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Implementation of Indoor Environmental Quality in Office Buildings in Batam City

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ABSTRACT

The majority of people spend a lot of their time indoors so it takes a room that has good environmental quality to provide comfort to the occupants of the room. To achieve good indoor quality, the way that can be used is by applying Indoor Environmental Quality (IEQ) to the room. This research aims to analyse and determine the parameters to evaluate indoor environmental quality. This research uses a literature study with a qualitative approach. Data collection was carried out using a literature study research method with a qualitative approach, namely by collecting data from various sources and the results were analysed through content analysis. The results of this research, it is concluded that the parameters of indoor environmental quality assessment are thermal comfort, visual comfort, acoustic comfort, and air quality in the environment. By applying and combining these parameters, the room will get an environmental quality that provides comfort to the occupants of the room.

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1. INTRODUCTION

The majority of people spend a lot of their time indoors According to Mujan et al.(2019), said that 80% of a person's life is spent inside buildings. By spending a lot of time indoors, people are constantly trying to find interior spaces that make them feel comfortable. Therefore, it is important to identify factors that influence occupant comfort in buildings in relation to Indoor Environmental Quality (IEQ). Mengingat bahwa IEQ dalam bangunan telah dianggap sebagai aspek penting yang harus dipertimbangkan pada tahap awal dan akhir proses pembangunan (Larsen *et al.*, 2020). Given that IEQ in buildings has been considered as an important aspect that should be considered in the early and late stages of the development process (Larsen et al., 2020), to maintain or improve the comfort of the indoor environment, everyday devices such as air conditioning and fans, heaters, and artificial light, and other devices are widely used. However, using these devices (especially cooling electrical appliances) can contribute significantly to energy consumption. Especially the building sector in cities that have many commercial buildings that can consume a lot of energy every day (Che et al., 2019). Therefore, providing scientifically appropriate energy-saving methods to make a suitable and comfortable indoor environment will have great social and economic significance.

Many studies have been conducted by various researchers to explore the relationship between indoor environmental factors and human satisfaction, perception, health or performance. Among these, researchers have extensively investigated the separate effects of single environmental factors namely thermal, acoustic, visual environment, and air quality on human perception or performance (i.e. main effects). On the basis of these studies, technical standards and design guidelines that perform how to build thermal environment, acoustic environment, light environment, air quality has been written and approved, aiming to create a comfortable working or living environment (Wu et al., 2020). Eziaku et al. (2022) point out that the cost implications of poor indoor environments on productivity cannot be ignored, as value is lost when building occupants are unhealthy and unable to function as expected. Even before the advent of COVID-19, absenteeism, productivity losses, and healthcare costs due to poor ventilation were estimated to have an economic impact on a region. Buildings such as offices that have low IEQ can put illnesses such as influenza and pneumonia at risk, increasing at lower ventilation rates with associated productivity impacts and health costs. Also highlighted is the role of 'presenteeism' (situations where workers are present at work even though they are not productive), contributing to poor IEQ in office environments and resulting in lost productivity. For example, workers with infectious diseases who go to work can spread infections to co-workers and impact the productivity of the entire staff and organization. The term indoor environmental quality (IEQ) has a broad meaning and includes several conditions that make up the indoor environment (Steinemann et al., 2017). These conditions can affect the overall comfort of building occupants. Some of the many factors that contribute to IEQ include thermal, visual (lighting), acoustic (sound), and indoor air quality (IAQ) comfort. Sometimes the terms IEQ and IAQ are used interchangeably but there are differences between the two concepts. IEQ refers to the overall environmental conditions within a building that includes IAQ, thermal, visual and acoustic comfort, while IAQ is the part of IEQ that deals with indoor air conditions and their effect on occupant health and comfort (Steinemann et al., 2017).

There is a connection between IEQ and Sick Building Syndrome (SBS). Sick Building Syndrome (SBS) is a condition where building occupants experience health problems or physical discomfort while in the building. According to Salleh et al. (2013), SBS symptoms such

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as dizziness, watery eyes, and nausea are also likely to be experienced by occupants in naturally ventilated buildings. For air-conditioned buildings, symptoms such as headache, dry skin, running nose and lethargy are more likely to be seen (Cheong & Chong, 2001). With poor indoor environmental quality, occupants experience health-related symptoms while in the building, and then the symptoms disappear when they leave the building. If poor environmental quality is left for a prolonged period of time, it can put building occupants at risk of illness.

