JPPIPA 9(12) (2023)

Jurnal Penelitian Pendidikan IPA

Journal of Research in Science Education

http://jppipa.unram.ac.id/index.php/jppipa/index

Indoor Environmental Quality & Occupant Satisfaction in Green Building (*Case Study: Company X at East Jakarta, DKI Jakarta*)

Yuniar Widya Larasati[1*], Rachmadhi Purwana[2], Ahyahudin Sodri[2]

[1] School of Environmental Science, Post-Graduate School, University of Indonesia, Jakarta, Indonesia.
[2] School of Environmental Science, University of Indonesia, Jakarta, Indonesia.

Received: October 9, 2023
Revised: November 23, 2023
Accepted: December 20, 2023
Published: December 31, 2023

Corresponding Author:
Yuniar Widya Larasati
yuniarwidya@gmail.com

DOI: 10.29303/jppipa.v9i12.6236

Abstract: The global movement in green building development has been going on since the early 1960s. Although initially driven by environmental agendas such as carbon and energy, there is a growing acknowledgment that green buildings can affect Indoor Environmental Quality (IEQ). Many researchers also state that improved indoor environmental quality is associated with better occupant satisfaction. However, some localized green buildings, especially in developing countries, often don't recognize IEQs and occupant satisfaction as important issues, so they remain unstudied. Therefore, this study aimed to evaluate the performance of IEQ and occupant satisfaction. The analytical methods used were descriptive statistics and regression analysis. The outcome demonstrated that green building standards do not automatically improve indoor environment quality, particularly when the lighting parameter is below the limit values. The analysis findings showed that most respondents expressed their satisfaction with IEQ and significantly influenced occupant satisfaction. In addition, this research contributes to the development of green building evaluation practices that prioritize environmental health and occupant satisfaction.

Keywords: Green building; Indoor environmental quality; Occupant satisfaction

Introduction

The global movement in green building construction began in 1960 and was proposed by Paolo Soleri. Paolo Soleri first introduced Arcology as a vision and concept of green urbanism to create a design that integrates architecture design and ecological principles. Paolo Soleri's Arcology concept was the foundation for the creation of green buildings in the future. Afterward, green building was officially presented in 1992 at the UN Conference on Environment and Development in Rio de Janeiro (Austin et al., 1974; Heerwagen, 2000; Marszal et al., 2011). When green buildings were first introduced, the main goals were to reduce the building's CO_2 emissions and achieve net zero emissions by 2050, and researchers have reported that green buildings can reduce CO_2 emissions by up to 35% (Klufallah et al., 2014). Although mainly focused on optimal energy efficiency, carbon reduction, and sustainable materials (Zhao et al., 2015). Green buildings also could affect the Indoor Environmental Quality (IEQ). Several studies have found that green-certified office buildings contribute to increased perceptions of indoor environmental quality compared to conventional office buildings (Hedge et al., 2014; Issa et al., 2011; Liang et al., 2014; Newsham et al., 2013). In the workplace, building occupants' satisfaction with their indoor environment has been linked to their health and well-being (Altomonte et al., 2019).

IEQ factors influence the satisfaction, health, and well-being of building occupants. The five main IEQ factors (air quality, lighting, interference, temperature, and humidity) that significantly impact occupant satisfaction are thermal comfort, IAQ, visual comfort and acoustic comfort. Various parameters further influence each IEQ factor. For example, previous

How to Cite:
Larasati, Y. W., Purwana, R., & Sodri, A. (2023). Indoor Environmental Quality & Occupant Satisfaction in Green Building (Case Study: Company X at East Jakarta, DKI Jakarta). *Jurnal Penelitian Pendidikan IPA*, *9*(12), 11773–11778. https://doi.org/10.29303/jppipa.v9i12.6236

literature shows that various parameters can influence thermal comfort, including air temperature, radiation temperature, relative humidity, air speed, metabolic rate, and clothing surroundings (Roumi et al., 2023). Therefore, knowing the IEQ performance parameters in achieving occupant satisfaction is very important.

