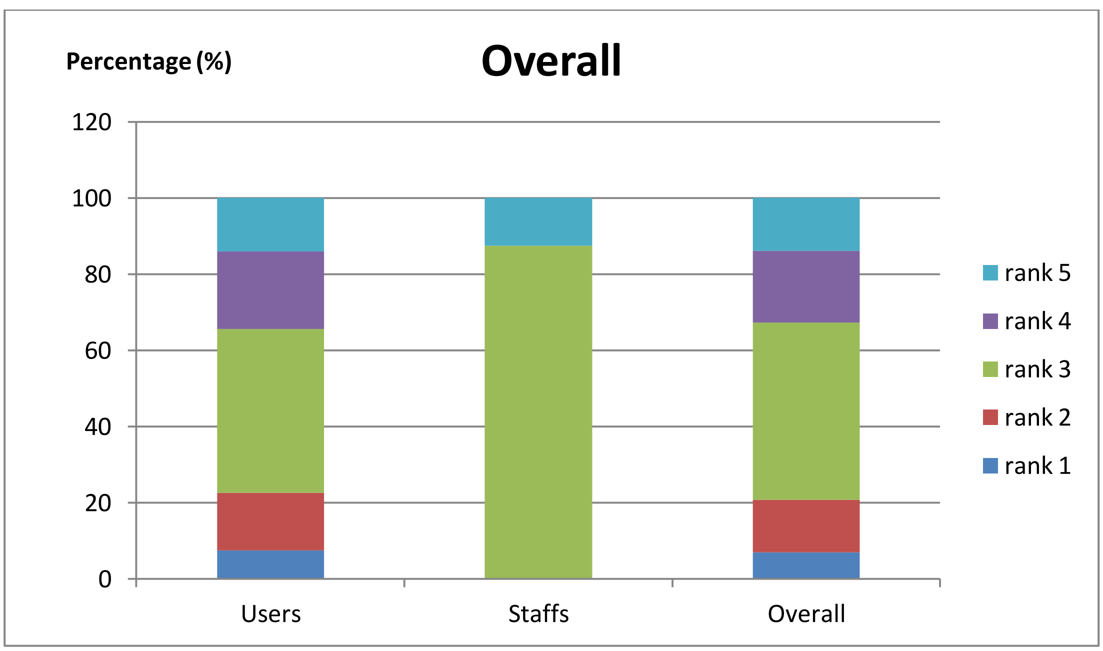
From the table shown above, most of the respondents do understand sustainable development concept and by that, they should aware the importance of sustainability for the future years ahead. While for climate change, majority of them responded as neutral if climate change is one of the driven factors of poor indoor environment. There are slightly number of respondents who do not fully aware climate change as one of the poor indoor environment contributors. On the other hand, majority of them agree on green building as one of the driven forces to reduce global warming and climate change and about quarter partially agree on that. This directly shows only slightly number of respondents are not too exposed with the importance of green buildings.

4.2.5.2 Opinions

Do you think poor indoor environmental quality in IRC have negative effect on your work performance/study?

Rating		Users		IRC Staffs		Overall
		Respondents	Percentage	Respondents	Percentage	
Strongly disagree	1	7	8%	0	0%	7%
	2	14	15%	0	0%	14%
	3	40	43%	7	88%	46%
	4	19	20%	0	0%	19%
Strongly agree	5	13	14%	1	12%	14%

Table 4.10 : Summary of IEQ's effect on Work Performance / Study



Rank 1 = strongly disagree, 5 = strongly agree

Figure 4.7 : Overall Summary of IEQ'S Effect on Work Performance/Study

Based on the overall analysis, most of the respondents responded as neutral if poor indoor environment in IRC affect their performances. Meanwhile, majority of the remaining respondents agreed on poor indoor environment affect work performance.

However, this question does not simply mean that current indoor environment in IRC is poor since field measurement hasn't yet conducted during this surveys were developed. Hence, it is convenient to conduct field measurement in order to identify the current IEQ measurement in IRC.

Overall, how would you rate your comfort and satisfaction with the current indoor environment in IRC?

Rating		**Users**		**IRC Staffs**		**Overall**
		Respondents	%	Respondents	%	
Not satisfied	1	1	1%	0	0%	1%
	2	3	3%	1	13%	4%
	3	35	38%	4	50%	39%
	4	47	51%	3	37%	49%
Very satisfied	5	7	7%	0	0%	7%
EQ 15 : Post Occupancy Comfort			96%		87%	95%

Table 4.11 : Summary of Post Occupancy Comfort

Majority of the respondents for both users and staffs are satisfied with the indoor environment in IRC. From combination analysis, 95% of respondents assure their comfort while spending their time there. This can be verified by evaluating comfort respond from staffs, with 87% of them gave positive feedback, and this result is reliable since they spend most of their time in IRC compared to the users. With this combination analysis, it directly shows that only 5% express their discomfort in IRC, thereby proving that this post occupancy comfort met Environmental Quality 15 (EQ 15) of GBI requirement. However, if this dissatisfaction on comfort exceeds 20%, a plan for corrective action need to be developed which include measurement of relevant environmental analysis variables (temperature, relative humidity, air speed, lighting, noise level, CO_2 level, VOCs, odour problem, particulate concentration) at particular problem areas.

Rank the top three indoor environmental quality (IEQ) parameters that you are most satisfied with.

Parameters	Rank 1			Rank 2			Rank 3		
	Users	Staffs	Overall	Users	Staffs	Overall	Users	Staffs	Overall
Air Quality	36%	63%	37%	26%	12%	25%	22%	0%	21%
Temperature	26%	12%	25%	26%	25%	26%	25%	25%	25%
Noise	18%	0%	17%	20%	38%	22%	29%	25%	28%
Lighting	20%	25%	21%	28%	25%	27%	24%	50%	26%

Table 4.12 : Summary of Most Satisfied Parameters

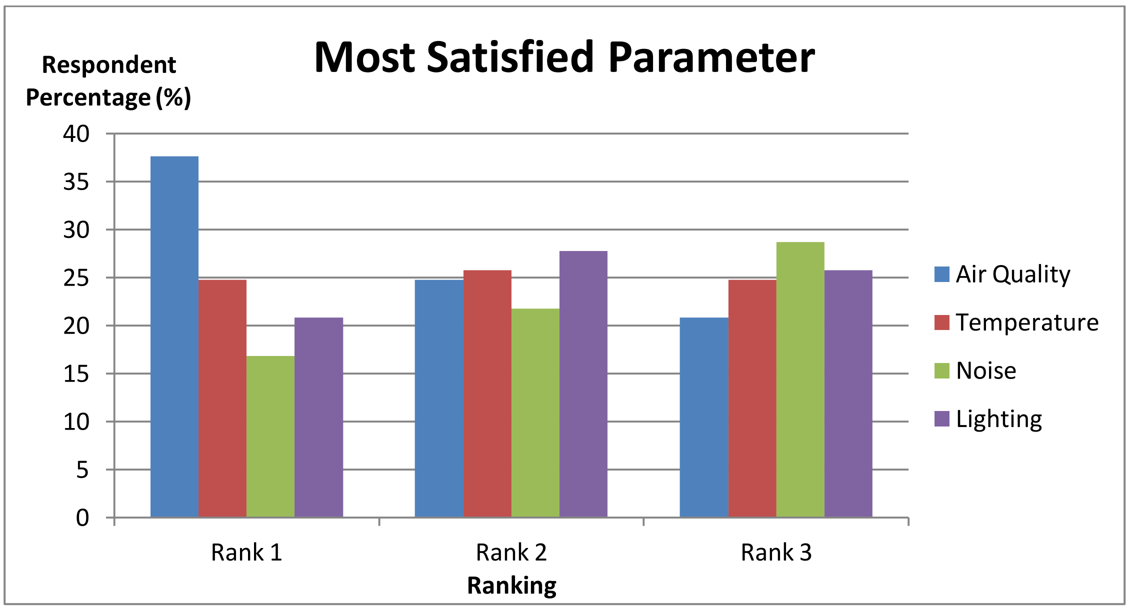


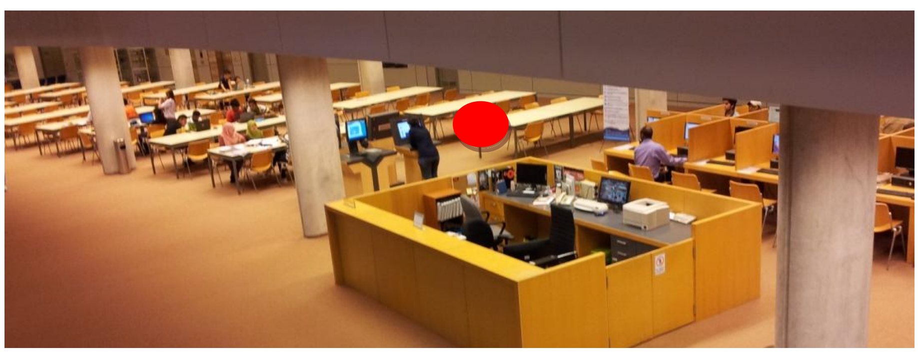
Figure 4.8 : Overall Most Satisfied Parameters

From the table and figure above, it clearly shows air quality is the most satisfied parameters for both users and staffs. For the second most satisfied parameter, users opted for lighting, while IRC staffs chose noise over others. Overall, lighting is rated as second most satisfied parameter. Meanwhile, noise is overall ranked as the third most satisfied parameter. However, staffs opted lighting the most for this ranking while most of the users chose noise. Since majority of the staffs have opted noise for the second rank, hence that percentage can be carried backward in order to rank the third parameter. In summary, the top three most satisfied parameter in IRC are :

1. Air Quality
2. Lighting
3. Noise

4.3 FIELD MEASUREMENT

Several parameters are measured which are Carbon Dioxide (CO_2), relative humidity, temperature, lighting and noise. To achieve the feasibility of measurement, IRC is divided into 2 portions, which are location A (reading area for each level namely Ground Floor, Level 1, Level 2 and Level 3) and location B (near the IRC entrance and glass wall and divided by 3 zones). All parameters are measured for each floors and zones in 30 minutes interval from 10.00 am until 4.00 pm. The average of measurements for all floors for Location A and all zones in Location B corresponding to the time of measurement are calculated and graphs for each parameter measurement are made.



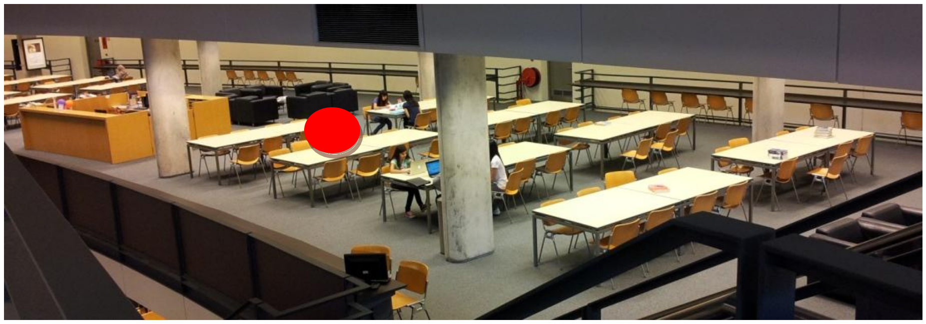


Figure 4.9 : Location A Assessment (Ground Floor, Level 1, Level 2, Level 3)