Indoor Environmental Quality (IEQ) is a condition in a building that has an influence on its occupants. Therefore, it is important to assess the IEQ of a space because poor IEQ conditions can have an impact on occupants' perception, satisfaction, health, and performance. In addition, the IEQ parameter is the biggest factor of building energy use. To assess IEQ, the following parameters should be evaluated:

1. Thermal Comfort
   A mind satisfaction experienced by humans against temperature conditions in the surrounding environment (Kapoor et al., 2021). The thermal comfort preference of the occupants is where the occupants of the building do not feel the room temperature is too hot or too cold.
2. Visual Comfort
   Conditions where humans feel undisturbed by the surrounding conditions received by their sense of sight. Visual conditions are characterised by parameters such as lighting distribution, illumination and its uniformity, glare, light colour and the amount of lighting during the day.
3. Acoustic Comfort
   Satisfaction with the sound conditions in the surrounding environment (Mujan et al., 2019). The quality of the sound environment is related to various physical parameters, which include the physical properties of the sound itself and the physical properties of the room (Wang et al., 2021). Sound is characterised by short- and long-term sound pressure levels and sound frequencies. The acoustic environment can be affected by the physical properties of the room such as sound insulation, absorption and reverberation time.
4. Indoor Air Quality (IAQ)
   Air quality refers to the quality of air within and around buildings and structures. Indoor air quality (IAQ), which is primarily related to the lack of discomfort due to odour and sensory irritation that may be caused by visitors to indoor spaces. When there are no harmful contaminants or odours present indoors, indoor air quality conditions are said to be satisfactory (Mannan & Al-Ghamdi, 2021).

2. RESEARCH METHODS

This research uses a literature study with a qualitative approach. One of these research methods is often used to collect data through note-taking, literature review, or reading. The methodology used by the author involved a thorough review of selected journals published from 2018 to 2023, and the results were analysed through content analysis. Content analysis, which is qualitatively orientated, typically uses a measure of rigour to characterise documents or compare them. (Putera et al., 2015). In data collection and data analysis, there are research aspects that make it easier for researchers to conduct this research, namely the Research Onion Diagram.

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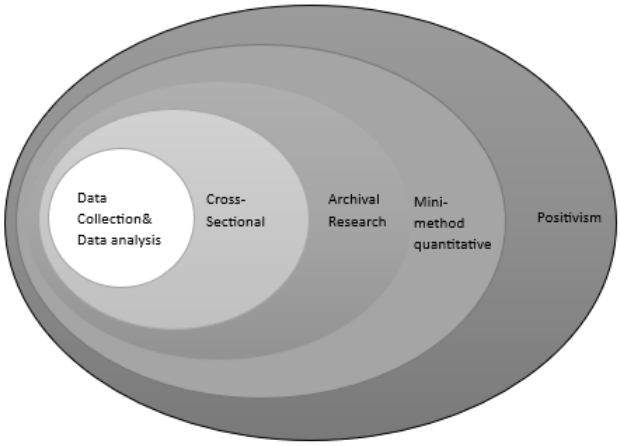

Figure 1. Research Onion Diagram
Source: Personal Documentation, 2023

The search was conducted through national and international journals, scientific research, books and other records that discuss the theory of critical factors affecting Indoor Environmental Quality (IEQ) and its impact on occupant comfort through, occupant satisfaction, perception, health and also performance in building occupants, sourced from different databases such as ScienceDirect, Emerald, ResearchGate, GoogleScholar and Web of Science. Some of the data collected by the authors are from areas that have a sub-tropical climate. Therefore, the data collected will be adjusted to the climate in Batam, which is a tropical climate. The following are the data used by the author after doing some comparisons of some data which are then included in this article.

Table 1. Related indicators based on data comparison results.

