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Effectiveness of Indoor Houseplant in Improving Indoor Air Quality of Standard Hotel Rooms to Temperature

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Abstract: In this modern era, developed countries such as Malaysia have rapid development. Rapid development is good for the country because it increases income, but it also produces a negative effect if the development is not managed well. The most critical side effect caused by uncontrolled development is air pollution. This study was conducted to analyze the thermal effect of a standard hotel room to improve indoor air quality by using an indoor houseplant design. The study was conducted at a standard hotel room of UiTM Cawangan Pulau Pinang, and three thermal parameters were analyzed in the study: temperature, relative humidity, and airflow rate. Three reading was taken daily for two weeks. The result shows that the average temperature of the hotel room with indoor houseplant decreased from 30.7°C to 28.5°C. The result for relative humidity also shows improvement with the presence of indoor houseplants. Reading of average relative humidity increased from 49.7% to 63.3% and achieved the recommended relative humidity at 50% to 70%. The impact of indoor air temperature by using indoor houseplants is significant to increase the room's ambient and comfort. This study contributes minimal maintenance methods in improving indoor air quality in terms of room temperature by using natural resources that may not harm the environment.

Keywords: Indoor houseplant, Indoor air quality, Standard hotel room, Thermal analysis, Temperature, Relative Humidity, Sustainable Design

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Introduction

In recent years, the rate of development in developed countries like Malaysia increased from one year to another. This rapid development harms our environment, including poor air quality, thermal, acoustics and lighting. Uncontrolled rapid development also can increase the temperature of the area. This was because the area usually had a flora population that was destroyed for the development work. Besides that, rapid development indirectly will affect our surrounding relative humidity because the plant that regulates the humidity was destroyed. Air quality can be divided into two sections: indoor air quality (IAQ) and outdoor air quality. The poor indoor air quality will cause irritation of the eyes, throat, nose, headache, dizziness, and fatigue (Lim et atl, 2009; Rani et al., 2018; Yang & Moon, 2019). Related to temperature and humidity, the thermal environment affects occupants' sensation of "warm" or "cool" and "humid" or "dry" and is considered to be the environmental factor to which guests pay the most attention. Some hotels use energy-intensive space-conditioning systems to maintain the indoor

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air quality of the hotel. Space conditioning (heating, cooling, and ventilation to maintain exacting standards of air quality and thermal comfort) typically consume the highest amount of energy for the building (Ehsan *et al*., 2011).

The tourism and hotel industry contributes positively to the country's socio-economic. But at the same time, it negatively affected further degradation of the surrounding. Green building and green hotel evaluation systems have emerged globally to operate sustainably with higher efficiency and maintain human comfort in space (Abdulaali *et al.*, 2020). In general, the hotel was designed to accommodate the guest. Customer satisfaction was crucial in determining the future of the hotel. Hotel room design was the main factor that satisfied customers (Nunkoo *et al*., (2019). Based on the guideline that has been publishing by the Ministry of Tourism, Arts and Culture Malaysia (MOTAC) in 2015, several requirements in hotel room design must be met by the hotel administrative to give satisfaction to the customers, such as; i) Minimum room size of for single bed was 13 m2 and 16 m2 for double bed; ii) Minimum height for the hotel room was 2.5m; iii) Hotel room has to be equipped with air condition to guarantee the thermal comfort in each room and designed so that the guest can regulate the room temperature in each room; iv) Hotel room shall be capable of being ventilated naturally and can be controlled by the room occupants (Ministry of Tourism, Arts & Culture, 2015).

Furthermore, to solve the problem, houseplants can be used to improve and maintain the good indoor air quality in a hotel room. An indoor houseplant can act as a mechanism to improve the thermal parameter of the room, such as temperature, relative humidity, and airflow rate. Varied species of houseplants will give a different result to the parameter. Implanting the indoor houseplant into the hotel room can improve the indoor air quality and the occupant's health without affecting the hotel room's interior design. This study is developed to achieve two main objectives: i) to determine the temperature and relative humidity for standard hotel room UiTM Pulau Pinang with and without indoor houseplant, ii) to develop a correlation between temperature and relative humidity for standard hotel room UiTM Pulau Pinang to improve indoor air quality using indoor houseplant based on MS1525 (Jabatan Standard Malaysia, 2014).