Figure 4.10 : Location B Assessment

4.3.1 Carbon Dioxide Measurement

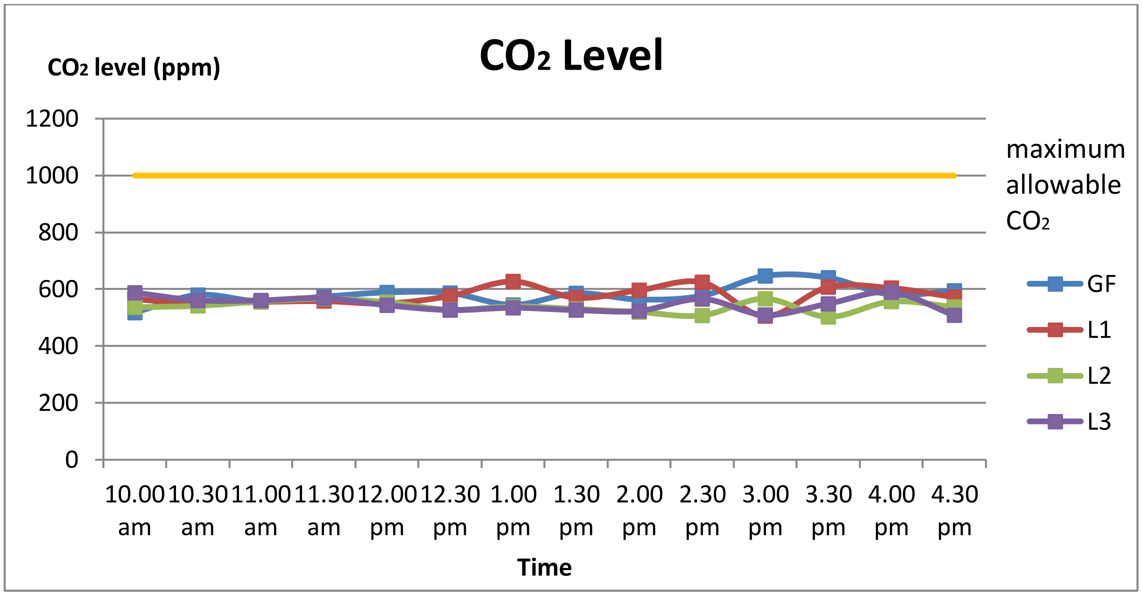


Figure 4.11 : Carbon Dioxide Level of Location A

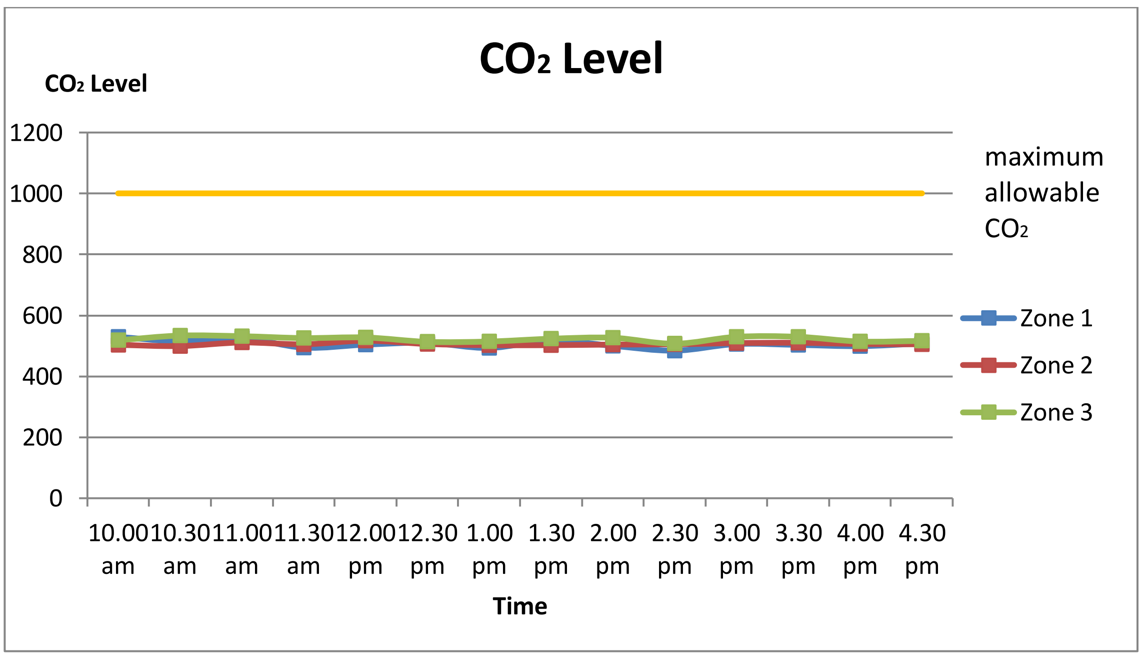


Figure 4.12 : Carbon Dioxide Level of Location B

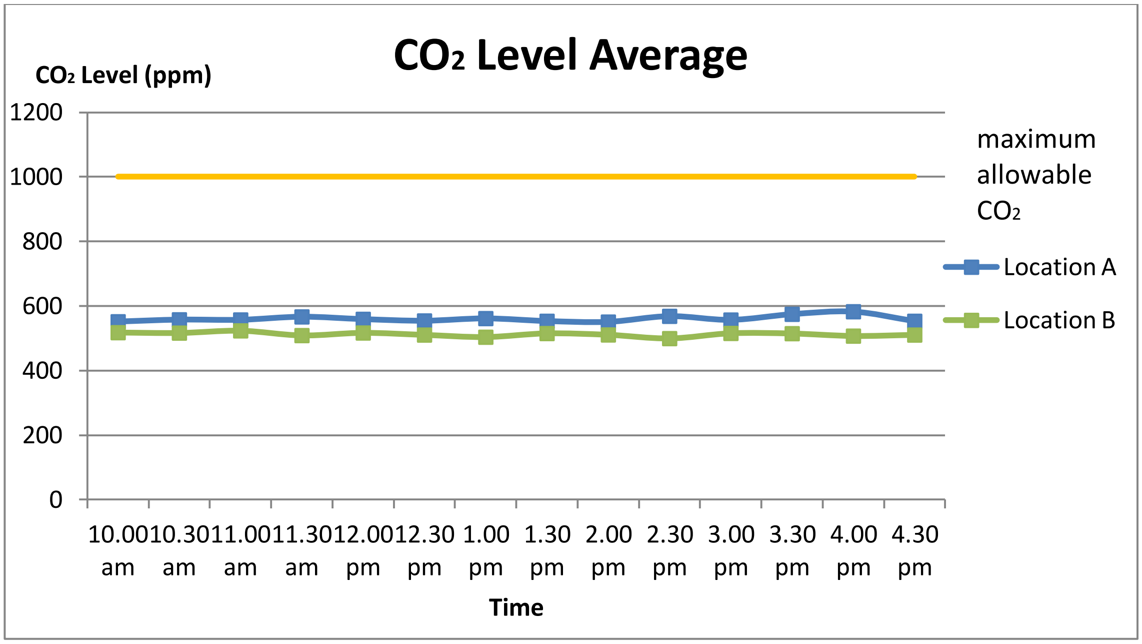


Figure 4.13 : Carbon Dioxide Level Average

From the figures above, they clearly show Carbon Dioxide levels for both locations are below 1000 ppm which is the maximum CO_2 allowed inside a building as specified by GBI. We can see that average CO_2 levels throughout the day are uniform for both locations. These CO_2 levels justified outside air is minimally delivered inside the building since CO_2 level is below the allowable value and indicates the adequacy of ventilation systems. It has been stated by NIOSH that indoor air concentration goes beyond 1000 ppm is a benchmark for inadequate ventilation.

4.3.2 Relative Humidity Measurement

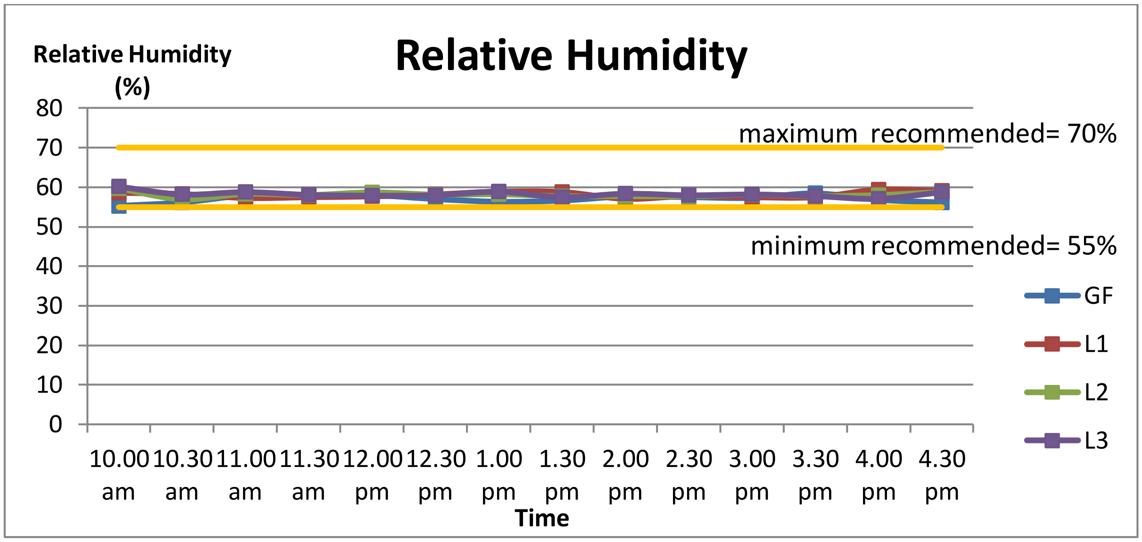


Figure 4.14 : Relative Humidity Level of Location A

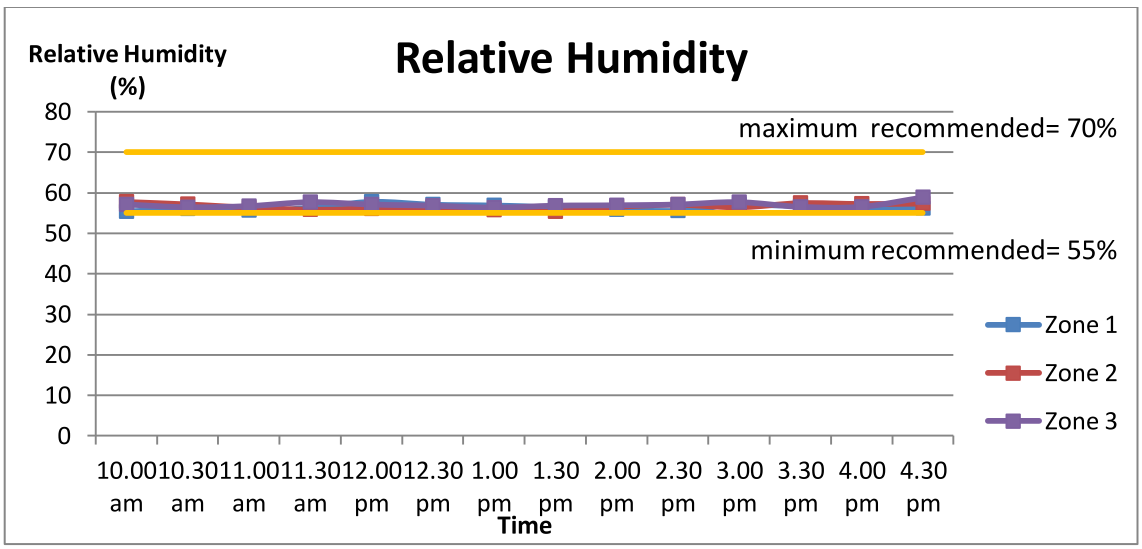


Figure 4.15 : Relative Humidity Level of Location B

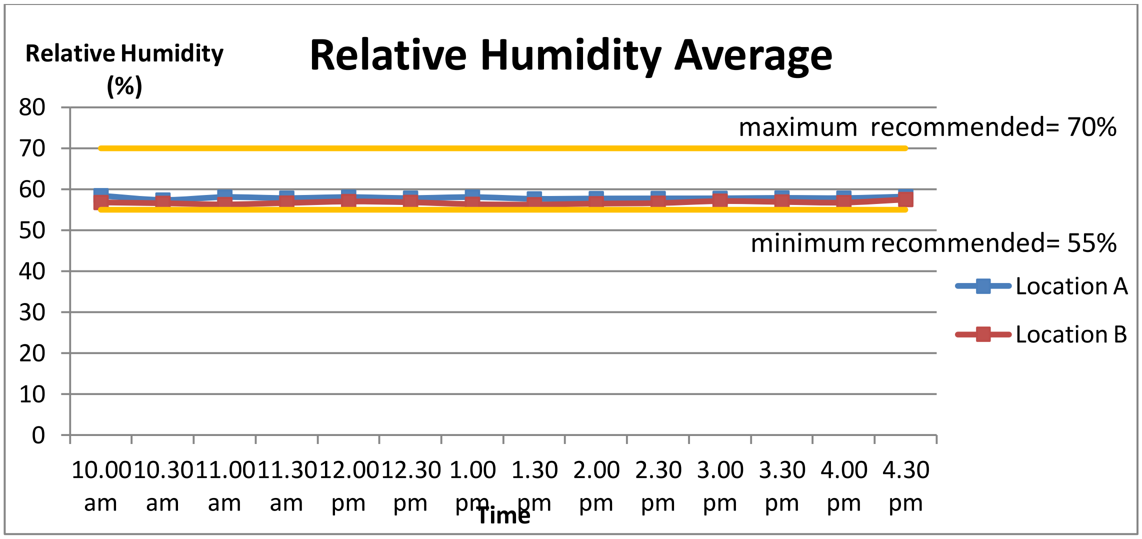


Figure 4.16 : Relative Humidity Level Average

From the Figure 4.16 shown above, the relative humidity averages in both locations are just slightly above the minimum range and still they comply with MS 1525 : 2007 which specified indoor relative humidity should be within the range of 55% - 70%. As stated earlier, humidity is one of the driven factors for occupants' satisfaction and it reflects that occupants can experience satisfaction while staying in IRC with this current relative humidity level. This result too can verify one of the questionnaire data where most of the IRC staffs haven't noticed any mould/corrosion/decay on any IRC equipments and furniture in which these moisture-related impairments are caused by high relative humidity.

