SRIWIJAYA JOURNAL OF MEDICINE

Survey of Association Between Indoor CO and CO_2 Levels and Symptoms of Sick Building Syndrome Among Employees at Alang-Alang Lebar and Plaju Health Centers

Delviana[1*], Agita Diora Fitri[2], Mariana[2]

[1]Medical Doctor Profession Study Program, Faculty of Medicine, Universitas Sriwijaya, Palembang, Indonesia
[2]Department of Public Health and Community Medicine, Faculty of Medicine, Universitas Sriwijaya, Palembang, Indonesia
*E-mail: delvianamirza@gmail.com

Abstract

Poor air quality and exceptionally high CO and CO2 pollutants can be contributing factors to Sick Building Syndrome (SBS). This study evaluated the relationship between individual factors and CO and CO2 levels with Sick Building Syndrome (SBS) symptoms in health center employees. 74 respondents work in the room of Alang-Alang Lebar and Plaju Health Center. Then, the respondents will fill out a questionnaire related to SBS symptoms. The rooms in the selected health centers will be measured for CO and CO2 levels. The results of filling out the questionnaire will be analyzed to determine whether SBS or not, and the results of measuring CO and CO2 levels will also be categorized as normal or not. Univariate and bivariate analyses related to individual employee factors, SBS symptoms, and CO and CO2. The results of 74 respondents showed that 36 respondents (48.6%) experienced SBS. The highest SBS symptoms were red, itchy, dry, or watery eyes (75%), and symptoms of dizziness or headache (71.4%). The highest CO level measurement result was seven ppm, the lowest was six ppm, while the highest CO2 level was 561 ppm, and the lowest was 498 ppm. These measurement results are still within the normal limits of the standards set. Bivariate test results showed that individual factors, CO and CO2, are not significantly related to SBS symptoms ($p > 0.05$).

Keywords: Sick Building Syndrome, Building Related Illnesses, Air Chemical Quality, IAQ, CO, CO2, Health Center, Health Facility

1. Introduction

Indoor air quality is a crucial factor, as people spend a significant portion of their time indoors, particularly at home and in the workplace.[1] According to an Environmental Protection Agency (EPA) survey, 80-90% of a person's time is spent indoors. This widespread exposure to indoor air pollution affects around 400 to 500 million people globally, with an estimated 3 million deaths attributed to air pollution—2.8 million of which are linked to indoor air quality and 0.2 million to outdoor pollution. The World Health Organization (WHO) reports that approximately 20% of building occupants experience multiple physical symptoms upon entering their workplace, commonly associated with Sick Building Syndrome (SBS).[2]

Sick Building Syndrome (SBS) refers to a set of health symptoms experienced by individuals in specific indoor environments, particularly in office or workplace settings.[3] Common symptoms of SBS include eye, nose, and throat irritation, headaches, fatigue, nausea, and other discomforts that tend to improve or disappear once the person leaves the building. Poor indoor air quality is a significant contributing factor to the development of SBS.[4,5] Air quality is particularly crucial in health facilities, such as community health centers, where a large number of individuals, including doctors, nurses, health workers, and patients, spend extended periods. Poor air quality in these environments can have significant implications for both the health of workers and patients alike.[6]

Indoor air pollution includes various substances, with carbon dioxide (CO2) being a key indicator of air quality and the potential risk of airborne disease transmission.[7] CO2 concentration above 1,000 ppm signals inadequate ventilation, which can negatively affect health and cognitive performance.[8] The Centers for Disease Control and Prevention (CDC) also considers CO2 levels an important metric in assessing the spread of COVID-19. Additionally, carbon monoxide (CO), another significant indoor pollutant, is a common cause of poisoning in enclosed spaces. It can be emitted by sources such as gas appliances, wood stoves, cigarette smoke, and incomplete combustion of fossil fuels.[9]