Methods

These subsections explain the overall methodology of the experimental work, including the preparation of data collection and measured parameter to obtain the results in analyzing the effectiveness of indoor houseplants in improving indoor air quality with respect to temperature.

Preparation of Data Collection

Preparation of data collection involving the determination of the case study location and designing indoor houseplant is critical to ensure that the data obtained in this study fulfil the results that reflect the dependent and independent variables in this study. The dependent variable determined in this study were the number and type of plants, while the independent variables were temperature and relative humidity.

Location of the Case Study

The study was conducted at the standard hotel room of UiTM Cawangan Pulau Pinang. The building plan of Hotel UiTM Cawangan Pulau Pinang was obtained from the facility Department of UiTM Cawangan Pulau Pinang to determine the direction of the sunlight toward the building. After the hotel room's location had been identified, two identical rooms side by side were selected to eliminate the factor of different amounts of sunlight entering the room. The size of the room and interior arrangement of the hotel room were the same to minimize the variation that can affect the result. The standard hotel room that has been chosen has an area of 26m2. Figure 1 shows the location of a standard hotel room that involves sunlight direction as a criterion in the hotel room selection. The plan was obtained from Facility Department, Universiti Teknologi MARA Cawangan Pulau Pinang.

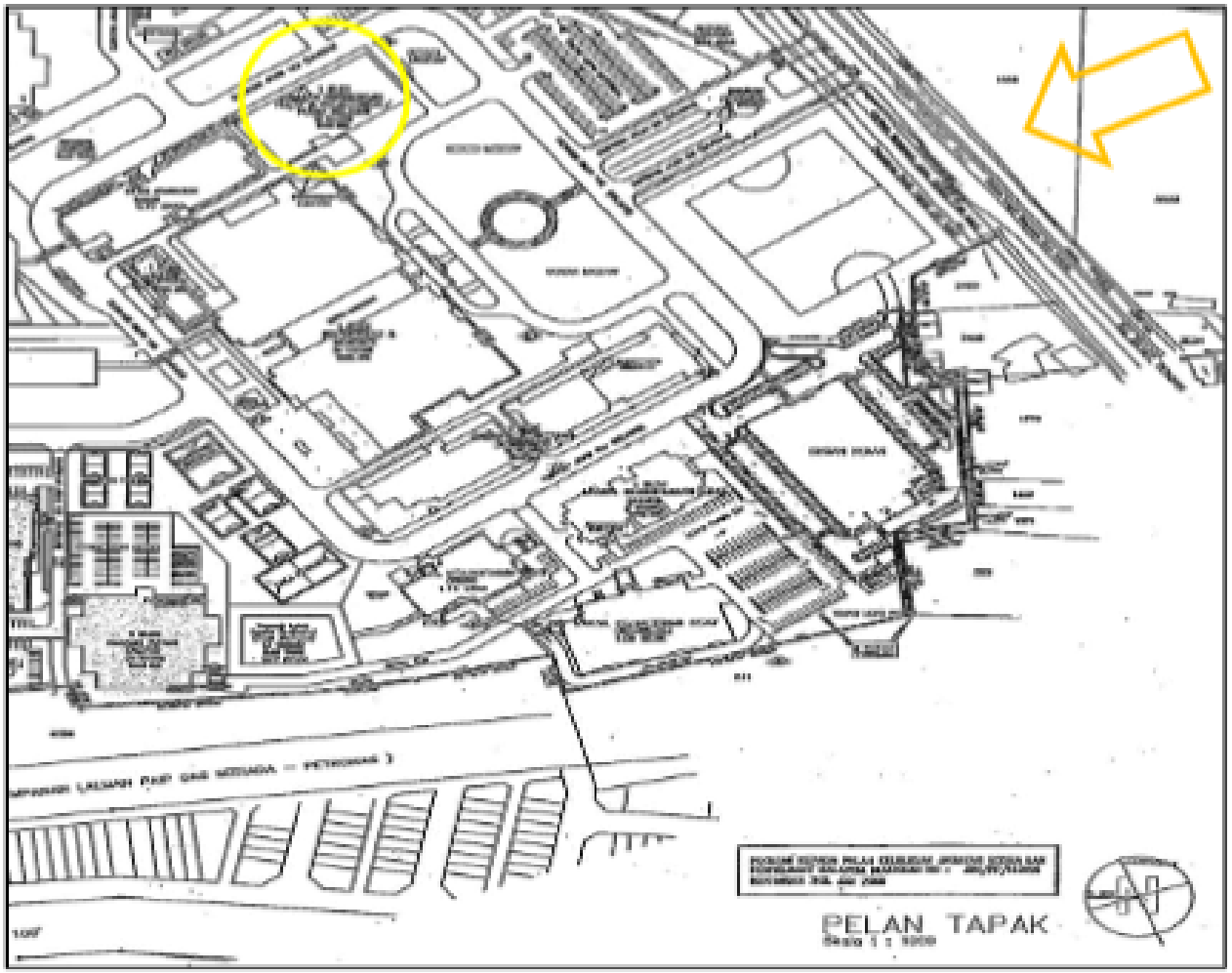

Figure 1. Location of Standard Hotel Room from Key Plan

Designing Indoor Houseplants

In this research, the suitable type of indoor houseplant and its ability will be analyzed before placing it in the variable room. The different plant has a different ability to improve indoor air quality. The houseplant's suitability is also considered when choosing an indoor houseplant. This is because some plants require a lot of sunlight and water to survive and help improve indoor air quality. It is also important to choose a plan that is easy to manage so that the hotel can implement the indoor houseplant. A potted method is chosen for this case study because limited space of standard hotel rooms. In this research, the number of indoor houseplants that will be used is eight, and the type of plant is succulent and foliage. The indoor houseplant was placed at the window and on the table. The indoor houseplant type and arrangement refer to the previous study conducted by (Asnani, 2017).