No.	Title	Author (Years)	Indicator
1.	Impact of poor Indoor Environmental Quality (IEQ) to Inhabitants' Health, Wellbeing and Satisfaction.	Che et al. (2019)	Indoor environmental Quality
2.	A Systematic Review on Indoor Environmental Quality in Naturally Ventilated School Classrooms: A Way Forward.	Kapoor et al. (2019)	Indoor environmental Quality
3.	IEQ-Compass – A tool for holistic evaluation of potential indoor environmental quality.	Larsen et al. (2020)	Indoor environmental Quality
4.	Influence of indoor environmental quality on human health and productivity - A review.	Mujan et al. (2019)	Indoor environmental Quality
5.	The green office environment: New Zealand workers' perception of IEQ.	Rasheed et al. (2022)	Indoor environmental Quality
6.	How indoor environmental quality affects occupants' cognitive functions: A systematic review.	Wang et al. (2021)	Indoor environmental Quality
7.	Impact of poor Indoor Environmental Quality (IEQ) to Inhabitants' Health, Wellbeing and Satisfaction.	Hayder et al. (2020)	Indoor environmental Quality & Sick Building Syndrome
8.	Sick Building Symptoms Among Children In Private Pre-Schools In Malaysia: Association Of Different Ventilation Strategies.	Naziah et al. (2013)	Sick Building Syndrome & Ventilation
9.	How our homes impact our health: using a COVID-19 informed approach to examine urban apartment housing.	Peters & Halleran (2013)	Sick Building Syndrome
10.	Combined effects of acoustic, thermal, and	Wu et al.	Acoustic Comfort, Thermal

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No.	Title	Author (Years)	Indicator
	illumination on human perception and performance: A review.	(2020)	Comfort & Visual Comfort
11.	*Menciptakan Kenyaman Thermal Dalam Banguunan*	Basaria Talarosha (2009)	Thermal Comfort
12.	Pentingnya Akustik dalam Desain Interior	Acourete (2023)	Acoustic Comfort
13.	Solutions to Improve Acoustics in Your Home	Giovana (2021)	Acoustic Comfort
14.	*Analisa Kenyamanan Akustik Pada Ruang Karaoke di Kota Manado Studi Kasus : Happy Puppy Karaoke dan Diva Karaoke.*	Mohammad & Nini (2018)	Acoustic Comfort
15.	*Analisis Tingkat Pencahayaan Ruang Kuliah Dengan Memanfaatkan Pencahayaan Alami Dan Pencahayaan Buatanklorofil.*	Tongkukut et al. (2016)	Visual Comfort
16.	Development and implementation of an indoor air quality audit to an air-conditioned building in Singapore.	Cheong & Chong (2021)	Indoor Air Quality
17.	*Studi Kualitas Udara Dalam Ruang (Indoor Air Quality) ada Ruang Kelas Sekolah Bangunan Cagar Budaya di Surabaya.*	Elizabeth et al. (2016)	Indoor Air Quality
18.	*Kualitas Udara dalam Ruang Kerja*	Ida Ayu (2011)	Indoor Air Quality
19.	Indoor Air Quality in Buildings: A Comprehensive Review on the Factors Influencing Air Pollution in Residential and Commercial Structure.	Mannan, M., & Al-Ghamdi (2021)	Indoor Air Quality
20.	Ten questions concerning green buildings and indoor air quality.	Steinemann et al. (2017)	Indoor Air Quality

Source: Analysis, 2024

3. RESULTS AND DISCUSSION

In terms of office building design, improving occupant comfort is a top priority while the building is still in the design stage given that the average occupant spends 80% of their time indoors. Air quality, thermal, lighting and acoustics significantly affect the overall Indoor Environmental Quality (IEQ). Overall occupant satisfaction is very important in any type of building. Therefore, buildings are responsible for facilitating the improvement of the indoor environment for their occupants and therefore, maintenance and evaluation of Indoor Environmental Quality (IEQ) parameters is necessary throughout. From the previous explanation, the main factors in Indoor Enviromental Quality (IEQ) are thermal, visual (lighting), acoustic, and the combination of these three factors results in the air quality in the building.

3.1. Thermal Comfort

Indoor temperature plays a key role in providing suitable air quality for indoor occupants. In addition to the occupants, inappropriate temperatures can affect indoor furnishings, especially those made from wood. Temperature has a direct effect on biological contaminants such as mould, as the main factor for mould growth is temperature. Gasification off of decorative materials can also affect indoor temperature. Exceeding the standard temperature will increase allergenic components while reducing occupant comfort (Abdulaali et al., 2020).