As primary care facilities, health centers see a high volume of patients, including those with airborne infectious diseases. Additionally, staff spend long hours indoors, which increases the risk of Sick Building Syndrome (SBS). To address this, researchers conducted a study to explore the relationship between individual factors (age, gender, and length of service) and environmental factors (indoor CO and CO2 levels) with SBS symptoms among health center employees. Identifying these risk factors can help mitigate the impact of SBS, improving employee comfort and productivity.[6]

2. Methods

This research is an observational analytical study with a cross-sectional design, aimed at examining the relationship between individual and environmental factors and the symptoms of Sick Building Syndrome (SBS) among employees at the Alang-Alang Lebar and Plaju Health Centers in Palembang City. Conducted in March 2024, the study focused on employees working in the Elderly General Polyclinic, Children's Polyclinic, Registration Room, and Administration Room at both health centers. The study's population consisted of 62 health center employees from these areas. Using total sampling, all individuals meeting the inclusion and exclusion criteria were included as study participants, resulting in a final sample size of 74 employees.

The inclusion criteria for this study consisted of all employees registered at the Alang-Alang Lebar and Plaju Health Centers in Palembang who worked in the Elderly General Polyclinic, Children's Polyclinic, ISPA Polyclinic, Registration Room, and Administration Room. Additionally, participants had to be willing to participate in the study and complete the questionnaire in full. The exclusion criteria included employees who worked outdoors or spent significant time in open spaces, those who declined to participate, employees who resigned during the study, and those who did not fully complete the questionnaire.

The independent variables in this study included individual factors (age, length of service, gender) and environmental factors (CO and CO2 levels in the workplace). The dependent variable was the presence of Sick Building Syndrome (SBS) symptoms. Primary data was collected using a questionnaire distributed via Google Forms. The questionnaire, adapted from a previous study by Rosalia (2021), was validated according to EPA translation standards, with a validity value of $p < 0.05$. The reliability of the instrument was assessed using Cronbach's Alpha, yielding an alpha value of $\alpha > 0.279$.

The research data will be analyzed using IBM SPSS Statistics version 27.0 for Windows, employing univariate, bivariate, and multivariate analyses. Univariate analysis will focus on variables such as age, length of service, gender, and the presence of Sick Building Syndrome (SBS) symptoms reported by respondents. For bivariate analysis, the Chi-Square test will be used; however, if more than 25% of expected cell counts are below 5, the Fisher's Exact test will be applied as an alternative. Additionally, the Spearman correlation test will be conducted to assess relationships between variables.

3. Results

This study involved 74 participants from two health centers: Plaju Palembang Health Center and Alang-Alang Lebar Health Center. Data was collected from various rooms within these centers, including the registration room, general and geriatric polyclinic, pediatric polyclinic, obstetric and gynecology polyclinic, Acute Respiratory Infection (ARI) polyclinic, and administration room. At Plaju Health Center, the respondents included 7 from the registration room, 10 from the general and geriatric polyclinic, 4 from the pediatric polyclinic, 6 from the obstetric and gynecology polyclinic, 3 from the ARI polyclinic, and 6 from the administration room. At Alang-Alang Lebar Health Center, the respondents included 7 from the registration room, 9 from the general and geriatric polyclinic, 4 from the pediatric polyclinic, 6 from the obstetric and gynecology polyclinic, 3 from the ARI polyclinic, and 9 from the administration room.

The study found that, of the 74 respondents, 36 (48.6%) reported experiencing Sick Building Syndrome (SBS), while 38 (51.4%) did not. At Plaju Health Center, 15 respondents reported symptoms of SBS, whereas at Alang-Alang Lebar Health Center, 21 respondents experienced SBS. In this study, 34 respondents (45.9%) were aged 40 or older, while 40 respondents (54.1%) were younger than 40. The majority of participants were female, with 69 women (93.2%) compared to 5 men (6.8%). Regarding work experience, 56 respondents (75.7%) had been employed for more than three years, while 18 respondents (24.3%) had worked for three years or less.

