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THE ACCLAIMED LANDSCAPE OF KNOWLEDGE SHARING

"Harmony in Spaces : Blending Heritage, Nature and Design"

E-PROCEEDING

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THE ACCLAIMED LANDSCAPE OF KNOWLEDGE SHARING

"Harmony in Spaces : Blending Heritage, Nature and Design"

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ORGANISED BY

College of Built Environment
Universiti Teknologi MARA Selangor Branch
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THE EFFECTS OF GREENERY BUILDINGS TOWARDS AIR QUALITY: A CASE STUDY AT TAMARIND SQUARE, CYBERJAYA

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ABSTRACT

The environment plays a vital role in sustaining human life on Earth. In urban contexts, where concrete jungles often dominate the landscape, there's a growing recognition of the need to harmonize human habitation with nature. Integrated greenery facades have emerged as a promising solution to strike this balance, offering a range of positive effects on the urban environment and its inhabitants. Urbanisation, deforestation, and the construction of buildings with minimal green spaces contribute to a reduction in the number of plants in many areas. This can lead to degraded air quality, increased levels of pollutants, and a loss of the natural mechanisms that help maintain a healthy atmosphere. With an emphasis on carbon dioxide (CO_2) levels, this study aims to measure and analyse the difference of indoor air quality in between spaces in Tamarind Square. This research employs a Delta OHM device as a robust methodology, offering a comprehensive and continuous monitoring approach. Due to that, it offers practical insights to improve air quality and support sustainable urban development practises, as well as advice for the best way to design, install, and maintain integrated greenery facades.

Keywords: *Greenery, Building facades, Environment, Sustainability, Carbon dioxide (CO_2), Air quality*

INTRODUCTION

There is increasing concern about the effect of Indoor Air Quality (IAQ) on human health. According to Petty, S. E. (2017) IAQ is the representation of pollutant concentrations and thermal conditions that may have an adverse effect on building occupants' health, comfort, and productivity. The parameters involved in determining a healthy IAQ include the effect of volatile organic compounds (VOC), microbial contaminants including mould and bacteria, gases including carbon dioxide (CO_2), radon (Rn) and carbon monoxide (CO), and particulate matter (PM) such as water, in addition to temperature, ventilation and humidity.(Zawawi, Azaiz, Kamaruzzaman, Ishak, & Yussof, n.d.) IAQ may result from inadequate ventilation, contaminated air and extreme temperatures. According to Jalaludin, Choo, Hamedon, & Adam, (2015), lack of monitoring these parameters may affect the performance of the building and its occupants.

According to accorded to Tamarind Square Brochure, urbanization's rapid pace exacerbates environmental challenges such as habitat loss and escalating air pollution. In response, integrating vegetation onto building facades, commonly known as 'green walls' or 'living walls,' emerges as a promising solution. This study focuses on Tamarind Square in Cyberjaya, a beacon of sustainable design that emphasizes features like vertical gardens and green roofs. Tamarind Square was selected as the ideal site for this study on indoor air quality due to its alignment with specific criteria: the presence of expansive open areas adorned with abundant greenery, enclosed spaces featuring thriving plants, and a basement parking facility. Its substantial foot traffic ensures unbiased readings, rooted in real-life scenarios, providing a comprehensive understanding of indoor air quality dynamics.

According to Howden-Chapman, (2017) sustainable Design Goal 3 often focuses on creating healthier and more sustainable environments for human habitation. In relation to the research conducted on indoor air quality at Tamarind Square, this goal correlates by emphasizing the importance of integrated greenery facades in enhancing air quality.

As cities expand, the detrimental impact on air quality becomes increasingly apparent. Green facades offer a strategic intervention by mitigating particulate matter and pollutants, countering these environmental

hazards. Its overarching aim is to illustrate how the deliberate incorporation of greenery fosters healthier, more sustainable urban environments, paving the way for future eco-centric urban planning strategies.