4.3.3 Temperature Measurement

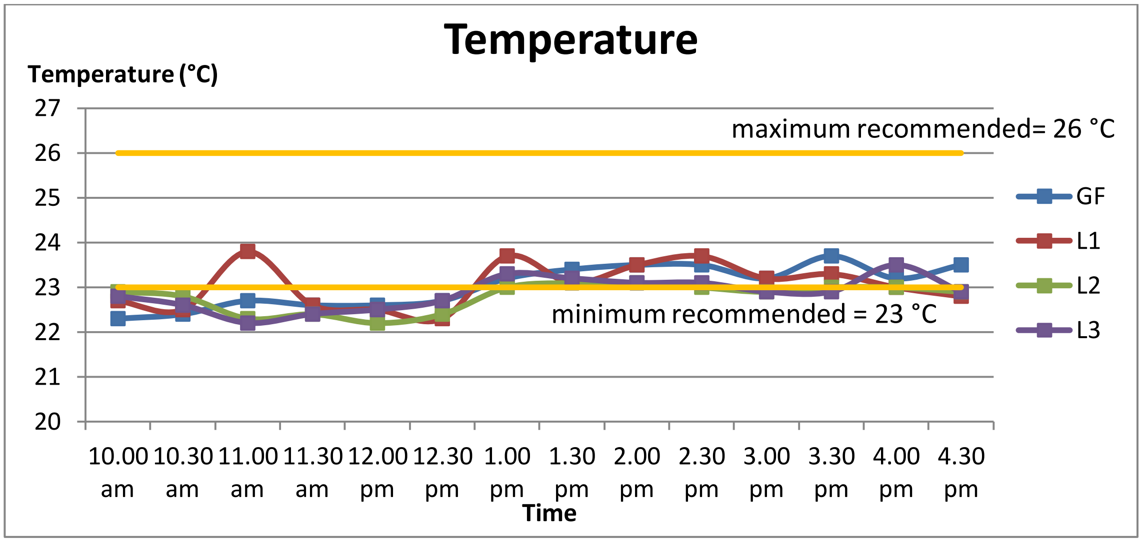


Figure 4.17 : Temperature Level of Location A

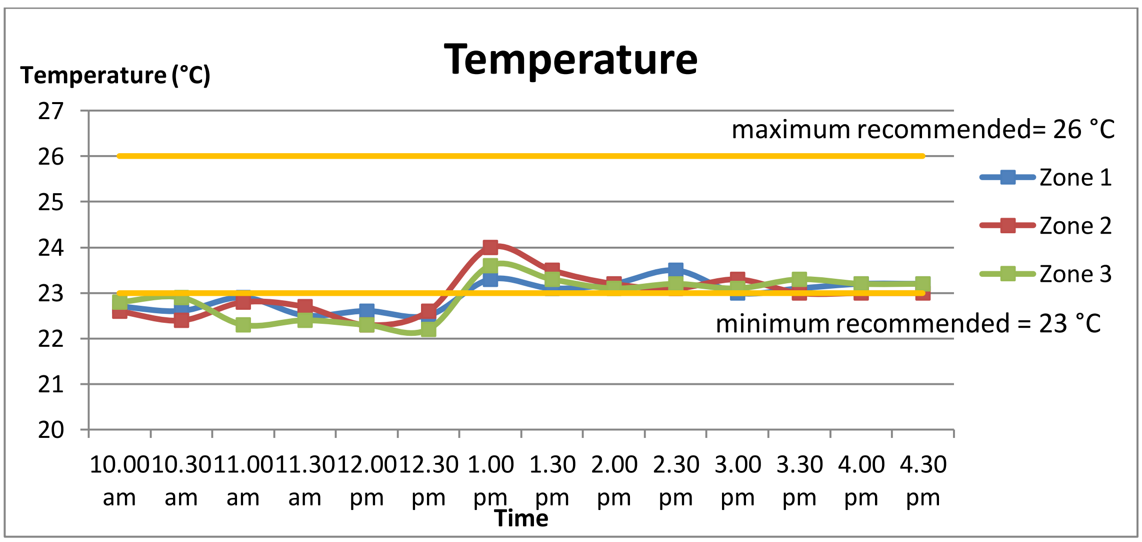


Figure 4.18 : Temperature Level of Location B

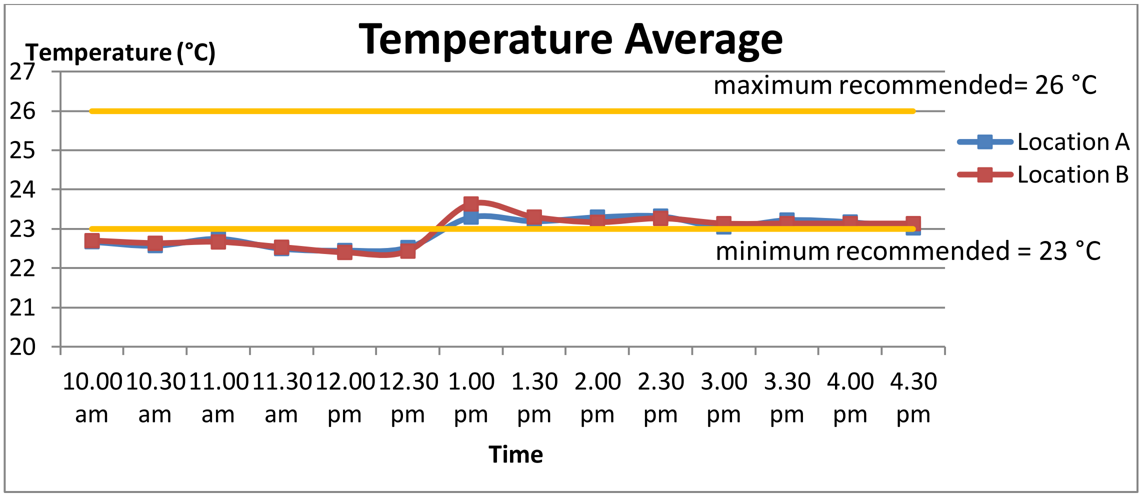


Figure 4.19 : Temperature Level Average

From Figure 4.17 and Figure 4.18, it can be seen that the temperature for both Location A and B at certain time for all floors and zones are below than the recommended range of 23 °C - 26 °C as specified in MS 1525 : 2007. However, MS 1525 : 2007 too has specified minimum temperature inside a building is 22 °C and this directly shows the temperature in IRC still comply with MS 1525 :2007 but it is not within the recommended range. Nonetheless, it is very important to ensure the temperature inside IRC to be within the recommended range.

4.2.4 Lighting Level Measurement

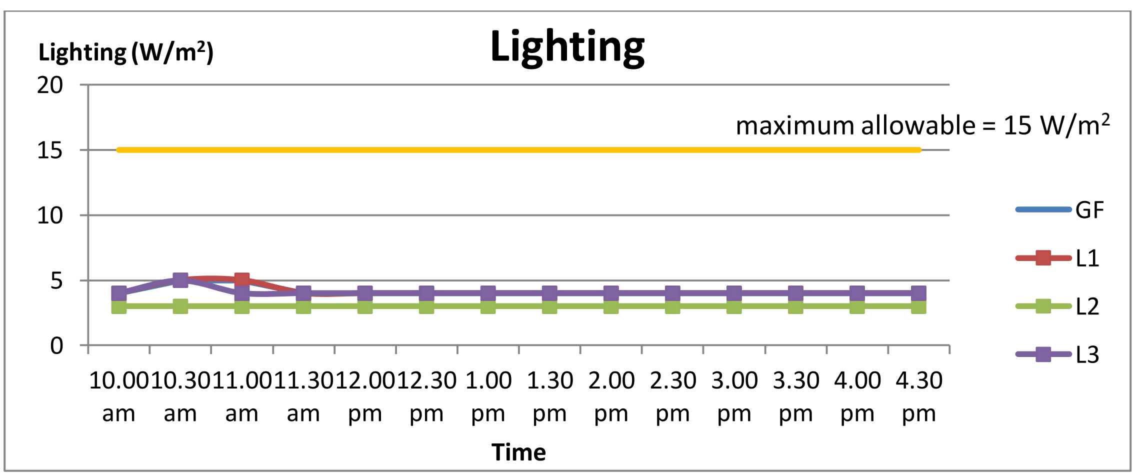


Figure 4.20 : Lighting Level of Location A

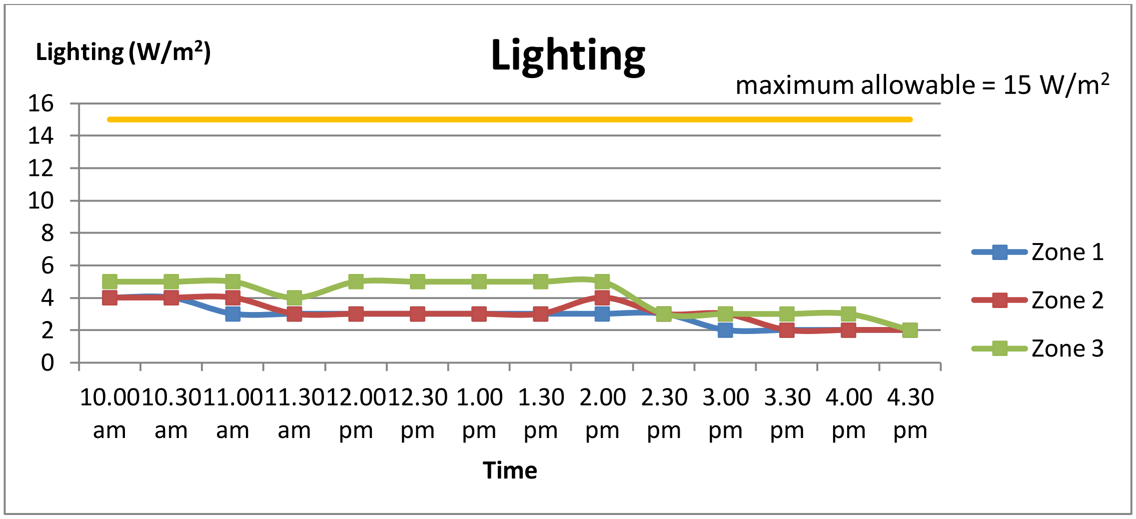


Figure 4.21 : Lighting Level of Location B

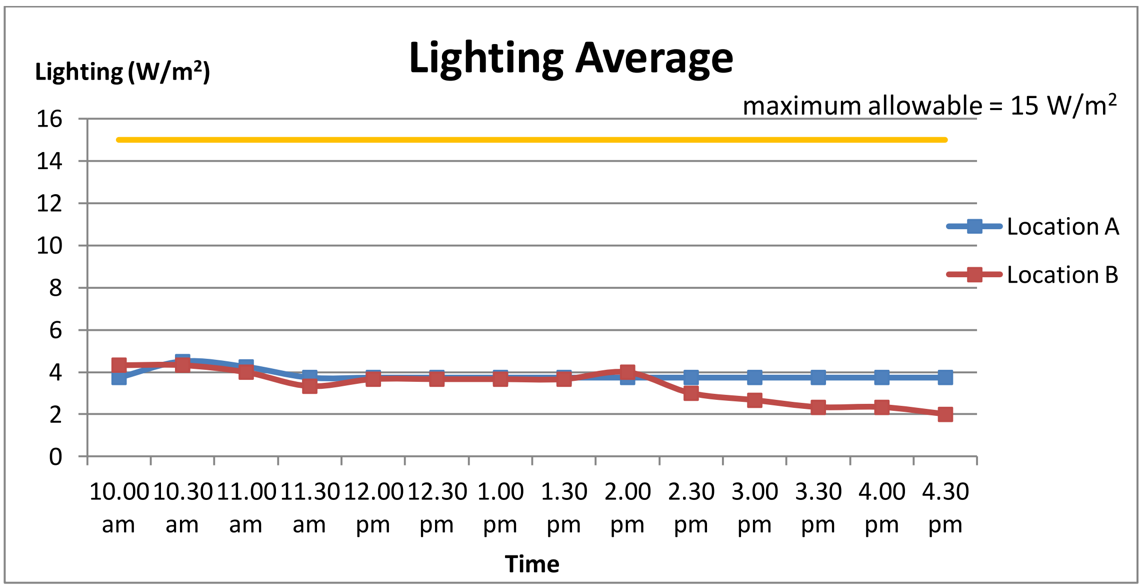


Figure 4.22 : Lighting Level Average

From all the figures above, it can be seen that the lighting power for both locations are below the prescribed value as specified in MS 1525 : 2007 which set maximum lighting power of 15 W/m^2 for classrooms and lecture theatres. This value is yet applicable for library too for the same purpose. From Figure 4.20 we can see the lighting power in reading area for all the levels in Location A are almost uniform throughout the day, and it differs from Location B. In Figure 4.21, the lighting power in all zones varied since their values are contributed from the sunlight due to their locations partially exposed to the natural light. Besides that, it can be interpreted the lighting power at location B could be recorded as low as 2 W/m^2 and this is due to the large height of ceiling built in with artificial light from the floor.