According to Chart 1, all 74 participants were in rooms with normal CO_2 and CO levels, by the established limits. Chart 2 presents the air quality data for the Plaju Health Center and Alang-Alang Lebar Health Center in Palembang, focusing on carbon monoxide (CO) and carbon dioxide (CO_2) concentrations. At Plaju Health Center, CO levels were measured at seven ppm in the registration room, general and geriatric polyclinic, pediatric polyclinic, and ARI polyclinic. The obstetric and gynecology polyclinic and administration room had slightly lower CO levels at six ppm. For CO_2, the registration room recorded 545 ppm, general and geriatric polyclinic 505 ppm, the pediatric polyclinic 514 ppm, the obstetric and gynecology polyclinic 521 ppm, and both the ARI polyclinic and administration room showed levels of 529 ppm. These measurements indicate that all rooms at the Plaju Health Center comply with the standards for CO and CO_2 concentrations.

At the Alang-Alang Lebar Health Center in Palembang, carbon monoxide (CO) levels were recorded at seven ppm in the registration room, pediatric polyclinic, obstetric and gynecology polyclinic, and administration room. In comparison, general and geriatric, and ARI polyclinics had slightly lower CO levels of 6 ppm. As for carbon dioxide (CO_2), the levels varied across the facility; 529 ppm in the registration room, 561 ppm in the general and geriatric polyclinic, 517 ppm in the pediatric polyclinic, 521 ppm in the obstetric and gynecology polyclinic, 498 ppm in the ARI polyclinic, and 505 ppm in the administration room. These findings suggest that all Alang-Alang Lebar Health Center areas meet the required standards for CO and CO2 concentrations.

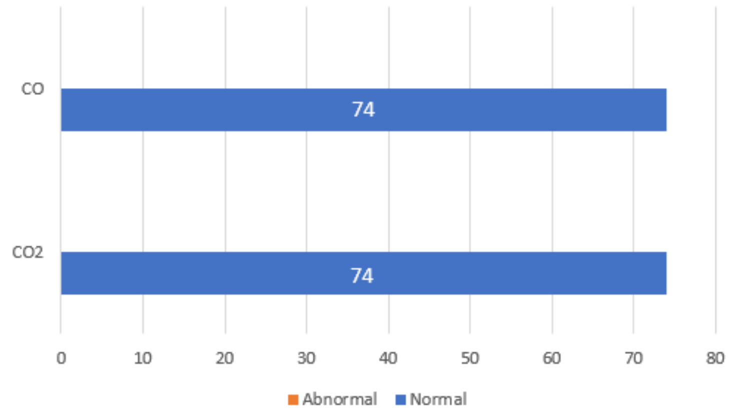

Chart 1. Distribution Respondents Based on CO and CO $_2$ levels at Plaju Health Center and Alang-Alang Lebar Health Center, Palembang

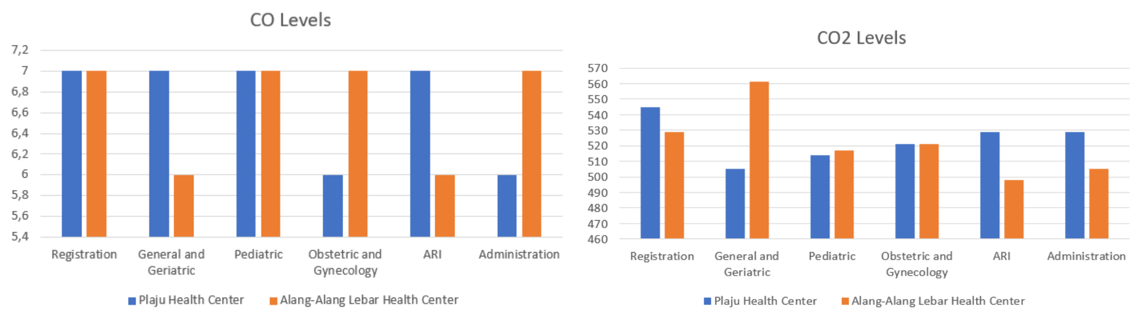

Chart 2. Description of Air Chemical Quality (CO and CO2) Based on Rooms at the Plaju Health Center and Alang-Alang Lebar Health Center, Palembang