AIM AND RESEARCH OBJECTIVE

The aim of this research is to quantitatively measure and analyse variations in indoor air quality among different spaces within Tamarind Square. The objectives include assessing key air quality parameters, identifying which area has better air quality, evaluating the impact of factors such as the presence of greenery, comparing the data with established standards, and proposing recommendations for improving indoor air quality based on the findings.

LITERATURE REVIEW

Significance of Green Space in Urban Planning

Urban green space is a key element of a city, both as a recreation destination and as an intersection of the city's main arteries. Its ecological characteristics support residential buildings, public buildings, and offices in the surrounding area. Thus, the city is fed with green architecture in two ways; the city's environmental performance increases as well as the land values in the surrounding green area. According to (Arda Akyilidiz, 2022) reveals the beneficial relationship between urban planning and public spaces by narrowing down the scope of green areas and their development throughout the historical development of cities with reference to urban architectural inheritance.

Green Wall Designs

Green walls are essentially the establishment of plants on the walls of building structures. According to (Baran & Gültekin, 2018) they could be traced back to ancient structures such as the Hanging Gardens of Babylon with plants grown on cascading artificial structures. Reffering to Perini, Ottelé, Fraaij, Haas, & Raiteri, (2011), establishing green walls typically

involves vegetating vertical surfaces such as partitions, facades, and walls and in some instances, they are named vertical greening systems or green vertical systems interchangeably. The positive effect of vegetation on humans has been proven a long time ago. Vegetation uses absorption to remove gaseous pollutants and produces an oxygen. However, this is just one of many possibilities and positive aspects of their application. Green walls can affect the spread of harmful substances and isolate places exposed to sound pollution. According to Wesoowska & Laska, (2019) the flora affects humans directly, improving their well-being.

Today, our green wall has several advantages like to ease the urban heat island (UHI) effect, some studies have pointed out that this type of cooling strategy affects the indoor and outdoor environment of the building and Bart Felder and Köhler found that the cooling effect of the green wall depends on the outdoor temperature. According to Hung, Chen, Yeh, & Tseng, (2019) The cooling effect of the green wall during the cold and hot days was 0.4°C and 5.8°C, respectively. Another advantage is reducing noise, some studies have pointed out that the leaves and branches of the green wall plants effectively reduce noise. The muffling effect of plants is that when sound waves propagate through the trees, they are reflected and refracted by leaves and branches, consuming some of the energy, thus reducing the noise. Living walls on the other hand make it possible to green high-rise building walls over bigger wall areas more quickly. According to (Manso & Castro-Gomes, (2015). They have the advantage of consistent growth on walls and may be specially designed to match various building types. Similar to indirect green facades, living walls are divided into two types: continuous and modular. The former entails building a lightweight, permeable frame on which individual plants are affixed, while the latter consists of repeating modules with plant-growing medium.

Importance of Carbon Dioxide (CO2) Monitoring for Indoor Air Quality

According to Peterborough Public Health (2022), When we exhale, we add CO2 to the air. In fact, each breath from an average adult contains 35,000 parts per million (ppm) of CO2. As more people remain in a room, CO2 levels increase quickly if there is not enough fresh air coming into the space. High indoor CO2 levels can cause tiredness, headaches and

other symptoms. Increasing CO2 levels show you that the space is not well ventilated. Other indoor pollutants can also increase within a poorly ventilated space. This includes respiratory particles and the viruses they carry. CO2 readings will help determine if simple steps are needed to lower the risk of transmission. This includes things like opening a window or reducing the number of people in a room.

Air Quality Improvement

Particulate matter (PM) is a major contributor to air pollution. The fine fraction of PM capable of penetrating deep into the lungs increases the risks of respiratory diseases, lung cancer, heart disease and stroke according to (Tang, 2023). Air pollution is related to climate change in the sense that certain air pollutants such as ground-level ozone, nitrous oxide, methane, and hydrofluorocarbons are greenhouse gases. According to Francesca Dominici, Michael Greenstone, & Cass

R. Sunstein, (2014). As organic air filters, green walls draw in pollutants and release oxygen. Studies have shown significant reductions in particulate matter and harmful gases, resulting in cleaner and healthier urban air. Since plants play essential roles in purifying air and breaking down some of the pollutants, the emergence of green walls and green roofs permits optimal greening of urban structures to facilitate urban air cleansing.