4.2.5 Noise Level Measurement

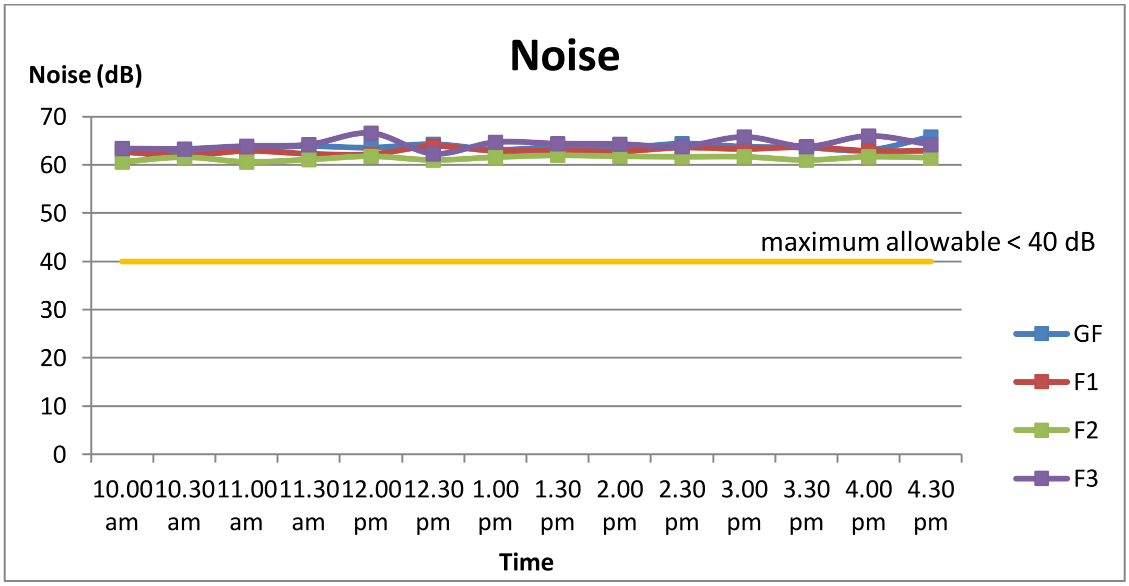


Figure 4.23 : Noise Level of Location A

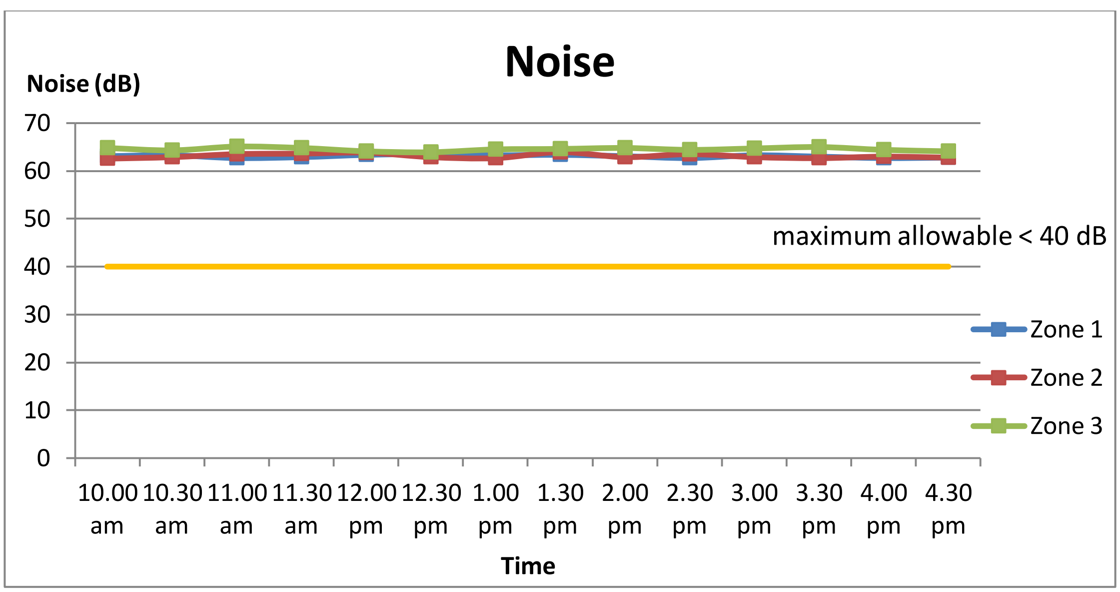


Figure 4.24 : Noise Level of Location B

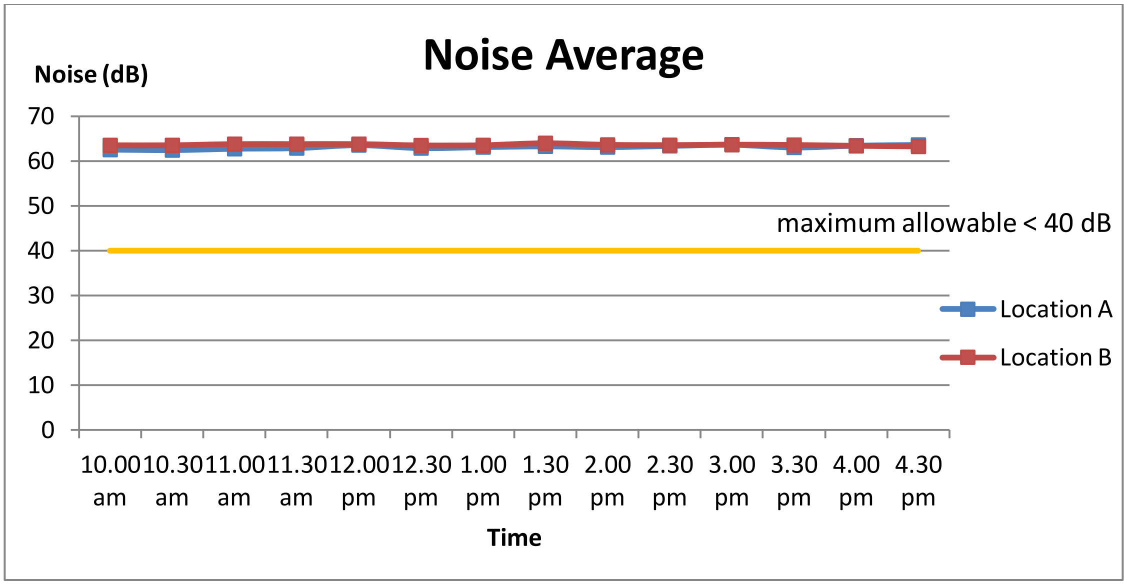


Figure 4.25 : Noise Level Average

Noise levels in IRC for both locations do not comply with the noise level as prescribed in GBI which is < 40 dB. The average of noise level is recorded to be within 62 dB – 64 dB. From Figure 4.23, it can be interpreted the noise levels are recorded highest in Level 3, and this can be justified by the reading area of Level 3 which is smaller as compared to other levels. However, outdoor noise does not contribute to this current noise measurement in IRC since the noise from outdoor is insignificant and negligible.

4.4 FINDINGS AND CONCLUSION

This section offered a detail explanation on the particular result obtained from both questionnaire survey and field measurement in order to enhance the understanding of interrelation between data analysis and field measurement that have been discussed in previous section.

4.4.1 Post Occupancy Evaluation Findings and Conclusion

From the data analysis on this survey, it can be interpreted that respondents perceived good air inside IRC, as most of them responded positively on particular air quality question. From the respondents' perception, majority of them satisfied with air smell the most as they perceived insignificant air smell besides experiencing fresh air. Almost half of them rated humidity inside IRC as neutral, which still can give them comfort since it has been stated too low or too high humidity can cause problems to the occupants health and comfort. Besides that, the result too shows they are satisfied with the lighting they perceived. However, respondents have expressed their dissatisfaction on temperature in which most of them specified temperature as cold. Meanwhile, it can be analyzed the respondents are pleased with the noise they perceived.

These analysis are further verified by severity index analysis for better visualization on which parameter respondents satisfied the most based on the their rankings as well as identify which parameter does not pass the severity index boundary. The parameter under severity boundary line indicates respondents' dissatisfaction as this parameter does not afford to give satisfaction as much as the one that is contributed by other parameters that have passed the severity boundary. From this analysis, it has been surfaced that noise is ranked as the most satisfied parameter perceived by the respondents and followed by air quality. Lighting ranking is crucial since it is just slightly above the severity index, and yet still can prove this parameter afforded to give satisfaction to the respondents. This can be verified further since most of them didn't experience a reflection or glare in their field of vision while staying at their particular IRC location. Temperature is the only parameter that did not pass the severity boundary thereby surfacing respondents' dissatisfaction on this parameter.

However, this severity index analysis is favorably argued with other survey question in which they have been asked to generally rank the top 3 most satisfied parameters given 4 parameter choices, which are air quality, temperature, noise and lighting without any specified questions. From this question, it has been stated that the respondents satisfied with air quality the most, followed by lighting and noise. Differ from the severity index analysis, noise is ranked as 3 instead of ranked as 1 in this general analysis.

Severity Index Analysis	General Analysis
1. Noise 2. Air Quality 3. Lighting	1. Air Quality 2. Lighting 3. Noise

Table 4.13 : Different Parameter Ranking

From these analyses, it is more reliable to consider the satisfaction from the severity index analysis as compared to the general analysis. This is because severity analysis involved more specific question for each parameter rather than general analysis which has solely asked the respondents to rank the parameter in general without any specification. The only similarity between these analysis is temperature as it is defined as the least satisfied parameter, in which can be translated this parameter gave dissatisfaction to the occupants compared to other parameters.

Despite that, Post Occupancy Comfort (EQ 15) in IRC did comply with the GBI requirement. Overall, the occupants still can express their comfort while staying in IRC as the respondents who have expressed dissatisfaction did not exceed 20%.

4.4.2 Field Measurement Findings and Conclusion

From all the field measurement conducted, it has been defined CO_2 level, relative humidity and lighting did comply with the recommended standard or prescribed value set by MS 1525 : 2007 and GBI. Meanwhile, temperature and noise level do not comply with the recommended range and standards.

4.4.2.1 Air Quality

For air quality covering CO_2 level and relative humidity, both parameters satisfy the standards. These show that occupants perceive good air in IRC and it is the driven factor in providing healthy library where conditions are good for learning and work activities. Besides that, low level of CO_2 has shown that IRC is provided with adequate ventilation. Otherwise, it is recommendable to install at least one CO_2 sensor at all main return points on each floor together with CO_2 monitoring and control system to facilitate continuous monitoring and alteration of outside air ventilation rates to each floor and ensure the independent control of ventilation rates to maintain CO_2 level below 1000 ppm. Besides that, encouraging plants in IRC is one of the methods to increase humidity that is just slightly above the minimum range. Humidity can be increased by watering the plants and they too capable to release water by having transpiration. It is better to provide ideal humidity inside IRC since there are significant number of respondents have claimed they experienced dry skin (See Appendix B-2) and this is due to low humidity even though relative humidity inside IRC has met the Malaysia standard.

4.4.2.2 Lighting

Proper lighting inside a building can enhance occupants work performance. This is because eye strain and fatigue can be reduced by the mean of effective and sufficient lighting that occupants perceived. It is very appropriate to provide lighting that is good enough for occupants' vision as well as capable to minimize glare and reflection.

Figure 4.26 : Lighting in IRC

4.4.2.3 Temperature

It has been discussed that the temperature at Location A and B at certain time below the recommended range as specified by MS 1525 : 2007. This further verified occupants' perception where most of the respondents rated ambient temperature inside IRC as cold, in which lead the severity index of this parameter does not pass the severity boundary. Even though this temperature is above the minimum value set by MS 1525 : 2007 but due to the dissatisfaction expressed by the occupants, it is important and recommendable to ensure the temperature inside IRC is within the recommended range for thermal comfort purpose.