Based on the previous findings, each plant species has its advantage in improving indoor air quality in terms of thermal. In this research, two foliage plants and two succulent plants were in the hotel room. A combination of two different types of plants will provide many advantages to the hotel room. Eight indoor houseplants were used in this study. For foliage species, the plant used two units of Pothos and two units of Peace Lily; for succulent species, the plant used two numbers of Sansevieria and two numbers of Aloe Vera. These types of plants were chosen because they were easy to find and required minimal maintenance for their ability to improve indoor air quality.

Figure 2 below shows the arrangement of the indoor houseplant in the hotel room. The indoor houseplant was located at the hotel room's window and on the bedside table to help improve the indoor air quality evenly.

(a) (b)

Figure 2. (a) Control Room without Indoor Houseplants; (b) Variable Rooms with Indoor Houseplants

Table 1 shows the type of indoor houseplants chosen in this study to obtain the indoor air temperature effectiveness for a standard hotel room. A description of the advantages was also included to explain the benefits of the indoor houseplants chosen in this study.

Table 1: Types of Indoor Houseplants Adopting

Name of plant	Advantage	Picture
Pothos Scientific name: Epipremnum aureum Local name: Pokok Duit-Duit	It can purify the air from harmful toxins, especially formaldehyde Minimal maintenance, water when necessary	
Peace Lily Scientific name: Spathiphyllum cannifolium Local name: Bunga Sepatu Lili Perdamaian	Help to improve sleep Filter toxic substances such as benzene, ethyl chloride and formaldehyde Does not need too much light. Required distilled water	
Rubber Fig Scientific name: Ficus Elastica Local name: India Rubber Tree	Remove toxins in the air Fight tropical diseases, parasites, and absorption of formaldehyde. Keep the leaves clean to maintain the ability to clean the environment.	
Sansevieria Scientific name: Sansevieria trifasciata Local name: Pokok Lidah Jin	It can absorb polluting toxins like benzene, formaldehyde, trichloroethylene (TCE), xylene, and toluene. The Leaves can be used as a holistic remedy for pain relief and skin irritation.	
Aloe Vera Scientific name: Aloe Vera Local name: Star Cactus Pokok lidah Buaya	It can monitor the air quality by showing brown leaves stains and can help control the air quality. Removing particles of formaldehyde, ammonia, xylene, and toluene.	

Measured Parameter

The measured parameter in this study is vital to obtain the independent variables used to examine indoor houseplants' effectiveness in improving indoor room temperature. Based on this study, two measured parameters were used: temperature and relative humidity. Generally, the data was observed three times per day in the morning, afternoon, and nighttime to monitor the different variables in the experimental work regarding temperature and relative humidity.