The results are expected to contribute to the development of ecological science in the field of sustainable built environment, particularly in the green building sector. The findings can also serve as reference material for further investigation. The study's practical benefits include providing information on the indoor environmental quality and occupation satisfaction of green buildings and serving as the Building Management (BM) reference in carrying out periodic assessments and improving indoor environmental quality.

Method

Data collection was carried out using primary data. Furthermore, the primary data were obtained from an occupant's satisfaction survey of 133 employees who worked in Company X green building. An online survey link was used to collect questionnaire data from building occupants from late May to mid-July 2023.

The process was then continued with the measurement of IEQ, including indoor air quality (CO, CO2, PM10, VOC), temperature, humidity, noise, and lighting. IEQ measurements are carried out using third-party laboratory services certified by KAN on June 19th, 2023, for eight working hours and repeated once the following week at the same time. Measurements were conducted during the summer when the average temperature was around 32-34^{o}C in the daytime.

Table 1. Threshold Value Criteria for IEQ

Parameter	Threshold Value Criteria (TVC)
Carbon Monoxide (CO)	10 ppm
Carbon Dioxide (CO_2)	1000 ppm
Volatile Organic Compound (VOC)	3 ppm
PM10	0.15 mg/m^3
Temperature	23 – 26 Celcius
Humidity	40 – 60%
Lighting	300 lux
Noise	55 – 65 dBa

This study was carried out using a quantitative method, which was used to analyze Indoor Environmental Quality (IEQ), occupant satisfaction and the relationship between IEQ variables and occupant satisfaction. Indoor Environment Quality (IEQ), such as indoor air quality, temperature, humidity, noise, and lighting, were analyzed based on the Threshold Value Criteria (TVC) of IEQ from Minister of Health Regulation No. 48 of 2016 using descriptive analysis. The threshold value criteria can be found in Table 1. Survey occupant satisfaction was analyzed using a correlation test and linear regression analysis.

Result and Discussion

Company X green building is located in East Jakarta City, DKI Jakarta Province. At the study location, Company X's green building was the primary headquarters of a contractor company located in East Jakarta. Furthermore, it was built in 2013 and was certified with a Greenship Silver certificate by the Green Building Council Indonesia (GBCI) in 2015. The building has five floors with a GFA of 4923.85 m^2 and an NLA of 4028.45 m^2.

Indoor Environmental Quality (IEQ)

IEQ measured in this study included indoor air quality (CO, CO2, PM10, VOC), temperature, humidity, noise, and lighting. The measurements were done over 8 hours of working time with two sampling locations by selecting the most densely populated office rooms. Furthermore, the assessments were conducted at two sampling locations on the basement and 3rd floors. Environmental quality measurements in the two locations were performed simultaneously from 8:00 to 5:00 p.m. and repeated twice, with the results being presented in Table 4.

The overall indoor air quality results (CO, CO_2, PM10, and VOC) were below the Threshold Value Criteria (TVC) set by the Ministry of Health in Regulations No. 48 of 2016. Indoor air quality was an essential component of green building. Some related studies showed that indoor air quality in green buildings had better performance when compared to conventional buildings (Agarwal et al., 2021; Gawande et al., 2020; Paital et al., 2021).

Based on the results of the temperature assessment, the basement floor had a slightly lower temperature than the 3rd floor. The temperature on the basement floor was 25.1^{O}C & 25.2^{O}C, and the 3rd floor was 25.5^{O}C & 25.4^{O}C. According to the Ministry of Health in Regulation No. 48 of 2016 on Standards for Safety and Health at Work, the ideal temperature in the office ranged from 23^{O}C to 26^{O}C. Regarding humidity, the humidity on the basement floor was 55.4% and, 51.8% & 52.6% on the 3rd floor. The overall humidity was below the Threshold Value Criteria (TVC) set by the Ministry of Health in Regulations No. 48 of 2016, with the ideal indoor humidity being 40% - 60%. The results of noise measurements at both sample locations were still under the required standards. The results showed that the

noise measurement was still relatively stable, ranging between 52.8 dBa – 57.55 dBa.