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Some studies suggest that the thermal comfort preferences of men and women may differ significantly, with the average woman favouring higher ambient temperatures. In addition, external effects such as weather also affect indoor thermals. The ideal ambient temperature for a room is 68-76 degrees Fahrenheit or 20-25 degrees Celsius. Within this range, the ideal room temperature will vary according to the variables owned by the building. For external variables, there are regional location (tropical or sub-tropical), season, solar orientation and vegetation. For variables inside the building, there is the floor area of the building, the wall material of the house and the ventilation/openings in the building.

There are several criteria to get thermal comfort in the building. Since Batam is located in a tropical climate region, the building should be west and east (facing north or south), it can support thermal comfort in the building because the building avoids or is not exposed to scorching sunlight and provides primary wind as cooling. Have openings for natural ventilation and have vegetation around the building. Using materials that have thermal insulation capabilities and radiative cooling properties.

3.2. Visual Comfort

Visual comfort or lighting is a must-have feature of any space. To increase human productivity, lighting is an important component in obtaining a comfortable room state when doing activities in buildings. With good lighting, people can see the objects they are looking at and working on clearly and in focus. Natural lighting comes from nature and artificial lighting comes from man-made equipment. Both types of lighting serve to provide appropriate lighting for the space. (Tongkukut & -, 2016). The biggest natural light that most people recognise is sunlight. Daylight is necessary for people's metabolism to function properly and for them to have the strength to engage in physical and mental activities during the day. As the majority of individuals spend most of their time indoors, it is imperative to design interiors to make full use of natural daylight (Peters & Halleran, 2020). These consequences should not be overlooked. Daylighting, which is the main source of interior lighting, is considered the optimal light source as it provides the best illumination for human vision while providing comfort without disturbing human vision.

The intensity of lighting in a room depends on the activities carried out in it. According to Indonesian National Standard 03-6575-2001, workspaces, especially offices, the strong artificial lighting used is 350 lux. The level of human productivity in the room will also be affected by a lighting system that meets the standards. Lighting that does not meet the standard, if left for a long time, can affect the vision of the occupants of the room, thereby reducing the productivity of the occupants of the room. In addition to reducing the productivity of occupants, decreased vision is also caused by other factors, such as exposure to strong lighting that is too bright for the eyes, old age, and refractive errors. To obtain visual comfort in a room, the lighting in the room must be designed to provide comfort for the people who see it and for the activities carried out in it. To find out how safe the lighting is, the designer can use a device called a lux meter to measure the lux of light. Resting rooms require low lighting/lux of 50-150 lux. For rooms that require high concentration, the required illuminance/lux is standard lighting which is 200-400 lux. For public rooms and lounges, the required illuminance/lux is 150-200 lux.

3.3. Acoustic Comfort

Indoor acoustic conditions can affect the comfort of a building. The acoustic comfort in question is to provide sound comfort to residents psychologically and physically. Given how sensitive the human ear is to sound and sound, it is not surprising that the planning and design of a building must also consider its acoustic aspects. With good acoustics, every activity in the

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room can be done well by receiving sounds and sounds in accordance with the recommended noise criteria (NC). (Imran & Nini, 2018).

To get acoustics that are suitable for indoor environmental comfort, a room or building that can produce sound comfort is needed. Sound comfort is the environmental and psychological situation of a person in an environment in terms of noise levels and other parameters that can interfere with operational functions / activities in building users, such as concentration, communication, rest or health. The sound that disturbs the comfort of the room is called noise. Noise consists of two (2) types, namely noise from outside and noise from inside the room. External noise is noise generated from outside the room or building such as vehicles, construction work, conversations, music, animal sounds, and so on, sounds that are part of big city life that are difficult to control. Indoor noise is the noise that is generated when the sound is reflected (such as echo and reverberation) from the materials in the room that are reflectors, resulting in an unclear sound that causes the occupants of the room to feel uncomfortable.

To overcome noise from outside the building, the best way to use is insulation. Insulating an environment from sound involves careful detailing of all extremities, walls, ceilings, and floors, their materials, and finishes, and windows must be properly sealed. Although complete isolation is only possible in highly controlled environments, this solution can help reduce noise from the neighbourhood and improve the quality of life of the occupants (Giovana, 2021). As for tackling noise from indoors, using sound-absorbing materials such as carpets, curtains and acoustic panels is an effective approach. To make hearing conversations and other sounds easier, these materials can help reduce echoes and dampen excess sound. Properly positioning furniture in the room can also help reduce the area of sound reflections present. (Acourete, 2023).