METHODOLOGY

The provided methodology encompasses qualitative aspects in the environmental study design.

(a) (b)

Figure 1. Delta OHM device

Source: Author, (2023)

The researcher analyses the map of Tamarind square to identify the strategic location fir IAQ observation. One unit of Delta Ohm instrument, shown in Figure 1 which includes measures of carbon dioxide (CO_2), carbon monoxide (CO), relative humidity (RH), temperature (°C) and wind speed (VA). Indoor Air Quality measurement was conducted to collect data on the levels of various indoor and ambient air constituents. Figure 2 shows Four areas of Tamarind Square that were chosen for the study and Table 1 shows the details of the areas and their different characteristics.

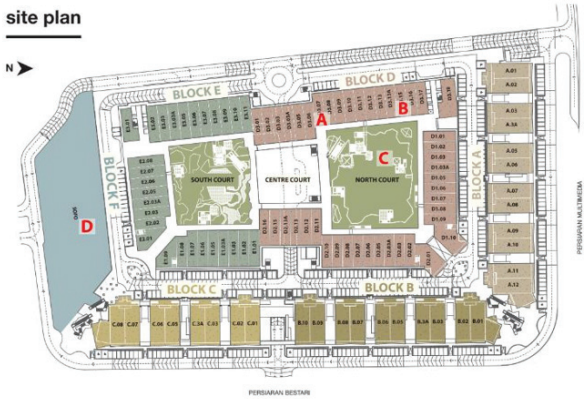

Figure 2. Plan of Tamarind Square

Source from Tamarind Square Brochure

Table 1. Comparison of the characteristics of all four Areas

Area	Location A	Location B	Location C	Location D
Area Chosen	Burger King	Herbs & Butter	Courtyard	Parking
Characteristic of Area	Enclosed area with no plants in the perimeters	Enclosed area with potted plants or green wall intergraded in the perimeters	Outdoor courtyard with lush greeneries	Basement parking

Source: Author, (2023)

Figure 3 serves as a reference point for assessing indoor air quality levels. Provided are comprehensive insights into the ppm levels ranging from excellent to bad.

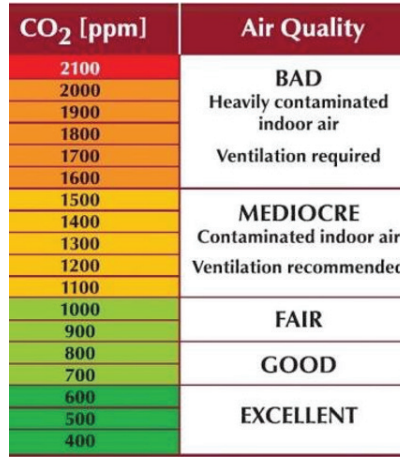

Figure 3. Indoor CO_2 levels

Source from IQ Home

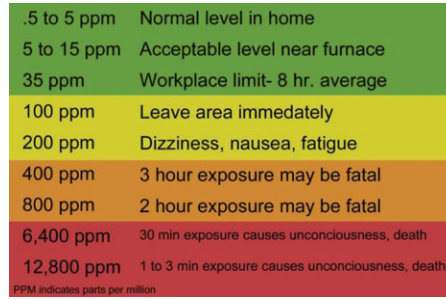

Figure 4. Carbon Monoxide Readings

Source from De Hart Plumbing Heating and Cooling

During the observation conducted across four distinct areas, A, B, C and D, adherence to protocols involved wearing a mask and positioning the indoor air quality monitoring device away from observer's face while collecting readings shown in Figure 4.