Meanwhile, the results of lighting measurements in both locations showed that the basement floor had brighter lighting than the 3rd floor, with ranges of 373 – 377 lux and 266–269 lux, respectively. Lighting measurement results on the 3rd floor were below the TVC set by Minister of Health Regulation No. 48 of 2016, establishing the threshold value for lighting in office spaces at 300 lux.

Table 2. The Results of Indoor Environment Quality

Parameter	1st Measurement		2nd Measurement	
	Basement Floor	3rd Floor	Basement Floor	3rd Floor
CO	1.19	0.8	1.18	0.77
CO_2	838	730	857	715
PM_{10}	0.046	0.055	0.045	0.054
TVOC	0.012	0.008	0.012	0.008
Temperature	25.1	25.5	25.2	25.4
Humidity	55.4	51.8	55.4	52.6
Noise	57.55	57	52.8	56.6
Lighting	373	269*	377	266*

The results of this research are in line with research conducted by Khoshbakht et al. (2018), Nkini et al. (2022) and Hwang et al. (2011) where their research reports weaknesses related to lighting in green buildings, where there is too much artificial lighting and poor indoor lighting is perceived in green buildings. The weakness of artificial lighting could be attributed to the fact that architects prioritize natural lighting design in green buildings. Many architects often overlook the use of artificial lighting design. Improper conditions could cause glare problems, visual discomfort, negative impacts on worker productivity, health challenges, and behavioral problems in workers (Kwong, 2020).

Indoor Environmental Quality (IEQ) Towards Occupant Satisfaction

The respondents in this study were employees who worked in the Company X green building in DKI Jakarta. The minimum number of samples calculated using the Isaac and Michael formula was 133 people. Furthermore, questionnaires were sent through virtual messages to respondents, and data were collected from May 31, 2023, to July 25, 2023.

Validity Test

Testing the instrument's validity is done by correlating each item score with the total score using the Pearson Correlation (Product Moment) technique. If the correlation coefficient (r) ≥ r table indicates that the questionnaire item is valid or can measure the variable as per the test criteria. For more details, please refer to the following table:

Table 3. Research Instrument Validity Results

Item	Validity Coefficient	Criteria	Result
Temperature Comfort Satisfaction	0.671	0.1703	Valid
Noise Comfort Satisfaction	0.782	0.1703	Valid
Air Quality Satisfaction	0.748	0.1703	Valid
Lighting Quality Satisfaction	0.608	0.1703	Valid

Based on Table 3, the r table value is 0.1703 using (db) = 131. Because the item correlation coefficient (r) > r table (0.1703), these items are declared valid or capable of measuring this variable so that they can be used as a valid data collection tool in this research.

Reliability Test

The reliability test was carried out after verifying the research instrument's validity. Cronbach's Alpha is used as a reliability testing technique. The Cronbach's Alpha coefficient is the most used consistency test. The decision-making criteria is that if the Cronbach's Alpha coefficient value is ≥ 0.6, the questionnaire items are declared reliable or consistent in measuring the variables they measure.

Table 4. Research Instrument Reliability Results

N of Items	Cronbach's Alpha	Result
4 Question Items Likert scale	0.635	Reliable

Table 4 shows that the value of Cronbach's Alpha for the four question items is greater than 0.6. According to the provisions mentioned previously, the items that measure the satisfaction variable are declared reliable or consistent in measuring this variable.