Furthermore, non ideal temperature inside a building can affect the occupants' activities and performances. For instance, low temperature will help to lower the body temperature in which lead to the sleepiness. This can be justified where most of the respondents specifically users experiences sleepiness while staying in IRC (See Appendix B-2). This in turn will affect their productivity in doing their works or study because they tend to become irritable in order to resist their sleepiness. Besides that, uniformity of temperature is very important for the comfort purpose.

4.4.2.4 Noise

Noise is another parameter which does not comply with GBI standard. It has been observed this noise source comes from the air conditioner blower located in Ground Floor, Level 1 and Level 2.

Questionnaire survey is not verified by this current noise measurement since respondents expressed their satisfaction on noise by rating there is insignificant noise inside IRC when actually noise level is above the prescribed value of 40 dB. Apparently, the respondents already get used to the noise by time they are staying in IRC that they tend to neglect the significance of the noise. Besides that, that is probably due to their location in IRC quite far away from air conditioner blowers which are built in the center of the reading zone for each floor. It has been found that the level and frequency of noise are acceptable to one person and while opposite to another since the amount of noise is perceived differently by every individual. Excessive indoor noise can reduce individual productivity in doing their work. It is very important to ensure the noise level to be below the prescribed value since library supposed to be in quiet without any distraction noise. However, it has been observed that there is no noise coming from outside since IRC building is fully enclosed.

Figure 4.27 : Air Conditioner Blower

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

5.1 CONCLUSION

This study has justified the importance of indoor environmental quality by dragging together issues that are relevant to the sustainable development and one of the driving forces in achieving that is green building. The detailed concepts related to green building and the indoor environmental details have been analyzed and examined by reviewing a number of literary sources as to reinforce the relevancy of the study.

Data analysis and findings that have been discussed in the previous chapter have surfaced the occupants' opinions on each IEQ parameters based on solely what they have experienced and perceived. Overall, it has been specified temperature is the only parameter IRC occupants did not satisfied with. Besides that, occupants' satisfaction and comfort too has been evaluated, and the percentage of occupants' dissatisfaction and discomfort is within the range of that has been specified by Green Building Index (GBI).

Nevertheless, from the field measurement conducted, it has been stated that temperature and noise do not comply with the recommended range or prescribed value as specified by MS 1525 : 2007 and GBI while other parameters do comply. We can see there is conflict data for noise where IRC occupants are very satisfied with the noise in IRC when actually the current noise level is above the prescribed value. In the meantime, overall occupants still can express satisfaction despite some of the parameters do not comply with the standards. Nonetheless, in order to ensure the betterment of IRC in longer term as well as to enhance the occupants' comfort and satisfaction, some improvement and rectification should be commenced in order to rectify the non compliance parameters.

UTP Management specifically Health Safety and Environment (HSE) Department is the management responsible for IRC improvement and betterment. They should develop corrective plan and initiative in order to rectify and improve IRC building performance to ensure the betterment of indoor environment. In this chapter, some recommendations are provided as guidelines to assist HSE department for IRC indoor environment improvement. In the meantime, as a conclusion, all of the objectives of this study are well achieved.

5.2 INFORMATION RESOURCE CENTRE (IRC) BUILDING IMPROVEMENT RECOMMENDATIONS

This section will provide the recommendations for non-compliance parameters in order to enhance the building performance as well as to ensure these parameters comply with the Malaysia standard in this tropical climate.

5.2.1 Temperature Betterment Recommendations

Temperature is one of the factors that can affect thermal comfort of occupants inside a building and thus, betterment of this parameter should be commenced in IRC. The corrective measures that can be taken in order to ensure the temperature within the recommended range is by changing the temperature set points and ensure the calibration accuracy of thermostats.

Good indoor temperature control can be achieved by applying good standard engineering practices. Maintenance of heating and air conditioning systems should be commenced in order to meet heating and cooling loads as well as ensure these systems have sufficient capacity. Single thermostat should not be installed in large sections of a building but that large sections should be treated as multiple thermal zones instead with multiple thermostats installed to control the indoor temperature.

Utilization of the equipment that encourages personal control of temperature could be implemented too for longer term. Comfort system controls for all shared multi-occupants spaces should be provided to enable adjustments to suit group needs and preferences. In the meantime, airflow inside IRC too should be considered, and this can be done by adjusting or balancing airflow to various portions of the building as demanded in retaining desired temperature.

5.2.2 Noise Betterment Recommendations

Indoor noise levels are primarily influenced by the internal noise which comes from the HVAC or MVAC equipment as well as people activities inside a building. As stated in Chapter 2, noise pollution can be controlled by reducing noise at the source, block the path of noise, increase the path length as well as protecting the noise recipients. Practically in IRC, it is more applicable to minimize the noise source by installing the sound absorber at air conditioner blower by the mean of insulator, rubber and other noise absorber materials.

Besides that, another alternative that can be taken into action is to check the mechanical parts of the HVAC system if they are well-functioned. Noise commonly comes from the fan and it is very crucial to conduct fan inspection. As time passed by, the movement of the fan blades and the air are maybe blocked by dirt and other materials as well as other mechanical part may block the fan blades to rotate properly hence generating the unwanted noise to the surrounding. Imbalance of the fan may occur too due to the dysfunctional of bearings of the fan motor, hence this mechanical part should be checked often. Otherwise, if the noise still cannot be rectified, compressor should be replaced for the noise betterment.

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5.3 FUTURE WORK RECOMMENDATION

Even though the study only focuses on the current measurements of IEQ and occupants' satisfaction as well as the improvement recommendations, it is recommendable for UTP management to take the recommendations into practice in order to improve IRC indoor environment. By achieving and maintaining good indoor environment, it will enhance occupants' comfort while staying in IRC. This too will improve their work performances and ensure the occupants' satisfaction as well as avoiding bad health symptoms from attacking them.

However, it would be better if more responses are gained through Post Occupancy Evaluation since more responses will enhance the accuracy of the result in achieving the objectives of the study. Besides that, the equipments to measure Particulate Matters (PM) and Volatile Organic Compounds (VOCs) such as Suspended Particulate Meter Monitor and VOC Meter should be provided to determine their current level in IRC since the work activities done by the occupants as well as the equipments in IRC can lead to the generation of PM and VOCs, respectively. Besides that, it is very important to measure PM and VOCs level since respondents have claimed they experienced symptoms like coughing and chest dizziness which are caused by PM and VOCs. By gaining current measurements of PM and VOCs in IRC, their measurements can be evaluated if they comply with the standards.

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APPENDIX A

(POST OCCUPANCY EVALUATION:

QUESTIONNAIRE SURVEY FORM)

UNIVERSITI TEKNOLOGI PETRONAS

INFORMATION RESOURCE CENTER (IRC) INDOOR ENVINROMENTAL ASSESSMENT - USERS

This questionnaire is prepared as one of the requirement to complete my final year project, which is Indoor Environmental Quality (IEQ) Assessment in Information Resource Centre (IRC), UTP. Indoor Environmental Quality (IEQ) simply refers to the quality of environment, overall comfort of a building's interior and the comfort and the health of its occupants. The purpose of this study is to assess the current indoor environment in IRC and identify its performance and condition, as well as gaining feedback from respondents expressing their opinions while staying in IRC. As to achieve those, I need your participation in this pilot study and looking forward to receive your positive reply. Your cooperation is greatly appreciated. Thank you.

SECTION A : DEMOGRAPHY

1. Gender
   - ☐ Male
   - ☐ Female

2. Occupation
   - ☐ Administrative Staff
   - ☐ Lecturer
   - ☐ Student
   - ☐ Other : ………………

3. How frequent do you go to IRC?
   - ☐ Always

- Seldom
- Rare
- Never

4. Which floor do you always use when spending time in IRC?
   - Ground floor
   - Level 1
   - Level 2
   - Level 3

5. Which location do you always use while spending time in IRC?
   - Post Graduate Lounge
   - Circulation Centre
   - IT Section
   - Thesis room
   - Reading Area
   - PG Research Room
   - Open Access collection
   - Discussion Room
   - Other : …………………………………………

6. How long do you spend your time in IRC for every visit?
   - Less than 1 hour
   - 1 hour – 2 hours
   - 2 hours – 4 hours
   - 4 hours – 6 hours
   - 6 hours - 8 hours

7. Do you use any of these at IRC? If yes, please tick. (Check all that apply)
   - Photocopier
   - Laser printer
   - Facsimile (fax)
   - Self-copying (carbonless) paper
   - Glue
   - Correction fluid
   - Other strong smelling chemicals
   - No

SECTION B : HEALTH CONDITION

8. In general, how would you rate your health?

(Very Poor)	1	2	3	4	5	(Excellent)
	□	□	□	□	□	

9. Have you experienced any of these symptoms while/after spending time in IRC? (Check all that apply)
   - □ Allergy
   - □ Coughing
   - □ Eye irritation
   - □ Headache
   - □ Itchy throat
   - □ Sneezing
   - □ Dry skin
   - □ Tightness
   - □ Chest dizziness
   - □ Short of breath
   - □ Respiratory symptoms
   - □ Blocked nose
   - □ Dark circle under eyes
   - □ Nose rubbing
   - □ Conjunctivitis
   - □ Asthma symptoms
   - □ Runny nose
   - □ Wheezing
   - □ Teary eyes
   - □ Sleepy
   - □ Other : ……………………………………

SECTION C : IRC OBSERVATION

10. Did you notice if books in IRC have these following problems? (Check all that apply)
    - □ Smell come from the books
    - □ A thin haze
    - □ A patch of spots

- ☐ Powdery flaking layer, normally white, black, or grey on the surface of the book or pages
- ☐ Fuzzy growth
- ☐ Strange spots or stains
- ☐ No, haven't noticed anything
- ☐ Other : ……………………………………..

Air Quality

11. How would you rate air humidity in IRC?

(Too humid)	1	2	3	4	5	(Too dry)
	☐	☐	☐	☐	☐	

12. Is the air fresh or stale?

(Stale)	1	2	3	4	5	(Fresh)
	☐	☐	☐	☐	☐	

13. Does the air smell?

(Smell)	1	2	3	4	5	(No smell)
	☐	☐	☐	☐	☐	

Temperature

14. How would you rate the temperature in IRC?

(Too cold)	1	2	3	4	5	(Too warm)
	☐	☐	☐	☐	☐	

Lighting

15. How would you rate the lighting at your particular IRC spot?

(Too dim)	1	2	3	4	5	(Too bright)
	☐	☐	☐	☐	☐	

16. Do you experience a reflection or glare in your field of vision at your particular IRC spot?
    - ☐ Yes
    - ☐ No

Noise

17. Is there any significant distraction from background noise in IRC? (example : air con duct)

(Very significant) 1 2 3 4 5 (Not significant)

☐ ☐ ☐ ☐ ☐

SECTION D : OPINION AND KNOWLEDGE

18. Do you understand sustainable development concept?

(Not understand) 1 2 3 4 5 (Understand)

☐ ☐ ☐ ☐ ☐

19. Do you think climate change is one of the factors that contribute to poor indoor environment in a building?

(Strongly Disagree) 1 2 3 4 5 (Strongly Agree)

☐ ☐ ☐ ☐ ☐

20. Do you agree green building is one of the solutions to reduce global warming and climate change?

☐ Yes
☐ Partially
☐ No

21. Is Indoor Environmental Quality assessment important for IRC?

(Strongly Disagree) 1 2 3 4 5 (Strongly Agree)

☐ ☐ ☐ ☐ ☐

22. Do you think poor indoor environment quality (if any) in IRC have negative effects on your work performance/study?

(Strongly Disagree) 1 2 3 4 5 (Strongly Agree)

☐ ☐ ☐ ☐ ☐

23. Overall, how would you rate your comfort and satisfaction with the current indoor environment in IRC?

(Very poor)	1	2	3	4	5	(Excellent)
	☐	☐	☐	☐	☐	

24. Please rank the top three (3) parameters of indoor environmental quality (IEQ) that you are most satisfied with
    - ☐ Air Quality
    - ☐ Temperature
    - ☐ Noise
    - ☐ Lighting

INFORMATION RESOURCE CENTER (IRC) INDOOR ENVIRONMENTAL ASSESSMENT - IRC STAFFS

This questionnaire is prepared as one of the requirement to complete my final year project, which is Indoor Environmental Quality (IEQ) Assessment in Information Resource Centre (IRC), UTP. Indoor Environmental Quality (IEQ) simply refers to the quality of environment, overall comfort of a building's interior and the comfort and the health of its occupants. The purpose of this study is to assess the current indoor environment in IRC and identify its performance and condition, as well as gaining feedback from respondents expressing their opinions while staying in IRC. As to achieve those, I need your participation in this pilot study and looking forward to receive your positive reply. Your cooperation is greatly appreciated. Thank you.