Location A: Burger King (Enclosed)

Figure 5. Wearing mask to adhere to protocols
Source: Author, (2023)

RESULT & DISCUSSION

In this section, the results and findings are summarised. The data collected is represented in graphs and tables for easy understandings. The data shows fluctuations in these measurements, with some locations experiencing higher levels of CO_2 and CO, as well as higher humidity and temperature. The remarks in the document indicate the number of people present in the location at certain times and the table is coloured according to the indoor air quality levels from Figure 3.Provided are the readings taken according to the location sa

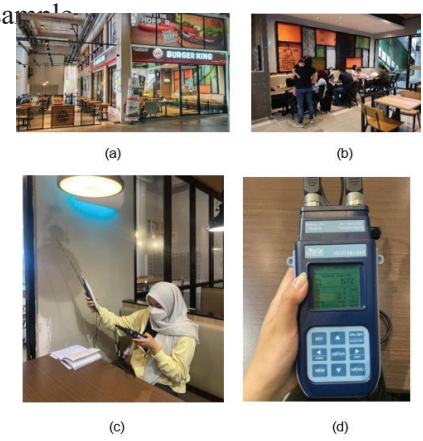

Figure 6. Location A Burger King

Source: Facebook and Author, (2023) Shot on personal phone

Table 2. Data collected at Location A Burger King. Green and lighter green indicates excellent and good indicators of CO_2 in the environment

Time	Carbon Dioxide	Carbo Monoxide	Relative Humidity	Temperature (Celsius)	Wind Speed	Remarks
9:00 AM	498 ppm	3 ppm	61.70 %	27.8 °C	0.04 m/s	
10:00AM	566 ppm	3 ppm	63.60 %	28.0 °C	0.06 m/s	
11:00AM	572 ppm	3 ppm	66.10 %	28.1°C	0.09 m/s	16 People in the restaurant
12:00PM	612 ppm	2 ppm	68.40 %	27.6 °C	0.12 m/s	
1:00 PM	594 ppm	3 ppm	68.30 %	27.4 °C	0.17 m/s	
2:00 PM	589 ppm	2 ppm	70.10 %	28.8 °C	0.24 m/s	
3:00 PM	656 ppm	2 ppm	68.50 %	29.5 °C	0.33 m/s	
4:00 PM	752 ppm	2 ppm	65.60 %	29.9 °C	0.28 m/s	
5:00 PM	759 ppm	2 ppm	66.70 %	29.9 °C	0.24 m/s	
6:00 PM	771 ppm	2 ppm	70.30 %	28.8 °C	0.22 m/s	Fully packed restaurant
7:00 PM	764 ppm	2 ppm	85.40 %	28.4 °C	0.29 m/s	
8:00 PM	647 ppm	2 ppm	85.60 %	27.7 °C	0.28 m/s	
9:00 PM	617 ppm	2 ppm	85.90 %	27.6 °C	0.28 m/s	
10:00PM	539 ppm	2 ppm	86.20 %	27.7 °C	0.12 m/s	Only 6 people due to the shop closing

Source: Author, (2023)

Table 2 provides data collected at Location A Burger King from 9:00 AM to 10:00 PM. The colours on the table derives from the indoor air quality levels readings in figure 3. Green indicates excellent indoor air quality, whereas lighter green indicates good. The highest carbon dioxide reading is 771 ppm, recorded at 6:00 PM. This is because the restaurant was fully packed with customers. When there are many individuals present in a confined space, the collective exhalation leads to a higher concentration of CO_2 in the air. The lowest carbon dioxide reading is 498 ppm, recorded at 9:00 AM because the shop has not opened and there are only 4 workers in the shop.