Chart 3 illustrates the prevalence of SBS symptoms at the Plaju Health Center in Palembang. In the registration room, dizziness or headaches were most common (71.4%), followed by fatigue (57.1%). General and geriatric polyclinic reported dizziness or headaches at 30%, with flu symptoms, fatigue, and skin irritation at 20%. In the pediatric polyclinic, red, itchy, dry, or watery eyes were most prevalent (75%), followed by dizziness or headaches (50%). The obstetric and gynecology polyclinic showed similar rates of eye irritation and headaches (33.3%), with fatigue, difficulty concentrating, and shortness of breath (16.6%). At the ARI polyclinic, dizziness or headaches were common (66.6%), along with sore throat, cough, and skin irritation (33.3%). In the administration room, symptoms such as runny or stuffy nose, fatigue, dizziness, and shortness of breath were reported (16.6%).

Chart 4 shows the prevalence of SBS symptoms at the Alang-Alang Lebar Health Center in Palembang. In the registration room, fatigue was the most common symptom (28.5%), followed by red, itchy, dry, or watery eyes and dizziness or headaches (14.2%). At the general and geriatric polyclinic, dizziness or headaches were most prevalent (55.5%), with red, itchy eyes, fatigue, and drowsiness reported by 22.2%. In the pediatric polyclinic, red, itchy, dry, or watery eyes were the most common symptoms (50%), followed by flu symptoms, fatigue, difficulty concentrating, and dizziness (25%). At the obstetric and gynecology polyclinic, the most frequent symptoms were red, itchy eyes, fatigue, and difficulty concentrating (33.3%), followed by drowsiness and dizziness (16.6%). In the ARI polyclinic, sore throat, fatigue, drowsiness, difficulty concentrating, and dizziness were most common (33.3%). Lastly, in the administrative room, dizziness or headaches (55.5%) and red, itchy eyes (44.4%) were the most reported symptoms.

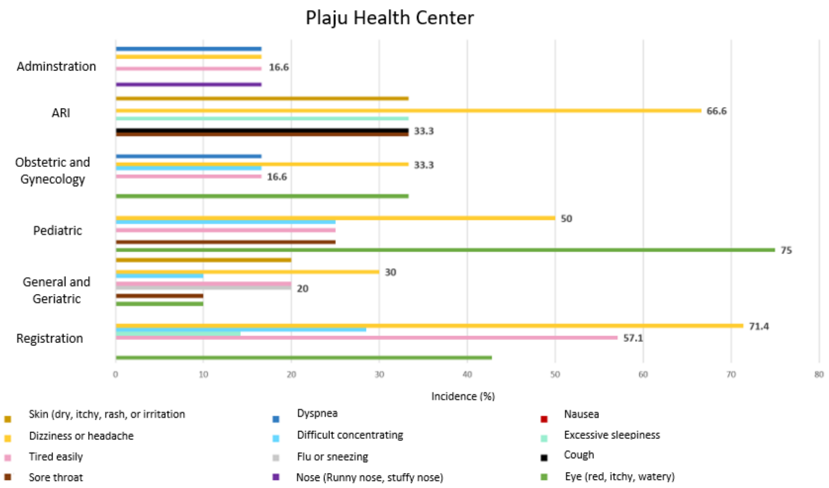

Chart 3. Prevalence of SBS Symptoms Based on Room at Plaju Health Center, Palembang