SECTION A : DEMOGRAPHY

1. Gender
   - ☐ Male
   - ☐ Female

2. Age
   - ☐ Under 21
   - ☐ 21-35
   - ☐ 36-50
   - ☐ 51-65

3. Designation in IRC department
   - ☐ Senior Manager

- Manager
- Senior Executive
- Executive
- Assistant Executive
- Administrative Assistant
- Other : ………………………………………

4. How long have you worked here?
   - 1 – 2 years
   - 2 – 4 years
   - 5 – 7 years
   - 8 – 10 years
   - 11 – 15 years
   - More than 15 years

5. Where do you spend most of your time at work?
   - Circulation Counter
   - Information Reference Service Room
   - Post Graduate Lounge
   - Circulation Centre
   - IT Section
   - Thesis room
   - Office
   - Reading Area
   - PG Research Room
   - Open Access collection
   - Discussion Room
   - Other : …………………………………………

6. How long do you spend your working hours in IRC per day?
   - Less than 4 hours
   - 4 hours – 6 hours
   - 6 hours – 8 hours
   - More than 8 hours

7. Do any of your work activities generate dust/particulates or odor?
   - Yes
   - No

8. Do you use any of these at work? (Check all that apply)
   - ☐ Photocopier
   - ☐ Laser printer
   - ☐ Facsimile (fax)
   - ☐ Self-copying (carbonless) paper
   - ☐ Cleanser
   - ☐ Glue
   - ☐ Correction fluid
   - ☐ Other strong smelling chemicals
   - ☐ No, I do not use any of these at work

SECTION B : HEALTH CONDITION

9. In general, how would you rate your health?

(Very Poor)	1	2	3	4	5	(Excellent)
	☐	☐	☐	☐	☐	

10. In the LAST FOUR WEEKS AT WORK, did you experience any of the following symptoms? (Check all that apply)
    - ☐ Allergy
    - ☐ Coughing
    - ☐ Eye irritation
    - ☐ Headache
    - ☐ Itchy throat
    - ☐ Sneezing
    - ☐ Dry skin
    - ☐ Tightness
    - ☐ Chest dizziness
    - ☐ Short of breath
    - ☐ Respiratory symptoms
    - ☐ Blocked nose
    - ☐ Dark circle under eyes
    - ☐ Nose rubbing
    - ☐ Conjunctivitis
    - ☐ Asthma symptoms
    - ☐ Runny nose
    - ☐ Wheezing

- ☐ Teary eyes
- ☐ Sleepy
- ☐ Other : ……………………………………

SECTION C : IRC OBSERVATION

11. Based on your observation for all this while in IRC, which have you noticed? (Check all that apply)
    - ☐ Unusual odors
    - ☐ Stuffy air
    - ☐ Dry air
    - ☐ Dusty
    - ☐ Work area is too cool
    - ☐ Work area is too warm
    - ☐ The temperature vary from room to room
    - ☐ Nothing

12. Which any of these water leaks occurred within the past year, if any? (Check all that apply)
    - ☐ Plumbing leaks
    - ☐ Roof leaks
    - ☐ Flooding
    - ☐ Sewage backups
    - ☐ Window leaks
    - ☐ No water leaking has occured
    - ☐ Other : ………………………..

13. Have you ever noticed the mould growth/corrosion/decay on, if any of these? (Check all that apply)
    - ☐ Books
    - ☐ Wall
    - ☐ Ceiling
    - ☐ Floor
    - ☐ Carpet
    - ☐ Shelf or stack
    - ☐ Furniture
    - ☐ Chair
    - ☐ Table
    - ☐ No

- ☐ Other : ……………………..

14. Did you notice if books in IRC have these following problems? (Check all that apply)
    - ☐ Smell come from the books
    - ☐ A thin haze
    - ☐ A patch of spots
    - ☐ Powdery flaking layer, normally white, black, or grey on the surface of the book or pages
    - ☐ Fuzzy growth
    - ☐ Strange spots or stains
    - ☐ No
    - ☐ Other : ………………

15. During the past year, have the following changes taken place within 5 meters of your current workstation? (Check all that apply)
    - ☐ New carpeting
    - ☐ Walls painted
    - ☐ New furniture
    - ☐ New partitions
    - ☐ New wall coverings
    - ☐ Water damage
    - ☐ No changes has taken place
    - ☐ Other : ………………

Air Quality

16. How would you rate air humidity in IRC?

	1	2	3	4	5	
(Too humid)	☐	☐	☐	☐	☐	(Too dry)

17. Is the air fresh or stale?

	1	2	3	4	5	
(Stale)	☐	☐	☐	☐	☐	(Fresh)

18. Does the air smell?

	1	2	3	4	5	
(Smell)	☐	☐	☐	☐	☐	(No smell)

Temperature

19. How would you rate the temperature in IRC?

(Too cold)	1	2	3	4	5	(Too warm)
	☐	☐	☐	☐	☐	

Lighting

20. How would you rate the lighting at your workstation?

(Too dim)	1	2	3	4	5	(Too bright)
	☐	☐	☐	☐	☐	

21. Do you experience a reflection or glare in your field of vision at your workstation?
    - ☐ Yes
    - ☐ No

Noise

22. Is there any significant distraction from background noise in IRC? (example : air con duct)

(Very significant)	1	2	3	4	5	(Not significant)
	☐	☐	☐	☐	☐	

SECTION D : OPINION AND KNOWLEDGE

23. Do you understand sustainable development concept?

(Not understand)	1	2	3	4	5	(Understand)
	☐	☐	☐	☐	☐	

24. Do you think climate change is one of the factors that contribute to poor indoor environment in a building?

(Strongly Disagree)	1	2	3	4	5	(Strongly Agree)

☐ ☐ ☐ ☐ ☐

25. Do you agree green building is one of the solutions to reduce global warming and climate change?
    - ☐ Yes
    - ☐ Partially
    - ☐ No

26. Is Indoor Environmental Quality assessment important for IRC?

(Strongly Disagree)	1	2	3	4	5	(Strongly Agree)
	☐	☐	☐	☐	☐	

27. Do you think poor indoor environment quality (if any) in IRC have negative effects on your work performance?

(Strongly Disagree)	1	2	3	4	5	(Strongly Agree)
	☐	☐	☐	☐	☐	

28. Overall, how would you rate your comfort and satisfaction with the current indoor environment in IRC?

(Very poor)	1	2	3	4	5	(Excellent)
	☐	☐	☐	☐	☐	

29. Please rank the top three (3) parameters of indoor environmental quality (IEQ) that you are most satisfied with
    - ☐ Air Quality
    - ☐ Temperature
    - ☐ Noise
    - ☐ Lighting

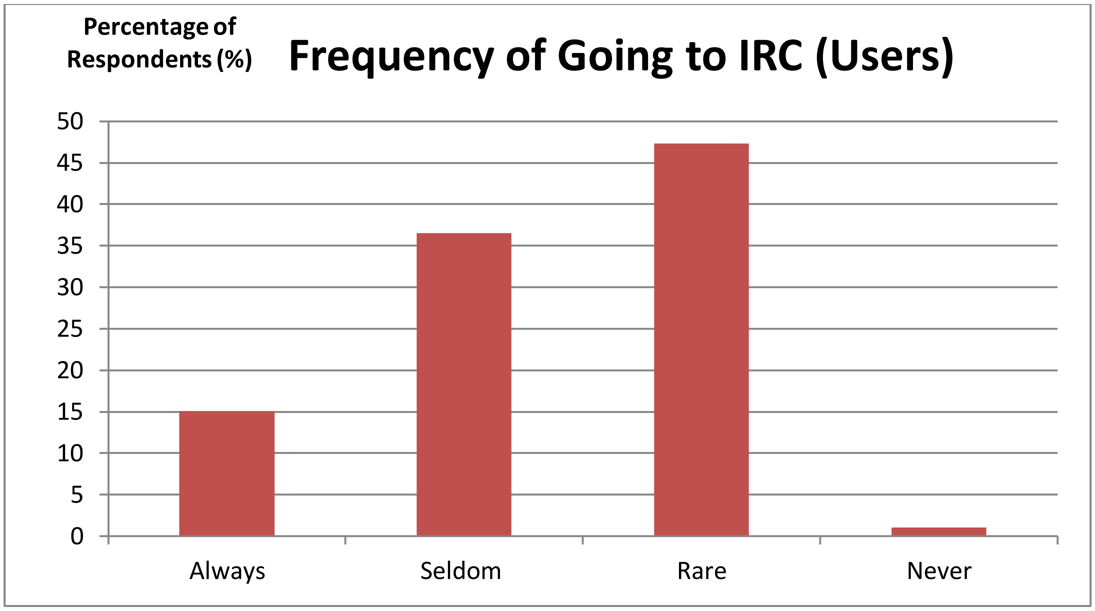
30. Are there any other factors that contribute to the quality of indoor environment in IRC? If yes, please state.

____

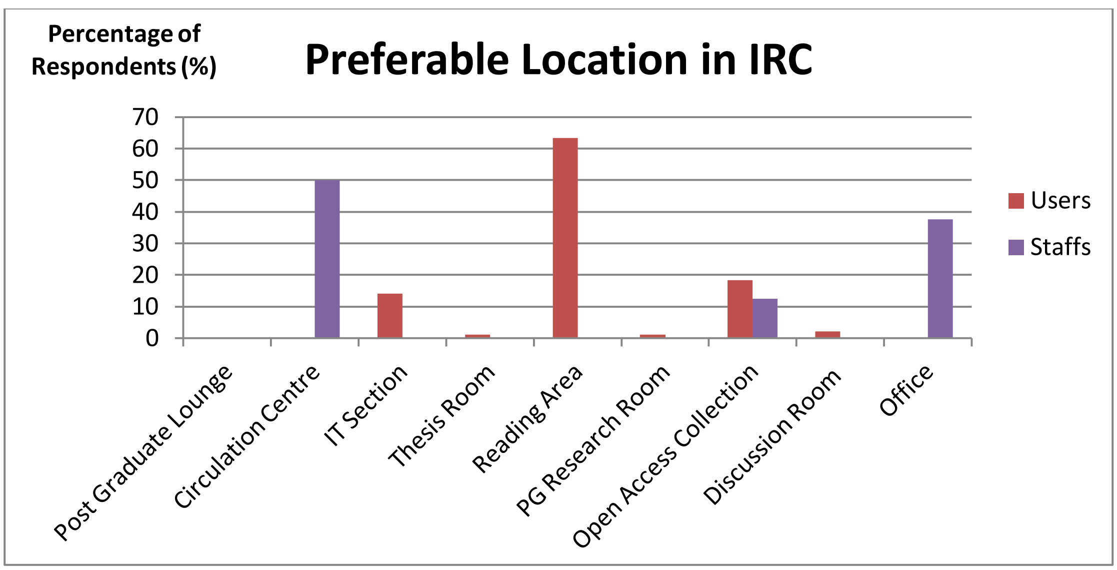
____

APPENDIX B

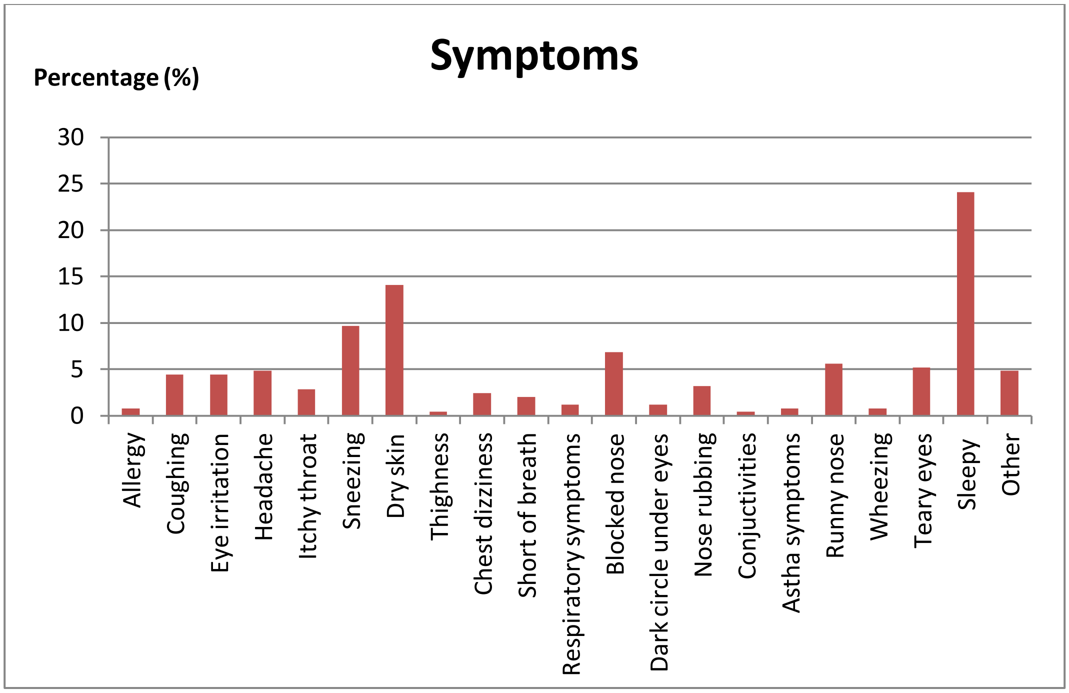
(POST OCCUPANCY EVALUATION: RESULT)



