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THE RELATIONSHIP BETWEEN INDOOR AIR QUALITY (IAQ) AND SICK BUILDING SYNDROME (SBS) IN INDUSTRIAL BUILDING

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Abstract

This study examines the relationship between Indoor Air Quality (IAQ) and Sick Building Syndrome (SBS) in an industrial setting, specifically PT XYZ, an electricity-generating company in Surabaya, Indonesia. The primary objectives are to assess the IAQ parameters in relation to SBS symptoms, compare the results to air quality standards, and propose appropriate control measures. Data were collected from 79 employees using the IQAir Visual Pro and lux meter to measure $PM_{2.5}$ concentration, temperature, CO_2 concentration, humidity, and lighting in different sessions throughout the workday. The results indicated that $PM_{2.5}$, CO_2 concentration, and temperature generally complied with established standards, while humidity and lighting did not. A significant correlation was found between $PM_{2.5}$ and CO_2 levels with SBS symptoms in the morning session ($p < 0.05$), but this correlation weakened during the midday and afternoon sessions. Confounding factors, such as employees' health histories and research limitations, were considered. The findings highlight the importance of targeted air quality control measures, including optimizing ventilation and lighting, and regular maintenance to mitigate the effects of poor IAQ on employee health and well-being.

Keywords: Air quality standards, Indoor air quality, Industrial buildings, Occupational health, Sick building syndrome.

1. Introduction

Indoor air quality (IAQ) plays a crucial role in human health, especially as most people spend a significant portion of their time indoors. A study by Prihardanu et al. [1] reported that, due to recent global circumstances such as the COVID-19 pandemic, people now spend approximately 80-90% of their time inside buildings, whether at home or work. IAQ refers to the environmental conditions within indoor spaces, including offices, public facilities like schools and hospitals, and private residences [2].

Research by Mukono et al. [3] has shown that indoor pollutant levels rise in tandem with increased building activity. Factors such as materials used, building structure, ventilation systems, room design, and the maintenance of equipment all contribute to IAQ [4]. Thendean et al. [4] emphasized that both physical and chemical pollutants contribute to indoor air pollution.

Globally, poor IAQ is associated with significant health risks. Norhidayah et al. [5] estimated that 2.7% of the global disease burden is attributable to indoor air pollution. In office buildings, particularly those with inadequate ventilation, poor IAQ can result in complaints from occupants, leading to decreased productivity and morale [6].

One of the most concerning health impacts of poor IAQ is Sick Building Syndrome (SBS), a condition where occupants experience symptoms like eye irritation, respiratory issues, and fatigue without an identifiable cause. These symptoms are often linked to time spent in a building with inadequate ventilation and air quality [7].

Data from PT XYZ, the location of this study, indicated that many employees reported respiratory symptoms, including asthma, bronchitis, and sinusitis, which could be linked to SBS. Previous research supports the connection between poor air quality and SBS, particularly related to factors like temperature and humidity [8].

Given that Surabaya, where the study is located, is a heavily industrialized and traffic-congested city, external factors such as pollution from traffic can also exacerbate indoor air pollution. This study seeks to assess the IAQ in a large industrial office building in Surabaya, with a focus on its potential relationship with SBS symptoms among employees. By analysing key IAQ parameters such as $PM_{2.5}$, CO_2, temperature, humidity, and lighting, this research aims to provide actionable insights for improving air quality and employee health.

2. Materials and Methods

This research was conducted at a governmental electricity company in Surabaya, East Java Province, Indonesia, which employs around 321 office workers across six floors. The main sampling locations were buildings A and C, focusing on floors 3, 4, 5, and 6, specifically in areas where employees were actively working during office hours. A total of 14 sampling points were used in the company building, with two devices placed in each wing of the area. Although the building is equipped with a central air conditioning system, it does not have an automated airflow controller.

Data collection involved the use of the IQAir Air Visual Pro to measure $PM_{2.5}$, CO_2 concentrations, temperature, and humidity, and a lux meter to assess lighting levels. The IQAir Air Visual Pro devices were placed near ventilation systems or close to employee activity areas at eye level, using a tripod. The lux meter was used to measure light illuminance. Although there is limited information about the sensors' accuracy, the IQAir Air Visual Pro is considered reliable for $PM_{2.5}$ and CO_2 measurements [9].