Temperature

The temperature was one of the parameters that were taken to determine the indoor air quality of the hotel room. The method that was used to measure was dry bulb reading. The procedure to measure the temperature in the building was referred from ASHRAE 55-2004 and was followed closely to achieve an accurate result. The data collection was conducted with the room air-conditioning, and ventilation fan switched off. This was to evaluate the effect of indoor houseplants on reducing the room temperature. Bed area was chosen because, according to ASHRAE guidelines, measurements shall be taken in locations where the most extreme values of the thermal parameters are estimated or observed to occur (Turner *et al.*, 2008). The temperature reading was measured using Hydro-Thermometer and placed at 1.1m from the floor as stated on the guideline in Figure 3. Data from the room with and without an indoor houseplant was compared to determine the ability to improve indoor air quality.

Figure 3: Extech 445703 Hydro-Thermometer

Relative Humidity

The second parameter in the thermal analysis was relative humidity. Lower relative humidity will give a colder feeling than higher relative humidity with the same temperature. With the reading of relative humidity, the ability of indoor houseplants to improve indoor air quality can be evaluated. The reading of the relative hotel room humidity with an indoor houseplant will be compared with the reading of a room without an indoor houseplant. Based on ASHRAE 55-2004, the measurement point for a room's relative humidity was only one. The measuring point for the relative humidity was taken at the bed area of the room for a proper representative relative humidity of the hotel room. Data measuring procedure was followed from ASHRAE 55-2004, and reading was taken by using Hydro-Thermometer (Turner *et al.*, 2008). The data was measured three times a day in the morning, afternoon, and night.

Results and Discussion

In these results and discussion, data was analyzed and compared with the Industry Code of Practice on Indoor Air Quality guideline produced by the Department of Safety and Health by referring to MS1525. The parameters that were measured were temperature and relative humidity.

Comparison of Temperature for Standard Hotel Room Between Control Room and Variable Room

Figure 4 shows the results explaining the temperature performance for standard hotel rooms between control and variable rooms. Based on the table, the average temperature for the control room slightly increased from day to day. It started at 28.6°C on the first day and continued to increase until the last day of the experiment at 31.3°C. The difference between the highest and lowest temperature readings of the control room was plus 2.7°C. For the variable room, an opposite situation occurred. The temperature reading continues to decrease. The average reading for the first day was 30.7°C and 28.5 for the last day. The different temperature reading between the highest and lowest for the variable room was slightly lower compared to the control room at minus 2.2°C but it shows a good sign by decreasing the hotel room temperature. As we can see, despite the variable room starting with a slightly higher temperature on the first day, the indoor houseplant manages to reduce the temperature to 28.5°C compared to the constant room that does not contain indoor houseplant at 31.3°C. The room was hotter than the initial because the room was beside the air handling unit room. The equipment in the room produces much heat that causes the room to heat up. Even though the average temperature of the variable room was not in the recommended temperature range between 23°C to 26°C based on the DOSH standard, it was the closest average temperature reading within the two rooms.

The result obtained from the experiment was like other previous research that was conducted (Asnani, 2017), which concluded that indoor houseplants significantly reduce the temperature of an area by as much as 8.5°C by using succulent plants. It may seem that indoor houseplant was not good enough to achieve the recommended temperature, but it surely helps to regulate the temperature of the hotel room. From the result, it can be confirmed that foliage and the succulent plant can be used as indoor houseplants to improve indoor air quality. With the houseplant, the environment can be preserved. It can reduce the use of non-renewable energy and act as a green decoration for the hotel room. The ability of the indoor houseplant to reduce the temperature naturally reduced the use of non-renewable energy by the air condition unit. Less power is used to translate to less pollution. In the overall analysis, the variable room resulted in an average temperature decreasing 2.2℃, about 7.7 per cent, and the control room increased by an average temperature increasing 2.7℃, about 8.5 per cent. Besides that, the number of indoor houseplants can be increased to improve and achieve the recommended value for temperature. A higher number of indoor houseplants can help further reduce hotel room temperature.