Location B: Herbs & Butter (Enclosed with Plants)

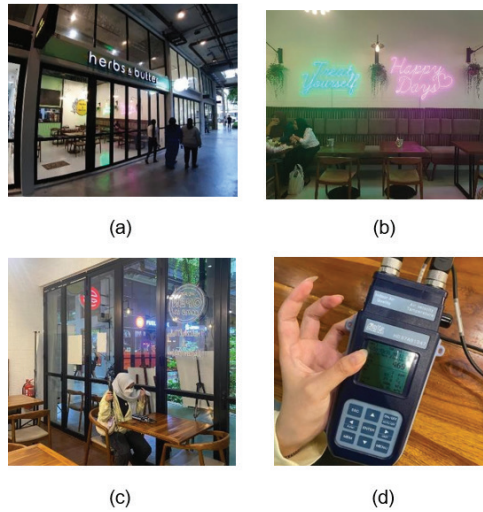

Figure 7. Location B Herbs & Butter

Source: Facebook, ,Blogger and Author, (2023)

Table 3. Data collected at Location B Herbs & Butter. Green indicates excellent and good indicators of CO_2 in the environment.

Time	Carbon Dioxide	Carbo Monoxide	Relative Humidity	Temperature (Celsius)	Wind Speed	Remarks
9:15 AM	466 ppm	2 ppm	87.80 %	26.8 °C	0.11 m/s	
10:15AM	467 ppm	2 ppm	87.20 %	27.0 °C	0.14 m/s	
11:15AM	469 ppm	2 ppm	87.10 %	27.0°C	0.16 m/s	
12:15PM	465 ppm	2 ppm	67.50 %	31.4 °C	0.23 m/s	
1:15 PM	455 ppm	2 ppm	57.80 %	31.7 °C	0.25 m/s	
2:15 PM	466 ppm	1 ppm	68.60 %	32.4 °C	0.36 m/s	
3:15 PM	543 ppm	1 ppm	69.30 %	32.5 °C	0.34 m/s	The shop was packed
4:15 PM	478 ppm	1 ppm	62.30 %	30.3 °C	0.43 m/s	Shop worker left the door open
5:15 PM	522 ppm	2 ppm	62.70 %	30.5 °C	0.41 m/s	
6:15 PM	529 ppm	2 ppm	70.10 %	31.2 °C	0.44 m/s	
7:15 PM	528 ppm	2 ppm	70.60 %	30.8 °C	0.38 m/s	
8:15 PM	503 ppm	2 ppm	72.40 %	29.6 °C	0.29 m/s	
9:15 PM	466 ppm	2 ppm	78.60 %	28.9 °C	0.23 m/s	

10:15PM	458 ppm	2 ppm	81.20 %	28.4 °C	0.21 m/s	

Table 3 provides data collected at Location B, Herbs & Butter, from 9:15 AM to 10:15 PM. The colour green indicates excellent indoor air quality. The highest carbon dioxide reading is 543 ppm, recorded at 3:15 PM. This is due to the restaurant being packed with customers. Despite the presence of potted plants in the shop, the collective exhalation from customers leads to a higher concentration of CO_2 in the air. Though it is the highest, but referring to the Indoor Air Quality levels in figure 3, it is still considered excellent indoor air quality. The lowest carbon dioxide reading is 455 ppm, recorded at 1:15 PM.

Location C: Courtyard (Outdoor courtyard)

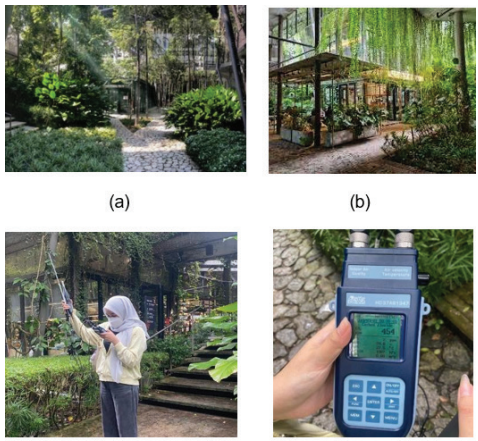

Figure 8. Location C Courtyard
Source: Green Ville Sdn Bhd,, Eries Goes To (2021), and Author, (2023)

Table 4: Data collected at Location C Courtyard. Green indicates excellent and good indicators of CO_2 in the environment