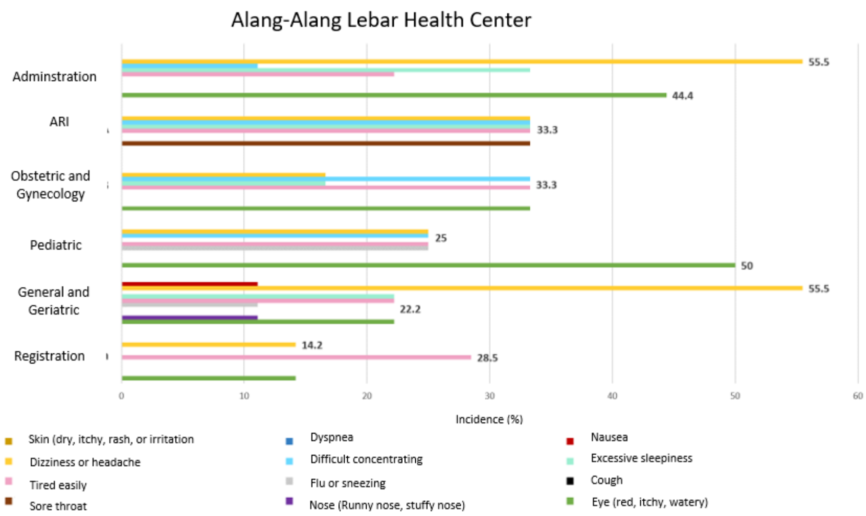

Chart 4. Prevalence of SBS Symptoms Based on Room at Alang-Alang Lebar Health Center, Palembang

The bivariate analysis presented in Tables 1 and 2 indicates no significant relationship between SBS symptoms and factors such as age (p = 0.654), gender (p = 0.358), or length of service (p = 0.077). Additionally, no significant correlation was found between SBS symptoms and CO2 (p = 0.509) or CO levels (p = 0.189).

4. Discussion

Sick Building Syndrome (SBS) refers to a set of symptoms that cause discomfort or potential harm to individuals within a building, particularly in work environments.[3] These symptoms, which occur while inside the building and subside upon leaving, can include eye, nose, and throat irritation, headaches, fatigue, nausea, and other health issues.[10–12]

Carbon monoxide (CO) is a toxic gas produced by incomplete combustion, primarily from motor vehicles and household appliances. CO concentrations are often higher indoors, particularly in enclosed spaces like parking garages.[13] Carbon dioxide (CO2), on the other hand, is generated by human respiration and is influenced by factors such as the number of people, room size, and ventilation.[14] Outdoor CO2 levels typically range from 250-350 ppm, while indoor levels of 350-1,000 ppm are considered normal.[15] According to the Environmental Health Quality Standards (SBMKL) in the Minister of Health Regulation Number 2 of 2023, the maximum allowable CO level in healthcare facilities is 10 ppm over 8 hours, while the CO2 limit is set at 1,000 ppm for the same duration.[1]

Table 1. Bivariate analysis of Individual Factors and SBS symptoms

Variables	SBS Incident			
	No (n)	Yes (n)	P Value	PR (95% CI)
Gender				
Man	4	1	0, 358	4,118 (0.438 – 38.739)
Woman	34	35		
Age				
< 40 years	22	18	0, 654	1,375 (0.549 – 3.441)
≥ 40 years	16	18		
Length of service				
≤ 3 years	13	5	0.0 77	3,224 (1,013 – 10,266)
> 3 years	25	31		

Table 2. Bivariate analysis of CO and CO_2 on SBS symptoms

Variables	SBS Incident			
	No (n)	Yes (n)	P Value	Spearman's rho 95% CI
CO2				
In accordance	38	36	0.509	-0.078
It is not in accordance with	0	0		0.307 – 0.169
CO				
In accordance	38	36	0.189	0.155
It is not in accordance with	0	0		0.084 – 0.376

CO2 indoors primarily results from human respiration during normal breathing. It becomes a concern for indoor air quality when levels exceed the 1.000 ppm threshold. High CO2 concentrations can negatively affect the cardiopulmonary system, leading to symptoms such as drowsiness, increased heart rate, and high blood pressure in individuals within the space.[15] Carbon monoxide exposure disrupts the blood's ability to deliver oxygen to tissues and vital organs. When inhaled, CO binds to hemoglobin, forming carboxyhemoglobin (COHb), which reduces hemoglobin's capacity to carry oxygen. CO has a 300 times stronger affinity for hemoglobin than oxygen, so even small amounts of CO can significantly impair oxygen transport.[16] Common symptoms of CO exposure include headache, nausea, rapid breathing, dizziness, weakness, and confusion. Acute poisoning can lead to hypoxia, causing temporary neurological issues or, in severe cases, long-term brain or heart damage, with effects that may appear later.[17]