Primary data was collected through questionnaires distributed to employees, as well as IAQ sampling conducted three times per day: morning (08:00-10:00 WIB), midday (11:00-13:00 WIB), and afternoon (14:00-16:00 WIB). The IAQ parameters were recorded every 10 minutes during each two-hour session. These data were compared to the Indonesian Government Regulation Number 22 of 2021, Appendix VII (ambient air quality standards), and the Minister of Health Regulation Number 48 of 2016 (occupational health standards for offices).

Additionally, secondary data included building layouts and employee health records from the company clinic, which provided information on disease history and health complaints.

The study used three types of variables: independent (X), dependent (Y), and supporting (Z). The independent variables (X) were IAQ parameters, including $PM_{2.5}$, CO_2 concentrations, temperature, humidity, and lighting. The dependent variables (Y) were the common symptoms of Sick Building Syndrome (SBS), which include ophthalmic (e.g., eye irritation, headaches, and dizziness), respiratory (e.g., sore throat, nasal congestion, coughing), and psychological (e.g., stress, depression) problems. The supporting variables (Z) included employee health histories, such as cases of asthma, sinusitis, and eczema.

The questionnaire responses were used to analyse the correlation between IAQ parameters and SBS symptoms, with 79 respondents selected based on predetermined criteria. Data processing was done using two statistical methods: the T-paired test and the point biserial correlation coefficient, both performed in SPSS software. The T-paired test was used to determine significant differences in IAQ parameters across three different time periods: morning, midday, and afternoon. The characteristics of respondents can be seen in Table 1.

Table 1. Characteristics of respondents.

No.	Characteristics	Frequency (n)	Percentage (%)	No.	Characteristics	Frequency (n)	Percentage (%)
	AGE				**YEARS of SERVICE**		
1	<25 Years	2	2.27	**1**	<1 Year	1	1.14
2	25 - 39 Years	57	64.77	**2**	1 - 5 Years	26	29.55
3	40 - 50 Years	24	27.27	**3**	6 - 10 Years	30	34.09
4	>55 Years	5	5.68	**4**	>10 Years	31	35.23
Total		**88**	**100**		**Total**	**88**	**100**
	GENDER				**LENGTH OF WORK**		
1	Male	61	69.32	**1**	6 Hours	4	4.55
2	Female	27	30.68	**2**	7 Hours	2	2.27
Total		**88**	**100**	**3**	8 Hours	56	63.64
	SMOKING STATUS			**4**	9 Hours	16	18.18
1	No	79	89.77	**5**	10 Hours	9	10.23
2	Yes	9	10.23	**6**	12 Hours	1	1.14
Total		88	100		**Total**	**88**	**100**

3. Result and Discussion

3.1. Correlation of IAQ parameters in three sessions

The t-paired test is conducted by comparing IAQ parameters in three approaches, which are morning-midday, morning-afternoon, and midday-afternoon in five aspects measured of IAQ parameters. Table 2 shows the correlation between parameters where there is significant correlation between temperature throughout three sessions and lighting only with midday-afternoon session.

Table 2. Correlation between IAQ parameters.

IAQ Parameters	Paired Samples Test (Sig.)		
	Morning-Midday	Morning-Afternoon	Midday-Afternoon
$PM_{2.5}$	0.000	0.000	0.001
Temperature	0.678	0.745	0.988
Humidity	0.055	0.027	0.263
CO_2	0.000	0.000	0.314
Lighting	0.005	0.016	0.788

3.2. Correlation between IAQ parameters and SBS symptoms

Point biserial correlation coefficient is conducted to identify the correlation between the questionnaire answer of SBS symptoms with IAQ parameters measured. Those who experienced the symptoms will be written as 1, while those who were not written as 0. The correlation conducted by using 24 respondents that are experiencing SBS symptoms during three sessions of measurements, where they are aware when the symptoms actually disappeared.