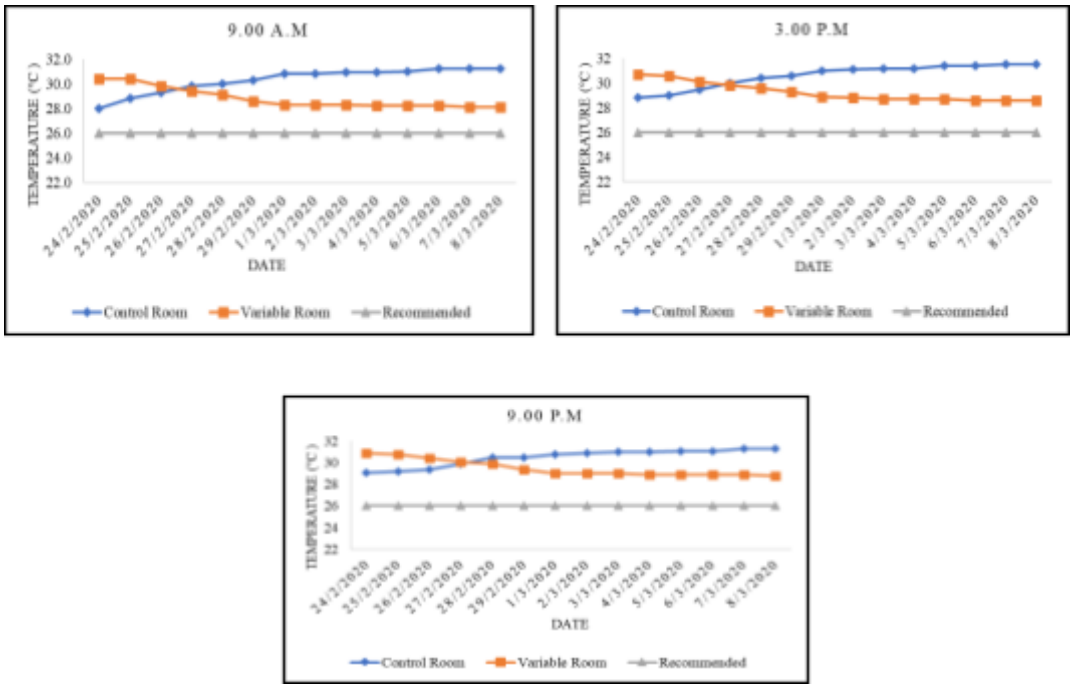

Figure 4. The temperature comparison for control and variable standard hotel room

Comparison of Relative Humidity for Standard Hotel Room Between Control Room and Variable Room

Referring to the results in Figure 5, the control room shows a decreasing trend of average relative humidity from the first day until the last day. On the other side, the variable room shows a constant increase of average relative humidity, with the reading on the first day being 49.7 per cent and 63.3 per cent on the last day. The difference in average relative humidity between the first day and the last for the control room and variable room was 17.3 per cent and 13.6 per cent. Even though the different average relative humidity for the control room was higher than the variable, the room showed negative progress. The reading of average relative humidity for the variable room shows an increased value that indicates a positive situation. Based on the Industry Code of Practice on Indoor Air Quality published by the Department of Safety and Health (DOSH), the recommended design relative humidity was between 40 per cent and 70 per cent. By referring to the table, both rooms were in the range recommended by the guideline. However, the variable room equipped with indoor houseplant achieved well in the recommended value compared to the control room, just above the minimum recommended value. Analyzing the data on relative humidity clearly shows that indoor houseplants can regulate relative humidity. An indoor houseplant can improve the indoor air quality of a hotel room. Previous research made by Asnani (2017) on the impact of a houseplant on indoor air quality, succulent and foliage types of plants has shown improvement in regulating the relative humidity of an area.

The research states that indoor houseplants reduce relative humidity up to 13.5 per cent as the characteristic of the indoor houseplant tends to release moisture into the environment, as shown in the variable room. Indoor houseplant regulates the relative humidity by using their leaves. For example, foliage type of plant has thin and broad leaves with a more extensive surface area that allows the houseplant to regulate the relative humidity by releasing or absorbing moisture from the surrounding. Even though the reading for the relative humidity of the variable room was lower on the first day compared to the control room, the indoor houseplant managed to increase the relative humidity. The indoor houseplant may have released water vapour into the surroundings, increasing the reading of variable rooms. The initial reading for the variable room was lower because the room

had a higher sunlight intensity, and the room was beside an air handling unit (AHU) room that produced much heat. Based on the result, the hotel does not have to install an additional device to regulate relative humidity. Hotel management can use indoor houseplants to improve their hotel's indoor air quality, which helps them reduce energy consumption. The control room decreases the average relative temperature by about 17.7 per cent, which proves that indoor houseplants significantly change this parameter and increase the room's comfort level. It is important to ensure that the hotel room is convenient for the customer by improving indoor air quality.