Descriptive Analysis

The satisfaction indicator for temperature has an average weight of 4.4 with a standard deviation of 0.59. Most respondents expressed satisfaction with the temperature comfort at Company X. The noise comfort indicator has an average weighted result of 3.68 with a standard deviation of 0.85. Most respondents indicated their satisfaction with the sound comfort at Company X. Regarding the air quality indicator, the average weighted result of the satisfaction indicator for air quality is 4.04, with a standard deviation of 0.70. The air quality at Company X was satisfactory to most respondents. The satisfaction indicator for lighting quality shows an average weighted result of 3.83 and a standard deviation of 0.92. The majority of participants

found the lighting quality at Company X to be satisfactory. If we look at the overall weighted average of the indicators studied, it is 3.92 with a standard deviation of 0.76.

The majority of respondents expressed satisfaction with the comfort of green buildings at Company X. The overall results of the descriptive analysis can be seen in Table 5.

Table 5. Descriptive Analysis Results

Indicator		Respondent's Answer					Mean	Std
		Very Disastified (1)	Not Satisified (2)	Quite Satisfied (3)	Satisfied (4)	Very Satisfied (5)		
Temperature	f	0	0	16	84	33	4.13	0.59
	%	0.0%	0.0%	12.0%	63.2%	24.8%		
Noise	f	1	10	39	63	20	3.68	0.85
	%	0.8%	7.5%	29.3%	47.4%	15.0%		
Air Quality	f	1	1	21	79	31	4.04	0.70
	%	0.8%	0.8%	15.8%	59.4%	23.3%		
Lighting Quality	f	0	13	30	56	34	3.83	0.92
	%	0.0%	9.8%	22.6%	42.1%	25.6%		
Total Mean							3.92	0.76

Regression Analysis

Table 6 displays the outcome of estimating a regression model to test the relationship between indoor environmental quality and employee satisfaction at Company X. Based on Table 6, the regression analysis results showed that the CO_2 parameter had a fairly high correlation coefficient of 0.982 and a p-value of 0.000. The results also showed the positive impact of CO_2 conditions on occupant satisfaction with air quality in Company X, where better CO_2 indoor conditions increased the satisfaction rate. Among the four parameters of air quality, CO_2 had the most dominant influence. Furthermore, the correlation analysis between the level of occupant satisfaction and two thermal comfort parameters (temperature and humidity) showed a significant relationship. Temperature and humidity conditions were reported to affect occupant satisfaction regarding thermal comfort positively. This showed that the better the indoor temperature and humidity conditions, the higher the level of the variable (Pan et al., 2021; Wolkoff et al., 2021).

Table 6. Regression Model Estimation of IEQ on Occupant Satisfaction

Satisfaction on	Parameter	Correlation Coefficient (r)	Regression Coefficient		t	P-value
			B	Std. Error		
Air quality	CO	0.189	0.730	0.490	1.490	0.141
	CO_2	0.982	0.005	0.000	41.095	0.000
	TVOC	0.189	72.581	48.700	1.490	0.141
	PM_{10}	0.189	-0.032	0.021	-1.490	0.141
Thermal Comfort	Temperature	0.990	0.167	0.003	53.747	0.000
	Humidity	0.990	0.079	0.001	53.702	0.000
Acoustic Comfort	Noise	0.341	0.404	0.144	2.808	0.007
Lighting Comfort	Lighting	0.971	0.012	0.000	31.812	0.000

The correlation analysis results between the occupant satisfaction level and noise parameter showed a significant relationship within acoustic comfort. Positive results were also obtained, showing that noise conditions positively affected occupant satisfaction regarding sound comfort. Furthermore, the better the noise conditions in the room, the higher the level of occupant satisfaction. The correlation analysis results between the occupant satisfaction level and lighting parameter showed a significant relationship. Lighting conditions positively affected the variable regarding visual comfort. This showed that the better the lighting conditions in the room, the higher the level of occupant satisfaction.

The correlation analysis results between the occupant satisfaction level and noise parameter showed a significant relationship within acoustic comfort. Positive results were also obtained, showing that noise conditions positively affected occupant satisfaction regarding sound comfort. Furthermore, the better the noise conditions in the room, the higher the level of occupant satisfaction. The correlation analysis results between the occupant satisfaction level and lighting parameter showed a significant relationship. Lighting conditions positively affected the variable regarding visual comfort. This showed that the better the lighting conditions in the room, the higher the level of occupant satisfaction.