The correlation result shown in Table 3 in five IAQ parameters are mostly negatively correlated. Therefore, another approach is conducted, where it is figured 4 out of 24 respondents have prolonged symptoms. It can be seen that as it gets late, the respondents rather experience the symptoms even more, which is contrary to the concentration of IAQ parameters that are lower as it gets late. Thus, by observing if the respondents experience SBS symptoms in the morning and continue to midday or afternoon, it will be known that continued symptom means it will not contribute to the reported symptoms in the midday and/or afternoon or categorized as invalid symptoms data because it could disrupt the correlation data analysis.

Table 3. Pearson correlation of SBS Symptoms and IAQ parameters.

IAQ Parameters	Pearson Correlation	Sig (p value)	Interpretation
$PM_{2.5}$	-0.329	0.005	Negative correlation
Temperature	0.136	0.253	Very low correlation
Humidity	-0.132	0.269	Negative correlation
CO_2	-0.278	0.018	Negative correlation
Lighting	0.124	0.298	Very low correlation

As shown in Table 4, the correlation between IAQ parameters and SBS symptoms experienced by respondents in the morning is more relevant, especially in $PM_{2.5}$ and CO_2 concentration parameters that shows high correlation significance value of 0.003 and 0.039 than those in the midday and afternoon, as shown in Table 5. This is because the concentration of IAQ parameters in the morning is worse than the rest of the sessions, as the accumulation of particulate matter occurred due to air conditioning or air ventilations that are turned off during non-work hours [10]. It stated that concentration increased during non-work hours, then decreased during work hours. Weekend concentration was substantially higher than weekday concentration ($p<0.05$). Because filtration was turned off or rendered ineffective after work when all the buildings had filtration systems, indoor $PM_{2.5}$ concentration was higher during non-work hours. On the other hand, a drop in indoor $PM_{2.5}$ levels during business hours shows that the building's filtration system was in operation.

Table 4. Pearson correlation of SBS symptoms and IAQ parameters on 20 respondents.

IAQ Parameters	Pearson Correlation	Sig (p value)	Interpretation
$PM_{2.5}$	-0.323	0.120	Negative correlation
Temperature	-0.160	0.902	Negative correlation
Humidity	-0.124	0.346	Negative correlation
CO_2	-0.221	0.900	Negative correlation
Lighting	0.255	0.490	Low correlation

As the result is similar with the previous one, another approach is conducted in each of the sessions.

Table 5. Pearson correlation of SBS symptoms and IAQ parameters in each session.

Session 1 Morning			
IAQ Parameters	**Pearson Correlation**	**Sig (p value)**	**Interpretation**
$PM_{2.5}$	0.799	0.003	Very strong correlation
Temperature	-0.320	0.310	Negative correlation
Humidity	0.317	0.315	Low correlation
CO_2	0.610	0.039	Strong correlation
Lighting	-0.159	0.622	Negative correlation
Session 2 Midday			
$PM_{2.5}$	-0.199	0.291	Negative correlation
Temperature	-0.010	0.995	Negative correlation
Humidity	-0.640	0.737	Negative correlation
CO_2	-0.477	0.080	Negative correlation
Lighting	-0.477	0.008	Negative correlation
Session 3 Afternoon			
$PM_{2.5}$	-0.614	0.000	Negative correlation
Temperature	0.041	0.820	Very low correlation
Humidity	-0.308	0.081	Negative correlation
CO_2	-0.224	0.209	Negative correlation
Lighting	0.297	0.093	Low correlation

4. Conclusion

This study examined the relationship between indoor air quality (IAQ) and Sick Building Syndrome (SBS) in an industrial office building at PT XYZ in Surabaya, Indonesia. The results showed that while $PM_{2.5}$ concentrations, CO_2 levels, and temperature complied with air quality standards, humidity and lighting did not meet the required thresholds. A significant correlation between SBS symptoms and IAQ parameters was observed during the morning session, particularly with $PM_{2.5}$ and CO_2 concentrations. However, this correlation diminished in the midday and afternoon sessions. The findings suggest that factors such as overnight accumulation of pollutants, variations in ventilation, and employee health histories may influence SBS symptoms.

To mitigate the risk of SBS and improve IAQ, several control measures are recommended, including upgrading ventilation systems, improving lighting, increasing humidity control, and implementing regular building maintenance. These actions will help ensure a healthier indoor environment, thereby enhancing employee well-being and productivity. Further research could expand on these findings by including additional IAQ parameters and larger sample sizes in different industrial settings.

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