Time	Carbon Dioxide	Carbo Monoxide	Relative Humidity	Temperature (Celsius)	Wind Speed	Remarks
9:30 AM	366 ppm	2 ppm	49.90 %	29.6 °C	0.09 m/s	
10:30AM	362 ppm	2 ppm	49.80 %	30.1 °C	0.02 m/s	
11:30AM	454 ppm	2 ppm	57.00 %	28.5°C	0.08 m/s	
12:30PM	455 ppm	2 ppm	48.30 %	35.6°C	0.08 m/s	
1:30 PM	459 ppm	2 ppm	53.00 %	34.6 °C	0.69 m/s	

2:30 PM	441 ppm	2 ppm	60.10 %	33.9 °C	0.25 m/s	Becoming cloudy
3:30 PM	453 ppm	2 ppm	52.20 %	33.6 °C	0.22 m/s	Becoming cloudy
4:30 PM	446 ppm	2 ppm	55.20 %	33.5 °C	0.13 m/s	Cloudy
5:30 PM	451 ppm	2 ppm	57.80 %	31.8 °C	0.11 m/s	Cloudy
6:30 PM	466 ppm	2 ppm	63.20 %	29.9 °C	0.21 m/s	
7:15 PM	489 ppm	2 ppm	68.30 %	29.4 °C	0.44 m/s	
8:30 PM	512 ppm	2 ppm	72.80 %	28.3 °C	0.68 m/s	Suddenly windy
9:30 PM	522 ppm	2 ppm	84.70 %	27.6 °C	0.83 m/s	
10:30PM	534 ppm	2 ppm	90.80 %	27.3 °C	0.03 m/s	

Source: Author, (2023)

Table 4 provides data collected at Location C Courtyard from 9:30 AM to 10:30 PM. The colour green indicates excellent air quality. Judging by the table. The highest carbon dioxide reading is 534 ppm, recorded at 10:30 PM. This is due to the lack of sunshine; plants only carry out respiration throughout the night. As a result, CO_2 emissions are concentrated more at night. The lowest carbon dioxide reading is 366 ppm, recorded at 9:30 AM. Plants absorb more carbon dioxide throughout the day through photosynthesis than they expel through respiration hence the lower CO_2 count in the morning.

Location D: Basement Parking (Parking)

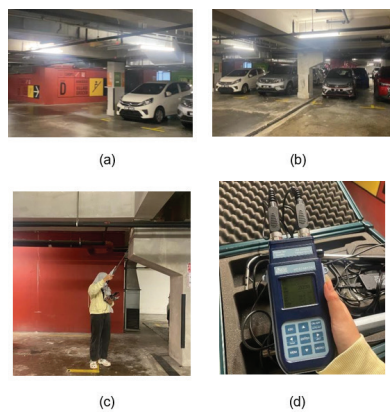

Figure 9. Location D Basement Parking

Source: Author, (2023)

Table 5. Data collected at Location D Basement Parking. Red and orange indicates bad indicators of CO_2 in the environment.

Time	Carbon Dioxide	Carbo Monoxide	Relative Humidity	Temperature Celsius)	Wind Speed	Remarks
9:45 AM	2077 ppm	3 ppm	55.40 %	26.0 °C	0.01 m/s	
10:45AM	2087 ppm	3 ppm	58.60 %	26.1 °C	0.01 m/s	
11:45AM	2090 ppm	3 ppm	64.80 %	26.3 °C	0.01 m/s	24 cars parked
12:45PM	2021 ppm	3 ppm	58.70 %	30.2 °C	0.01 m/s	
1:45 PM	2672 ppm	3 ppm	59.30 %	31.6 °C	0.01 m/s	A lot of cars coming in and out
2:45 PM	2655 ppm	3 ppm	59.80 %	31.6 °C	0.02 m/s	
3:45 PM	2497 ppm	3 ppm	60.10 %	33.2 °C	0.03 m/s	
4:45 PM	2563 ppm	3 ppm	59.90 %	30.6 °C	0.01 m/s	Parking deliberately full
5:45 PM	2696 ppm	3 ppm	61.00 %	32.3 °C	0.02 m/s	Parking deliberately full
6:45 PM	2725 ppm	3 ppm	66.70 %	32.8 °C	0.01 m/s	
7:45 PM	2587 ppm	3 ppm	68.30 %	30.7 °C	0.01 m/s	
8:45 PM	2298 ppm	3 ppm	68.40 %	30.4 °C	0.03 m/s	
9:45 PM	2109 ppm	3 ppm	71.60 %	29.6 °C	0.02 m/s	
10:45PM	2084 ppm	3 ppm	72.20 %	27.7 °C	0.02 m/s	