Personal attitudes may influence satisfaction reported by occupants and vary depending on time spent in the building and the occupant's position in the office hierarchy. Research also shows that 'green branding' can increase pro-environmental perceptions (Altomonte et al., 2019; Górska-Warsewicz et al., 2021).

Conclusion

In conclusion, the results of IEQ in this study included indoor air quality (CO, CO_2, PM10, and VOC), noise, temperature, humidity, and lighting. The overall indoor air quality, noise, temperature, and humidity results were consistent with TVC values. However, the lighting parameter was below the limit values based on the Ministry of Health in Regulation No. 48 of 2016. 4) The regression analysis of occupant satisfaction on air quality showed that, among four air quality parameters, CO2 had the most dominant influence on the level of satisfaction concerning air quality.

Our study shows that adhering to green building standards automatically improves indoor environment quality. The evidence suggests that periodic evaluation of green building operations performance is necessary to identify potential problems that could arise. Follow-up action needs to be taken by the building management to address this problem and improve the quality of the indoor environment to ensure and maintain the comfort of the occupants.

In addition, future studies on green building evaluation could investigate how indoor environmental quality affects the health and productivity of occupants.

Acknowledgments
The author would like to thank Company X for allowing them to collect and conduct research on their green office building. In addition, the author would also like to thank the employees of Company X who have consented to participate in this research.

Author Contributions
Conceptualization, analysis & writing – original draft preparation, Yuniar Widya; supervision, validation, writing – review & editing, Rachmadhi Purwana; methodology, validation, writing – review & editing, Ahyahudin Sodri.

Funding
This research received no external funding.

Conflicts of Interest
The authors declare no conflict of interest.

References

Agarwal, N., Meena, C. S., Raj, B. P., Saini, L., Kumar, A., Gopalakrishnan, N., Kumar, A., Balam, N. B., Alam, T., Kapoor, N. R., & Aggarwal, V. (2021). Indoor air quality improvement in COVID-19 pandemic: Review. *Sustainable Cities and Society*, *70*, 102942. https://doi.org/10.1016/j.scs.2021.102942

Altomonte, S., Schiavon, S., Kent, M. G., & Brager, G. (2019). Indoor environmental quality and occupant satisfaction in green-certified buildings. *Building Research and Information*, *47*(3), 255–274. https://doi.org/10.1080/09613218.2018.1383715

Austin, H. M., & Soleri, P. (1974). Arcology: The City in the Image of Man. *The Journal of Aesthetics and Art Criticism*, *33*(1), 115. https://doi.org/10.2307/428967

Gawande, M. B., Fornasiero, P., & Zbořil, R. (2020). Carbon-Based Single-Atom Catalysts for Advanced Applications. *ACS Catalysis*, *10*(3), 2231–2259. https://doi.org/10.1021/acscatal.9b04217

Górska-Warsewicz, H., Dębski, M., Fabuš, M., & Kováč, M. (2021). Green Brand Equity—Empirical Experience from a Systematic Literature Review. *Sustainability*, *13*(20), 11130. https://doi.org/10.3390/su132011130

Hedge, A., Miller, L., & Dorsey, J. A. (2014). Occupant comfort and health in green and conventional university buildings. *Work*, *49*(3), 363–372. https://doi.org/10.3233/WOR-141870

Heerwagen, J. (2000). Green buildings, organizational success and occupant productivity. *Building Research and Information*, *28*(5–6), 353–367. https://doi.org/10.1080/096132100418500

Hwang, T., & Jeong, T. K. (2011). Effects of indoor lighting on occupants' visual comfort and eye health in a green building. *Indoor and Built Environment*, *20*(1), 75–90. https://doi.org/10.1177/1420326X10392017

Issa, M. H., Rankin, J. H., Attalla, M., & Christian, A. J. (2011). Absenteeism, performance and occupant satisfaction with the indoor environment of green Toronto schools. *Indoor and Built Environment*, *20*(5), 511–523. https://doi.org/10.1177/1420326X11409114