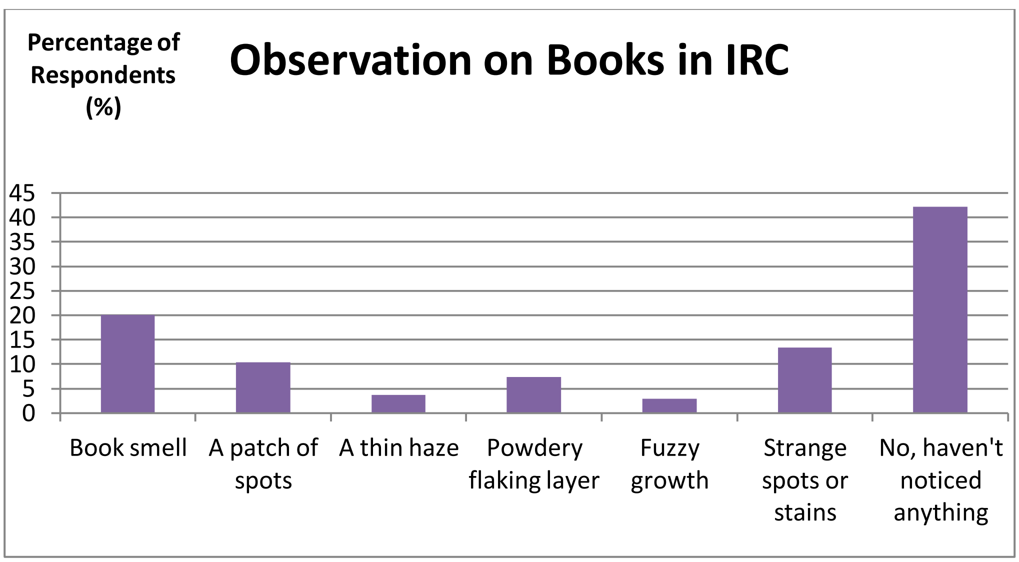
Frequency of Going to IRC (Users)



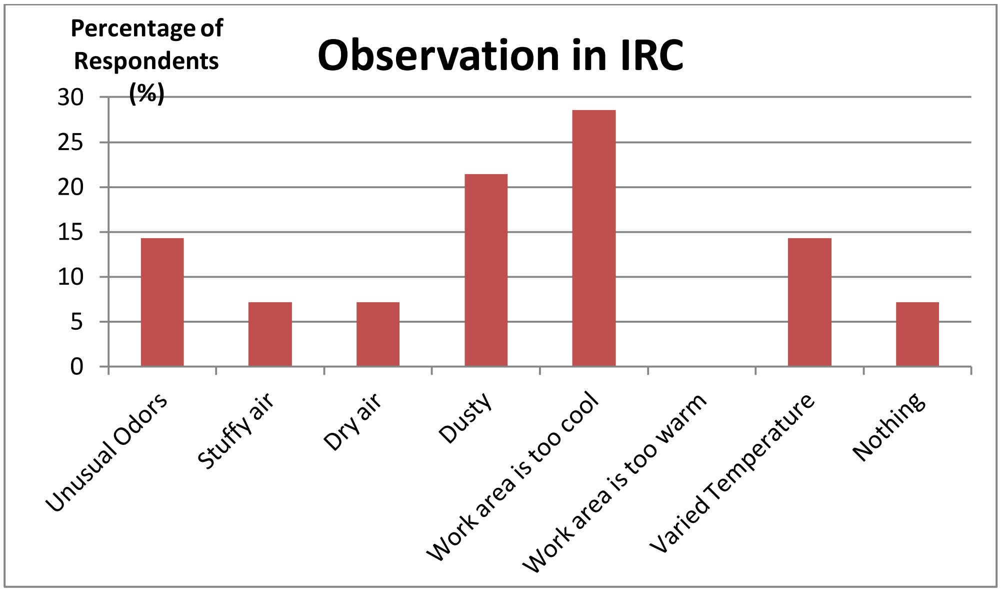
Preferable Location in IRC



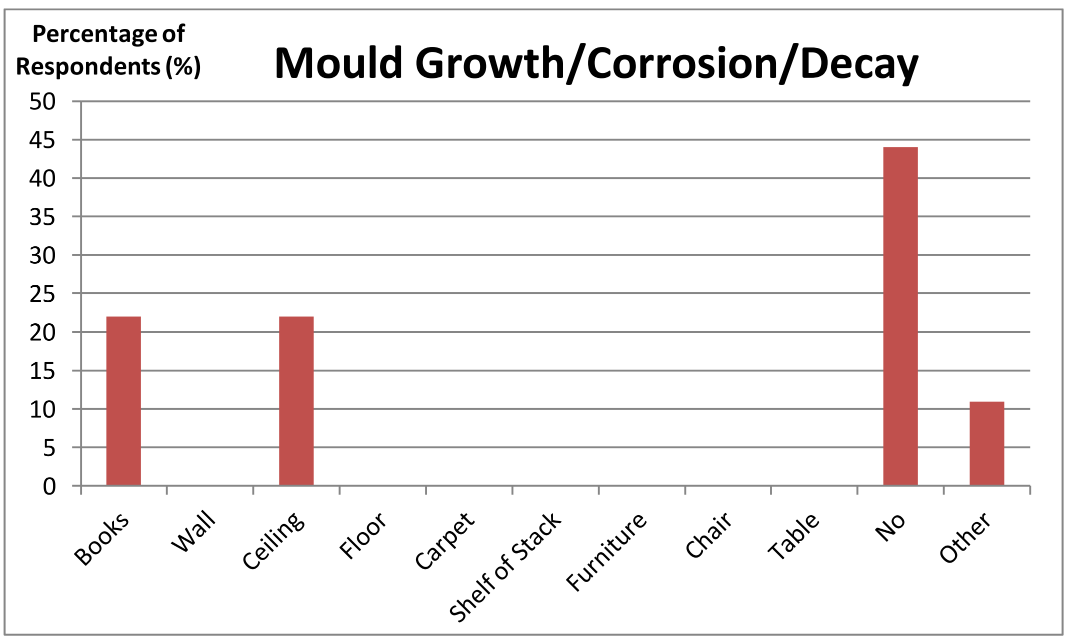
Symptoms Experienced by Users in IRC



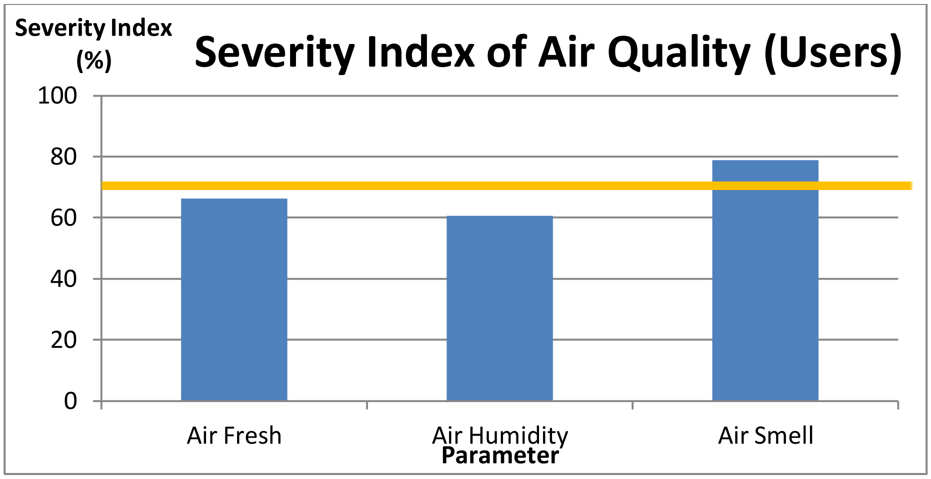
Observation on Books in IRC



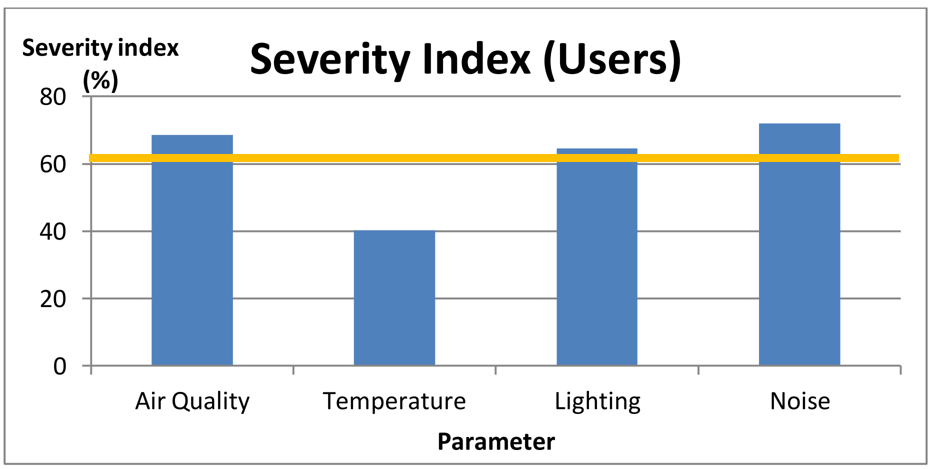
General Observation in IRC (IRC Staffs)



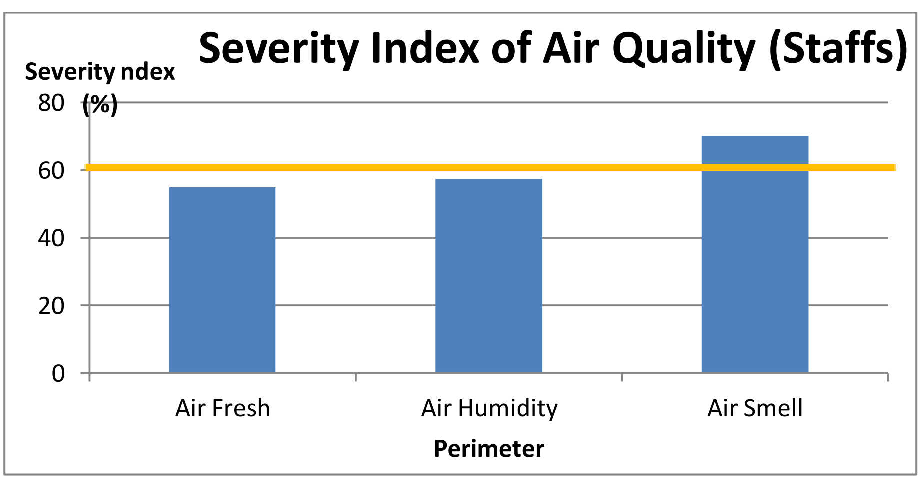
Mould Growth / Corrosion / Decay Observation (IRC Staffs only)