3.4. Indoor Air Quality

Indoor air pollution has been categorised by many indoor air quality (IAQ) experts as one of the most significant global environmental problems and the link between indoor pollutants and occupant health. There are several indoor air pollutants (IAPs) that can cause illnesses, such as eye pain, nose and throat discomfort, headaches, allergies and other health problems. In addition, the influence of indoor air quality on workers' perception of job satisfaction and performance has been highlighted. Therefore, it is important to ensure the best possible indoor air quality conditions to create a space that is conducive to work and study activities and to prevent adverse health impacts. To date, many studies have been directed at evaluating air quality in workplaces, learning institutions, and residences that include cooking areas to identify the main causes of poor IAQ and ways to improve these problems. Poor indoor air quality in buildings is the main reason for sick building syndrome (SBS). Therefore, there is a need to analyse the occurrence of SBS symptoms in buildings to come up with IAQ management plans to prevent or mitigate potential indoor air problems.

According to Ida (2011), there are several types of pollution or contaminants that can deteriorate indoor air quality. These include carbon dioxide (CO2) particles, formaldehyde, ozone (O3), dust from cooking, clothing, paper, and carpets, abscess fibres from building materials, and fibreglass fibres from Air Conditioning pipes. In addition, combustion by-products include carbon monoxide gas (CO), nitrogen oxides (NO and NO2) and hydro carbon (HC). Apart from the pollution mentioned, there are also other factors that can degrade indoor air quality. High humidity, poor air circulation, buildings that are too close to each other, and air conditioning systems that use water and condensation are all sources of microbiological pollution that encourage the development and growth of microorganisms such as viruses, bacteria, fungi, protozoa, and others. Weather consists of variables such as

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air temperature, air movement speed, and air humidity. Since these factors affect how people perceive the air indoors, it is important that we ensure that the air temperature and humidity are always within acceptable ranges for occupant comfort. Uncomfortable indoor air results from humidity and air movement outside the recommended limits. To achieve comfortable air for occupants, air velocity and movement should be adjusted according to local air conditions.

The implementation to control comfortable indoor air quality is to have ventilation. Ventilation is an effective way to control indoor quality. For rooms that have openings such as windows and doors, you must look at the condition of the incoming outside air. The incoming air must be clean and not polluted by smoke from combustion, vehicles, dust and others. For rooms that are closed and do not have openings, you can use artificial ventilation, namely air conditioning. Use of air conditioning. Must be followed by good maintenance. Maintenance is needed so that indoor pollutants are not high. However, air conditioning does not produce new air so an exhaust fan is needed to help exchange air in the room (Elizabeth et al., 2016). Vegetation around buildings can reduce pollution because vegetation can filter existing pollution and produce fresh air for building occupants.

3.5. IEQ Analysis of Office Buildings in Batam

3.5.1. Graha Pena Batam

Graha Pena Batam inaugurated in 2005 is a property division developed by Riau Pos Group (Group of Jawa Pos Surabaya) into a modern office centre in the heart of Batam's international business. It is built on 10 floors in a very strategic location, close to Batam Center International Port, Batam Government Office (PEMKO), and others.

Figure 2. Graha Pena Building
Source: PT Jaya Propertindo, 2023

From Picture 2, it can be seen that the exterior of the Graha Pena building has vegetation around the building that can provide fresh air around the building. The distance from the building to the main road is 60 metres, so as to reduce noise from vehicles. The Graha Pena building faces east. For the facade of the Graha Pena building, the building is made to extend backwards, so that the wider sides of the building face north and south, which can reduce direct sunlight exposure that can provide thermal comfort to building occupants. For the building walls themselves, each floor of the building is surrounded by glass so as to provide natural lighting on each side of the building.