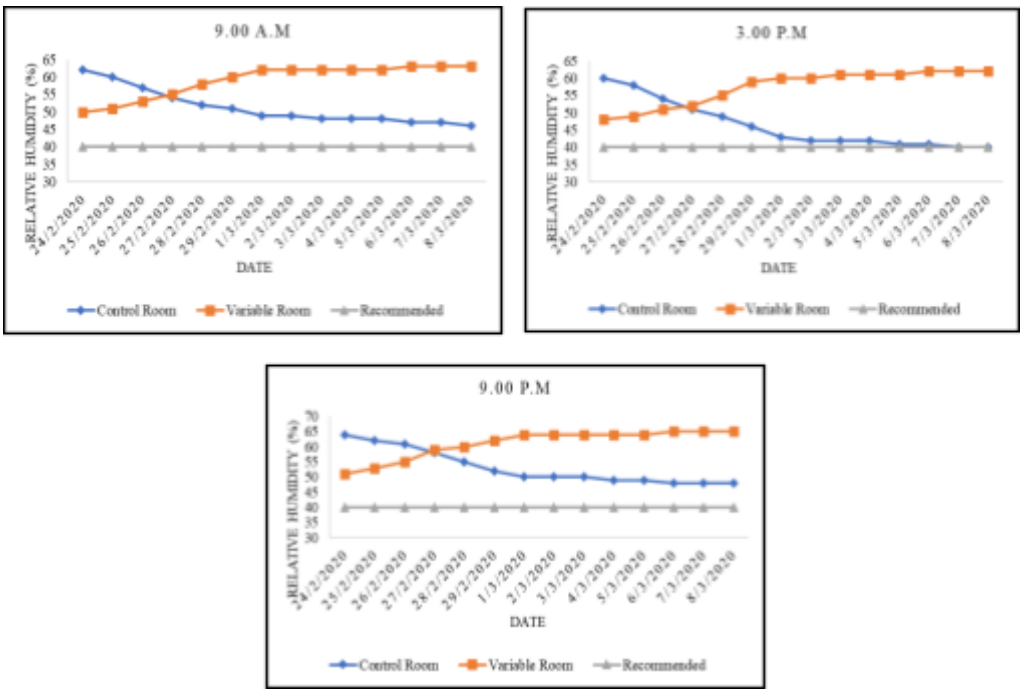

Figure 5. The relative comparison for control and variable standard hotel room

Correlation of Temperature and Relative Humidity for Standard Hotel Room Between Control Room and Variable Room

A linear relationship was produced based on regression analysis as the best-fitted relationship of both parameters, as shown in Figure 6. The correlation pattern shows a negative slope due to the relationship between the parameters, concluding with temperature decreasing while relative humidity increases. Furthermore, the pattern shows that the actual and predicted data obtained in this study produce a strong correlation due to the R2 value 0.991 where it is representing 99.1 per cent of the variances same as the predicted values of the relationships. Besides that, it is also showing a significant correlation between temperature and relative humidity based on a regression analysis that was done in this study due to the exceptionally low probability of the outliers' data observed in this study representing by significance F-value with 1.15 x 10-12 where it is near to zero.

A few factors were found in this study as the main consideration that produced significant results, which are succulent and foliage indoor houseplants positively produce a significant effect on the indoor air quality. The proposed arrangement of the indoor houseplants referred to Asnani (2017) proves the significant correlation between the indoor air quality parameters. Furthermore, controlling the number of plants is important because the temperature is slightly constant after ten days of experimental work. Therefore, to optimum the significant effect of increasing the relative humidity, decreasing room temperature by using indoor houseplants should be controlled by determination of the number and location of the plants.

Based on the linear equation of both parameters, the slope shows an interpretation of -6.02 degrees Celsius reflected in each percentage of relative humidity. An increase of one per cent in relative humidity is linked to an average decreasing of 6.02 Degrees Celsius. The intercept relationship of correlation between temperature and

relative humidity happened when the temperature is at zero degrees Celsius, and the relative humidity is 234.9 per cent. This model is suitable for predicting the requirements of standard indoor relative humidity based on the Department of Safety and Health Malaysia (DOSH) average indoor temperature, which is 26 Degree Celsius. Based on the analysis, the indoor room temperature will meet 26 degrees Celsius when the relative humidity is 78.4 per cent. Therefore, increasing the number of indoor houseplants in the room is significant to increase the relative humidity and decrease the temperature to meet the Indoor Air Quality Standard by DOSH.