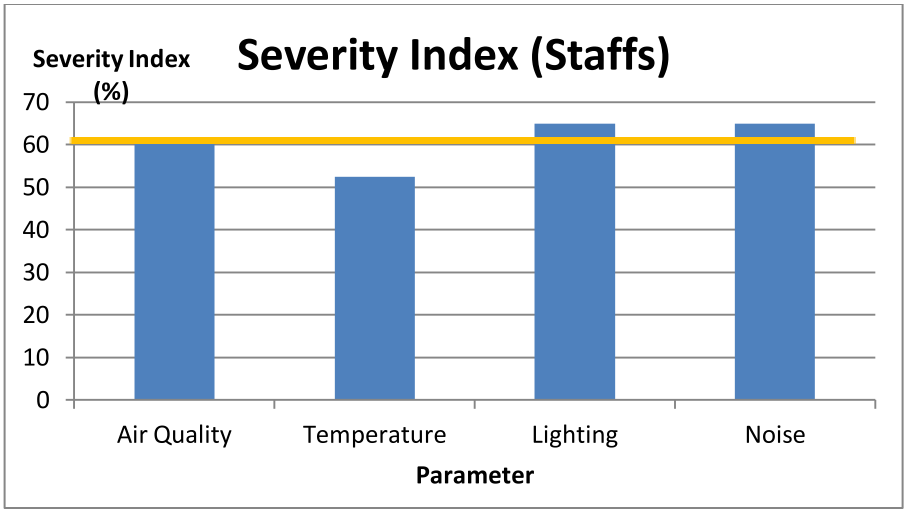
Severity Index of Air Quality (Users)



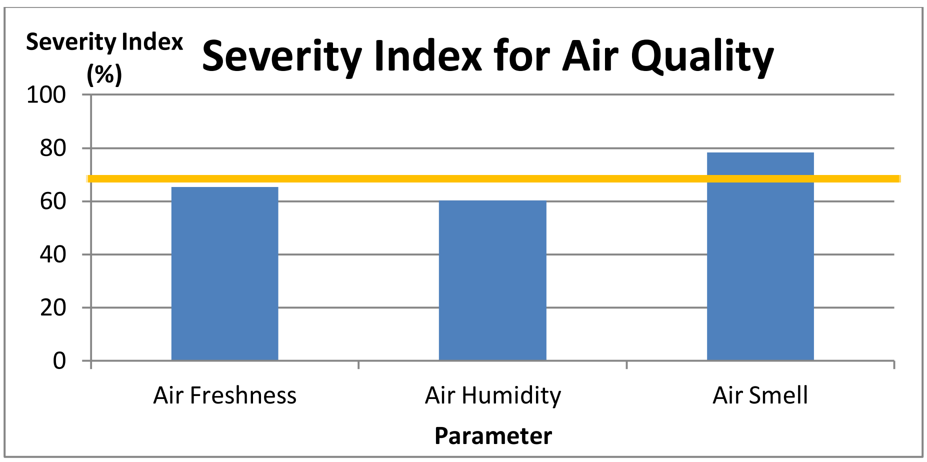
Severity Index for User



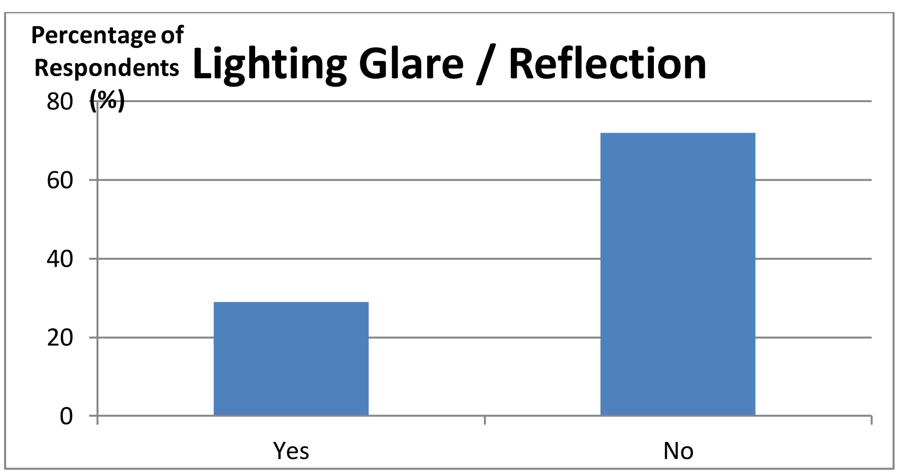
Severity Index of Air Quality (IRC Staffs)



Severity Index for IRC Staffs



Severity Index of Air Quality (Combination Analysis)



Lighting Glare / Reflection Perceived by IRC Staffs and Users

APPENDIX C

(FIELD MEASUREMENT: RESULT)

Parameter : Carbon Dioxide, CO_2 (ppm)

Location A

Date : 18th July 2013

	10.00 am	10.30 am	11.00 am	11.30 am	12.00 pm	12.30 pm	1.00 pm	1.30 pm	2.00 pm	2.30 pm	3.00 pm	3.30 pm	4.00 pm	4.30 pm
GF	517	579	556	573	588	586	544	585	563	576	646	640	580	594
L1	565	549	555	558	550	576	627	570	596	624	505	607	604	572
L2	536	541	556	566	554	527	539	530	519	507	566	502	556	537
L3	587	560	560	568	543	526	534	526	523	565	509	548	589	508
AVERAGE	551.25	557.25	556.75	566.25	558.75	553.75	561	552.75	550.25	568	556.5	574.25	582.25	552.75

Location B

Date : 23rd July 2013

	10.00 am	10.30 am	11.00 am	11.30 am	12.00 pm	12.30 pm	1.00 pm	1.30 pm	2.00 pm	2.30 pm	3.00 pm	3.30 pm	4.00 pm	4.30 pm
Zone 1	530	515	526	494	504	510	493	518	500	484	506	503	499	508
Zone 2	503	499	511	505	517	506	502	502	504	505	509	510	506	505
Zone 3	519	534	532	526	528	514	515	524	527	508	530	530	515	517
AVERAGE	517.33	516.00	523.00	508.33	516.33	510.00	503.33	514.67	510.33	499.00	515.00	514.33	506.67	510.00

Parameter : Relative Humidity (%)

Location A

Date : 18th July 2013

	10.00 am	10.30 am	11.00 am	11.30 am	12.00 pm	12.30 pm	1.00 pm	1.30 pm	2.00 pm	2.30 pm	3.00 pm	3.30 pm	4.00 pm	4.30 pm
GF	55.2	56.1	57.9	57.7	58	57	56.3	56.6	57.7	57.5	57.3	58.5	56.8	56.1
L1	58.6	58.3	57.3	57.5	57.7	58.2	58.9	58.8	57.1	57.8	57.5	57.5	59.4	59.1
L2	59.7	56.9	58.3	58	58.7	58.1	58.2	57.7	57.7	57.7	58.1	57.7	58	58.8
L3	60.2	58.2	58.8	58.1	57.9	58	58.9	57.5	58.4	58	58.2	57.8	57.1	58.8
AVERAGE	58.425	57.375	58.075	57.825	58.075	57.825	58.075	57.65	57.725	57.75	57.775	57.875	57.825	58.2

Location B

Date : 23rd July 2013

	10.00 am	10.30 am	11.00 am	11.30 am	12.00 pm	12.30 pm	1.00 pm	1.30 pm	2.00 pm	2.30 pm	3.00 pm	3.30 pm	4.00 pm	4.30 pm
Zone 1	55.4	56.1	55.7	56.3	57.8	57.1	56.9	56.5	55.9	55.6	57.1	56.7	56.4	56.2
Zone 2	57.8	57.2	56.4	55.9	56.1	56.5	55.8	55.4	56.6	57.1	56.5	57.5	57.3	57.4
Zone 3	57.1	56.4	56.7	57.7	57.1	56.8	56.3	56.8	56.9	57.1	57.7	56.5	56.5	58.9
AVERAGE	56.77	56.57	56.27	56.63	57.00	56.80	56.33	56.23	56.47	56.60	57.10	56.90	56.73	57.50

Parameter : Temperature (^{o}C)

Location A

Date : 18th July 2013

	10.00 am	10.30 am	11.00 am	11.30 am	12.00 pm	12.30 pm	1.00 pm	1.30 pm	2.00 pm	2.30 pm	3.00 pm	3.30 pm	4.00 pm	4.30 pm
GF	22.3	22.4	22.7	22.6	22.6	22.7	23.2	23.4	23.5	23.5	23.2	23.7	23.2	23.5
L1	22.7	22.5	23.8	22.6	22.5	22.3	23.7	23.1	23.5	23.7	23.2	23.3	23	22.8
L2	22.9	22.8	22.3	22.4	22.2	22.4	23	23.1	23.1	23	22.9	23	23	22.9
L3	22.8	22.6	22.2	22.4	22.5	22.7	23.3	23.2	23.1	23.1	22.9	22.9	23.5	22.9
AVERAGE	22.68	22.58	22.75	22.50	22.45	22.53	23.30	23.20	23.30	23.33	23.05	23.23	23.18	23.03

Location B

Date : 23rd July 2013

	10.00 am	10.30 am	11.00 am	11.30 am	12.00 pm	12.30 pm	1.00 pm	1.30 pm	2.00 pm	2.30 pm	3.00 pm	3.30 pm	4.00 pm	4.30 pm
Zone 1	22.7	22.6	22.9	22.5	22.6	22.5	23.3	23.1	23.2	23.5	23	23.1	23.2	23.2
Zone 2	22.6	22.4	22.8	22.7	22.3	22.6	24	23.5	23.2	23.1	23.3	23	23	23
Zone 3	22.8	22.9	22.3	22.4	22.3	22.2	23.6	23.3	23.1	23.2	23.1	23.3	23.2	23.2
AVERAGE	22.70	22.63	22.67	22.53	22.40	22.43	23.63	23.30	23.17	23.27	23.13	23.13	23.13	23.13

Do not comply with MS 1525 : 2007, temperature = 23 ^{o}C – 26 ^{o}C

Parameter : Lighting (W/m^2)

Location A

Date : 18th July 2013

	10.00 am	10.30 am	11.00 am	11.30 am	12.00 pm	12.30 pm	1.00 pm	1.30 pm	2.00 pm	2.30 pm	3.00 pm	3.30 pm	4.00 pm	4.30 pm
GF	4	5	5	4	4	4	4	4	4	4	4	4	4	4
L1	4	5	5	4	4	4	4	4	4	4	4	4	4	4
L2	3	3	3	3	3	3	3	3	3	3	3	3	3	3
L3	4	5	4	4	4	4	4	4	4	4	4	4	4	4
AVERAGE	3.75	4.5	4.25	3.75	3.75	3.75	3.75	3.75	3.75	3.75	3.75	3.75	3.75	3.75

Location B

Date : 23rd July 2013

	10.00 am	10.30 am	11.00 am	11.30 am	12.00 pm	12.30 pm	1.00 pm	1.30 pm	2.00 pm	2.30 pm	3.00 pm	3.30 pm	4.00 pm	4.30 pm
Zone 1	4	4	3	3	3	3	3	3	3	3	2	2	2	2
Zone 2	4	4	4	3	3	3	3	3	4	3	3	2	2	2
Zone 3	5	5	5	4	5	5	5	5	5	3	3	3	3	2
AVERAGE	4.33	4.33	4.00	3.33	3.67	3.67	3.67	3.67	4.00	3.00	2.67	2.33	2.33	2.00

Parameter : Noise (dB)

Location A

Date : 18th July 2013

	10.00 am	10.30 am	11.00 am	11.30 am	12.00 pm	12.30 pm	1.00 pm	1.30 pm	2.00 pm	2.30 pm	3.00 pm	3.30 pm	4.00 pm	4.30 pm
GF	63.4	62.9	63.5	63.9	63.6	64.3	63.2	63.7	63.5	64.4	63.8	63.6	63.1	65.8
L1	62.7	61.9	62.9	62.3	62.2	63.9	62.9	63	62.8	63.6	63.3	63.7	62.9	62.9
L2	60.6	61.6	60.6	61.1	61.8	61	61.6	62	61.8	61.7	61.7	61	61.7	61.5
L3	63.4	63.3	63.9	64.2	66.6	62.3	64.7	64.4	64.3	63.8	65.8	63.8	66	64.2
AVERAGE	62.53	62.43	62.73	62.88	63.55	62.88	63.10	63.28	63.10	63.38	63.65	63.03	63.43	63.60

Location B

Date : 23rd July 2013

	10.00 am	10.30 am	11.00 am	11.30 am	12.00 pm	12.30 pm	1.00 pm	1.30 pm	2.00 pm	2.30 pm	3.00 pm	3.30 pm	4.00 pm	4.30 pm
Zone 1	63.1	63.3	62.7	62.9	63.4	63.6	63.3	63.4	63.1	62.7	63.3	63	62.7	62.8
Zone 2	62.6	62.9	63.5	63.6	63.8	62.9	62.7	63.9	62.9	63.5	62.9	62.7	63	62.8
Zone 3	64.8	64.3	65.1	64.8	64.1	63.9	64.5	64.6	64.8	64.4	64.7	65	64.4	64.1
AVERAGE	63.50	63.50	63.77	63.77	63.77	63.47	63.50	63.97	63.60	63.53	63.63	63.57	63.37	63.23

Do not comply with GBI, noise < 40 dBAeq