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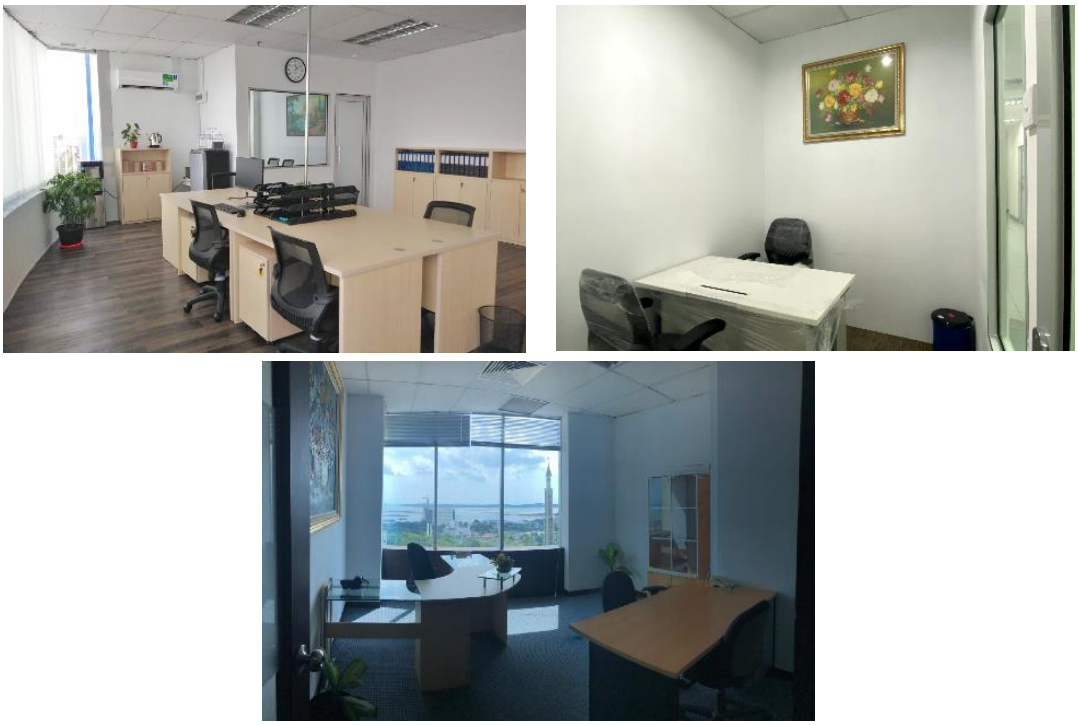

Figure 3. Interior of Graha Pena BUilding
Sumber: PT Jaya Propertindo, 2023

From Figure 3, it can be seen that the interior of the Graha Pena building, for openings in each room there are only doors that can provide air circulation, so artificial ventilation is provided on the ceiling of the room. For windows used in the room are Fix Window (dead glass windows) which cannot be opened, can only provide lighting from outside. Artificial Lighting is also given to each room to add visual comfort to the occupants of the room, because even though there is already glass that can provide natural lighting, there are some rooms that still look dark, so artificial lighting is given such as lamps that can provide lighting in the room that makes residents more comfortable in their eyesight.

3.5.2. Aria Office Tower

Aria Tower is located in the centre of Batam's Batu Ampar business district, next to Harbour Bay Residences and Marriott Hotel, this sea-facing office tower is only 40 minutes away from Singapore via ferry and accessible via Bayfront Mall. Aria Tower is 16 storeys and opened in 2018. There are facilities such as a bank, ATM Centre, restaurant and café.

Figure 4. Aria Office Tower
Source: PT Citra Buana Prakarsa, 2022

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From Figure 4, it can be seen that the exterior of the Menara Aria building has vegetation in the front area of the building. The road around the building is a secondary road so the noise around the building is limited. The distance from the building to the main road is 450 meters. The Aria Office Tower building faces northwest, so the building does not directly face sun exposure, providing thermal comfort to the building occupants. The walls on the building facade use Curtain Wall Reflective Glass Panels that provide maximum protection against ultra-violet rays and solar heat gain that can provide thermal comfort to the building, while allowing a high level of visible light transmission, without high reflectivity or glare entering the building.