Source: Author, (2023)

Table 5 provides data collected at Location D parking from 9:45 AM to 10:45 PM. The colours showcased on the table indicates that the indoor air quality is bad. It shows that the reading is really bad and in need of proper ventilation. The highest carbon dioxide reading is 2725 ppm, recorded at 6:45 PM. This is because the basement parking was full and there were cars coming in and out of the basement. The combustion of fossil fuels in car engines generates carbon dioxide as a byproduct. With this high reading, it falls under bad indoor air quality which, if possible, needs proper ventilation. The lowest carbon dioxide reading is 2021 ppm, recorded at 12:45 PM. This too is still high of a reading.

This section presents a comprehensive graph that combines readings from all four locations, displaying data on carbon dioxide, carbon monoxide, relative humidity, temperature, and wind speed using Microsoft Excel.

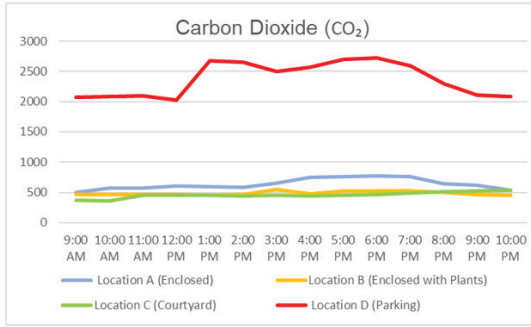

Figure 10. Carbon Dioxide Graph

Source: Author, (2023)

Figure 8 includes a graph depicting the levels of carbon dioxide which showcases Location A, B, C and D. It clearly shows that Location D has a high CO_2 ppm count due to the restricted airflow in a basement parking compared to the open-aired courtyard. The highest data collected is 2725pmm whereas the lowest is 362ppm Without adequate ventilation, high CO_2 emission can contribute to several environmental and health-related issues.

When comparing the indoor air quality readings between location A, which is enclosed, and location B, enclosed with plants, it is evident that location B exhibits better indoor air quality. This improvement in air quality in location B is attributed to the presence of plants in the vicinity.

Although both location C Courtyard and D the basement parking represent outdoor areas, a noticeable difference in the CO_2 readings, clearly favouring outdoor spaces enriched with lush flora. This accentuates and substantiates the premise that the inclusion of plants substantively amplifies the quality of air.

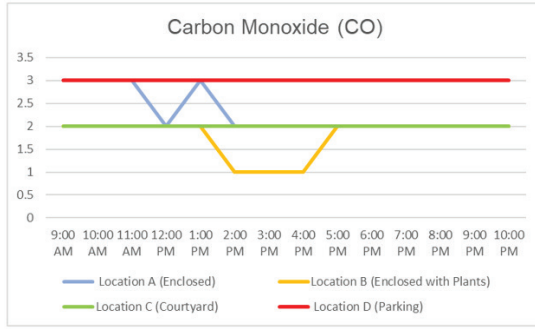

Figure 11. Carbon Monoxide Graph

Source: Author, (2023)

Figure 11 includes a graph depicting the levels of carbon monoxide which showcases Location A, B, C and D. The lowest CO count is 1 ppm which is at location B and the highest is 3 ppm is at location D. Based on Figure 4, these four CO readings are on a normal level. At levels between 1-5 ppm, CO exposure is unlikely to cause immediate health effects in most individuals.