In conclusion, this correlation relationship is significant to be used as predicted values for temperature and relative humidity for hotel or indoor rooms to improve the indoor air quality that meet the MS1525 requirement by DOSH.

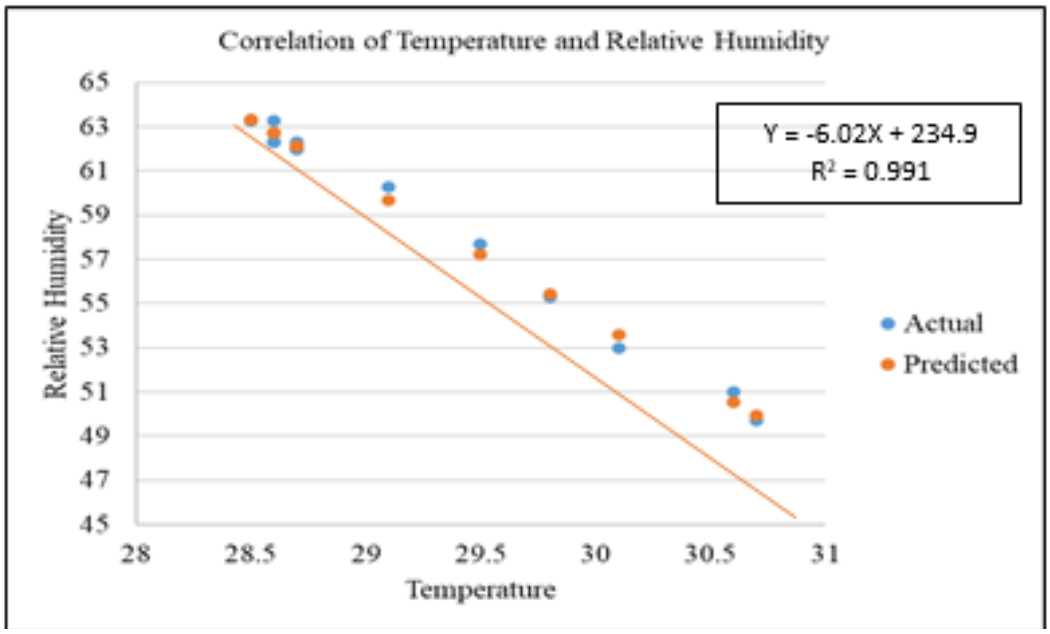

Figure 6. Correlation of Temperature and Relative Humidity of Variable Room

Conclusion

The research study is able to explain indoor houseplants' effect on improving indoor air quality. The analysis of the temperature parameter shows that indoor houseplant helps to improve the indoor air quality in the standard hotel room. Placing four succulent plants and four foliage plants reduced the hotel room's average temperature from 30.7°C to 28.5°C, which was a reduction of 2.2°C. Increasing the number of indoor houseplants is recommended to improve the significant changes in temperature and relative humidity. For the analysis of the relative humidity, each room achieved the recommended range based on the DOSH standard. Indoor houseplant indicates its ability to further improve the hotel room's indoor air quality by showing an increasing trend of average relative humidity reading from 49.7 per cent to 63.3 per cent with a 13.6 per cent difference. A linear type of graph was formed based on the regression analysis. The graph shows a negative slope that indicates that temperature decreased while relative humidity increased. This research shows a strong correlation between predicted value and actual value as the value was very close between each other and the value of R2 of 0.991. Other than that, regression analysis shows a significant correlation between temperature and relative humidity with an F-value close to zero. Based on the linear equation, an increase of one per cent in relative humidity was found, causing the temperature to decrease by 6.02°C. This information was suitable to predict the relative humidity required based on the DOSH standard with an average indoor temperature of 26°C.

In conclusion, it can be deduced that indoor houseplants improved the indoor air quality of a standard hotel. In the research, indoor houseplant shows a significant positive effect on the temperature and relative humidity of

the hotel room, except for the air flow rate. The correlation pattern produced was significant and can be used to predict indoor areas' temperature and relative humidity to improve indoor air quality and meet the Departmental of Occupational, Safety and Health (2010) standards.

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