Khoshbakht, M., Gou, Z., Lu, Y., Xie, X., & Zhang, J. (2018). Are green buildings more satisfactory? A review of global evidence. *Habitat International*, *74*, 57–65. https://doi.org/10.1016/j.habitatint.2018.02.005

Klufallah, M. M. A., Nuruddin, M. F., Khamidi, M. F., & Jamaludin, N. (2014). Assessment of Carbon Emission Reduction for Buildings Projects in Malaysia-A Comparative Analysis. *E3S Web of Conferences*, *3*, 1016. https://doi.org/10.1051/e3sconf/20140301016

Kwong, Q. J. (2020). Light level, visual comfort and lighting energy savings potential in a green-certified high-rise building. *Journal of Building*

Engineering, *29*. https://doi.org/10.1016/j.jobe.2020.101198

Liang, H. H., Chen, C. P., Hwang, R. L., Shih, W. M., Lo, S. C., & Liao, H. Y. (2014). Satisfaction of occupants toward indoor environment quality of certified green office buildings in Taiwan. *Building and Environment*, *72*, 232–242. https://doi.org/10.1016/j.buildenv.2013.11.007

Marszal, A. J., Heiselberg, P., Bourrelle, J. S., Musall, E., Voss, K., Sartori, I., & Napolitano, A. (2011). Zero Energy Building - A review of definitions and calculation methodologies. *Energy and Buildings*, *43*(4), 971–979. https://doi.org/10.1016/j.enbuild.2010.12.022

Newsham, G. R., Birt, B. J., Arsenault, C., Thompson, A. J. L., Veitch, J. A., Mancini, S., Galasiu, A. D., Gover, B. N., MacDonald, I. A., & Burns, G. J. (2013). Do green buildings have better indoor environments? New evidence. *Building Research and Information*, *41*(4), 415–434. https://doi.org/10.1080/09613218.2013.789951

Nkini, S., Nuyts, E., Kassenga, G., Swai, O., & Verbeeck, G. (2022). Evaluation of occupants' satisfaction in green and non-green office buildings in Dar es Salaam-Tanzania. *Building and Environment*, *219*, 109169. https://doi.org/10.1016/j.buildenv.2022.109169

Paital, B., & Agrawal, P. K. (2021). Air pollution by NO2 and PM2.5 explains COVID-19 infection severity by overexpression of angiotensin-converting enzyme 2 in respiratory cells: a review. *Environmental Chemistry Letters*, *19*(1), 25–42. https://doi.org/10.1007/s10311-020-01091-w

Pan, J., Tang, J., Caniza, M., Heraud, J., Koay, E., Lee, H. K., Lee, C. K., Li, Y., Nava Ruiz, A., Santillan-Salas, C. F., & Marr, L. C. (2021). Correlating indoor and outdoor temperature and humidity in a sample of buildings in tropical climates. *Indoor Air*, *31*(6), 2281–2295. https://doi.org/10.1111/ina.12876

Roumi, S., Zhang, F., Stewart, R. A., & Santamouris, M. (2023). Weighting of indoor environment quality parameters for occupant satisfaction and energy efficiency. *Building and Environment*, *228*, 109898. https://doi.org/10.1016/j.buildenv.2022.109898

Wolkoff, P., Azuma, K., & Carrer, P. (2021). Health, work performance, and risk of infection in office-like environments: The role of indoor temperature, air humidity, and ventilation. *International Journal of Hygiene and Environmental Health*, *233*, 113709. https://doi.org/10.1016/j.ijheh.2021.113709

Zhao, D. X., He, B. J., Johnson, C., & Mou, B. (2015). Social problems of green buildings: From the humanistic needs to social acceptance. *Renewable and Sustainable Energy Reviews*, *51*, 1594–1609. https://doi.org/10.1016/j.rser.2015.07.072