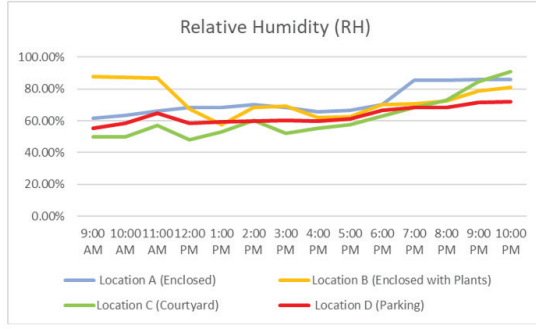

Figure 12: Relative Humidity Graph

Source: Author, (2023)

Figure 12 is a graph depicting the levels of relative humidity from Location A, B, C and D. The highest percentage of humidity is at location C which is 90.80% at 10:45 PM. This is because at night, temperatures often drop, causing a decrease in the air's capacity to hold moisture. When the air cools down, its ability to retain water vapor diminishes, potentially

leading to higher relative humidity levels. If the humidity remains constant but the temperature decreases, the air becomes relatively more saturated with moisture, leading to a higher perceived humidity. Whereas the lowest humidity percentage is 48.30% at 12:45 PM located in location C. As the day progresses and approaches midday (12:45 pm), temperatures tend to rise. Warmer air has a higher capacity to hold moisture, which means that the relative humidity—the ratio of moisture in the air to the maximum it can hold—often decreases as temperatures increase.

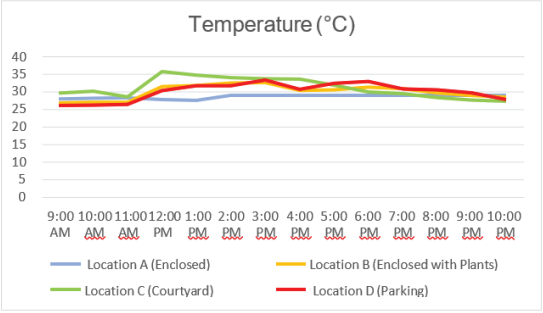

Figure 13. Temperature Graph

Source: Author, (2023)

Figure 13 is a graph depicting the levels of temperature taken at Location A, B, C and D. The highest recorded temperature is at location C with a reading of 35.6°C at 12:45 PM. At this time, the sun's rays are most direct and because the sun reaches its highest point in the sky, resulting in maximum heating of the Earth's surface. The Earth absorbs a significant amount of solar radiation, which leads to increased temperatures. However, the lowest temperature recorded is 26°C at location D. This is because underground parking has limited exposure to direct sunlight. As a result, they don't receive the same amount of solar radiation that warms surfaces above ground. Without sunlight, the surroundings remain cooler. Other than the lack of sunlight, basement parking often has limited ventilation and airflow. Without natural air movement, heat exchange with the outside environment is reduced.

CONCLUSIONS AND FUTURE WORKS

The impact of integrated greenery on air quality was studied at Tamarind

Square, Cyberjaya. This research deliberately showed the difference in air quality reading in the four areas. The areas with greenery have better air quality than areas without. It was shown that enclosed spaces (Location B), had better indoor air quality, highlighting the contribution of plants to lowering carbon dioxide levels and also the outdoor locations, showing rich vegetation in courtyards (Location C) is positively correlated with improved air quality as compared to less vegetated places such as enclosed area (Location A) and parking lots (Location D).

Throughout the study, notable limitations were encountered, including the impact of rainy weather on data collection and the constraint of limited time due to the considerable distance between myself and Tamarind Square. Despite these challenges, the completion of this paper was successfully achieved.

The advantages of vegetation outweighed the reduction of CO_2 and included regulating humidity, and temperature. These results highlight the critical connection between green space and more sustainable, healthy urban environments. To conclude, the study supports future urban planning which promotes the use of vegetation in both indoor and outdoor environments to promote better air quality.

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