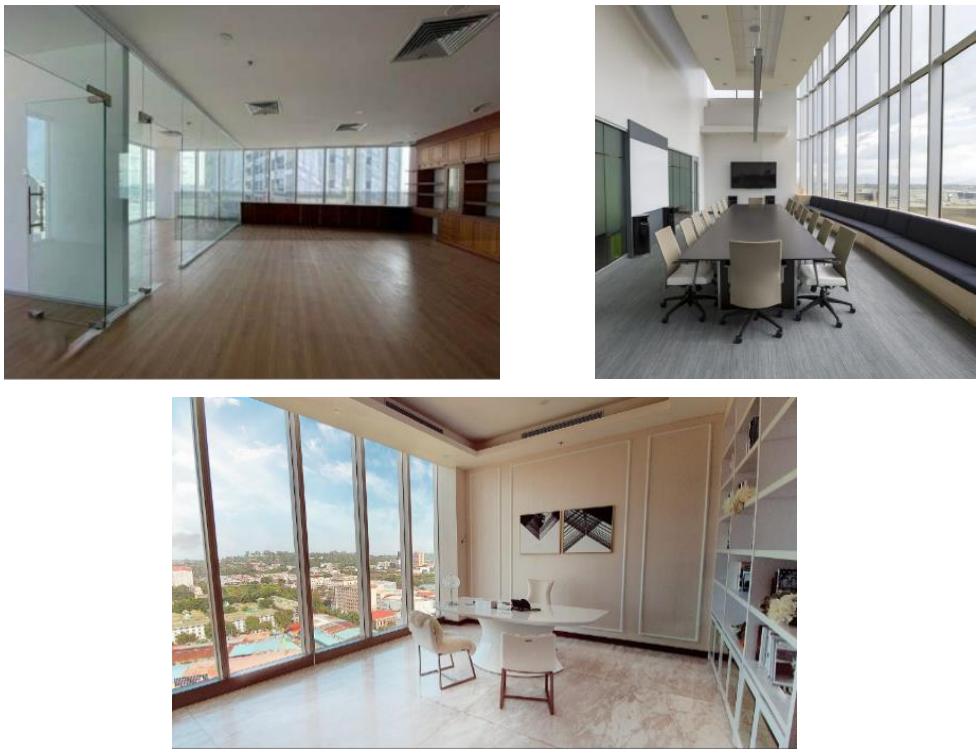

Figure 5. Interior of Aria Office Tower
Sourcer: Google, 2024

For the interior of Menara Aria, the Indoor Enviromental Quality (IEQ) assessment is not much different from the Graha Pena Batam building. Menara Aria also uses fixed windows for lighting and adds artificial lighting. Openings for air circulation only have doors so that artificial ventilation is used on the ceiling of the room.

4. CONCLUSION

Based on the above discussion, it can be concluded that most people spend a lot of time indoors so it needs a room that has good environmental quality to provide comfort to the occupants of the room. The main factors in Indoor Enviromental Quality (IEQ) are thermal, visual (lighting), acoustic (sound), and the combination of the three factors produces air quality in the building. The four factors are interrelated with each other. To overcome poor indoor environmental quality, the author can conclude that there are several important things that can be the focus in solving the problem.

1. Openings / vents such as windows can provide natural lighting, and provide air circulation to improve indoor air quality. Air circulation converts hot indoor air into fresh air in the surrounding environment. Closures on openings can provide an insulating condition that can reduce noise from outside the building.

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2. Artificial Ventilation such as *air conditioning*, can help in thermal regulation such as making the temperature in the room cool. Because artificial ventilation cannot produce new air, exhaust fans are needed to circulate air (air replacement).
3. Selection of the right material / materials in buildings and *furniture*, can help in regulating thermal and acoustic. For the use of materials that have thermal insulation capabilities and are *Radiative Cooling* can help reduce heat from outside so as to maintain the thermal in the building. Sound absorbing materials / materials can reduce noise so as to provide comfort in acoustics.
4. Buildings that cross to the west and east (facing north or south), can support the thermal comfort of the building because the building avoids or is not exposed to strong sunlight, but still provides enough lighting in the building and provides cooling from the primary wind.
5. Vegetation around the building can also help in maintaining the quality of the indoor environment. With the presence of vegetation, in addition to helping reduce heat from the sun, it also helps provide cooling to the building. Vegetation also helps filter pollution around the building and produces fresh air.
6. The choice of location for the building can also have an effect on the quality of the environment in the building. Building locations in big cities (densely populated) have higher levels of noise and air pollution compared to other locations.

The analysis of two office buildings in Batam, Graha Pena Batam and Aria Office Tower, based on the results of the previous discussion, it can be concluded that both buildings have good Indoor Environmental Quality (IEQ). Although both buildings have shortcomings such as few openings, it has been improved by providing artificial ventilation in the room.

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