Socio-demographic factors such as age, gender, and length of service are often thought to influence the occurrence of SBS. However, statistical analysis in this study found no significant correlation between these factors and SBS at the Plaju and Alang-Alang Lebar Health Centers in Palembang in 2024 (age, p = 0.654; gender, p = 0.358; length of service, p = 0.042). Similar results were found in a study by Mawarni et al., where age, gender, and length of service also showed no significant relationship with SBS incidence (age, p = 0.174; gender, p = 0.212; length of service, p = 1.000). [5] Additionally, research by Thach et al. supports these findings, showing no significant link between age (p = 0.217) and gender (p = 0.576) and SBS.[18] As people age, their immune system weakens, and their ability to regenerate cells and tissues declines, increasing the risk of illness. The National Institute for Safety and Health (NIOSH) reports that workers over 40 are at a higher risk of experiencing SBS. However, younger workers are often exposed to longer working hours and more time in the workplace, which also increases the likelihood of developing SBS.[5,19]

In this study, CO levels were relatively consistent across rooms in both health centers, ranging from 6 ppm to 7 ppm. The low CO levels may be attributed to effective room ventilation. Supporting research from a Health Service Center in Thailand found the highest average CO levels in naturally ventilated areas (2.5 ± 0.9 ppm), followed by air-conditioned spaces without ventilation fans (2.2 ± 1.4 ppm) and those with ventilation fans (1.2 ± 0.6 ppm). Another study by Mendes et al. (2013) in Portugal found the highest CO levels in rooms near busy roads.[7] Nevertheless, the CO levels in this study were still well below the Threshold Limit Value (TLV) of 10 ppm, as established by Permenkes No. 2 tahun 2023.[1]

Ventilation quality in a room is often assessed by monitoring CO2 levels. In health facilities, that have a high presence of disease pathogens, proper ventilation is crucial.[20,21] CO2 levels are influenced by factors such as room size, occupancy, mechanical ventilation, and the presence of plants.[8,15] In health center rooms, CO2 primarily accumulates due to the activities of patients and staff in poorly ventilated areas.[20] Natural ventilation through doors and windows is effective in reducing CO2 levels.[7,22] In this study, the highest CO2 concentration was recorded in the general and geriatric polyclinic at Alang-Alang Lebar Health Center, reaching 560 ppm. This polyclinic is the most crowded, with more staff and patients, which likely contributed to the elevated CO2 levels compared to other rooms.

A study in a Chinese hospital found that CO2 levels were higher in crowded departments and during peak hours, often exceeding 1,000 ppm. Another study in China indicated that indoor CO2 concentrations were influenced by patients' habits, such as opening or closing windows and doors or adjusting air conditioning. CO2 levels tended to rise in closed rooms without fresh air ventilation.[23] This aligns with the present study, where the lowest CO2 levels were recorded in the ARI polyclinic at Alang-Alang Lebar Health Center (498 ppm). This polyclinic, located in a well-ventilated area with open doors and windows, also benefits from the presence of plants and trees nearby. Previous research supports the idea that rooms with indoor plants have lower CO2 levels, suggesting that plants may help reduce CO2 and improve air quality. CO2 in buildings primarily comes from human respiration. In this study, the highest average CO2 level recorded was 560 ppm, well below the 1,000 ppm threshold set by the Permenkes no 2 tahun 2023. This indicates that the risk of CO2 exposure in the health center building is relatively low.[15]

High levels of carbon monoxide (CO) and carbon dioxide (CO2) can significantly affect indoor air quality and contribute to Sick Building Syndrome (SBS). In this study, the most common SBS symptoms were red, itchy, dry, or watery eyes (75%) and dizziness or headaches (71.4%). At low CO concentrations, healthy individuals may experience fatigue, while those with heart conditions could suffer chest pain. Higher CO levels can cause vision and coordination problems, headaches, dizziness, confusion, and nausea, with flu-like symptoms that typically subside after leaving the affected area. Very high CO concentrations can be fatal due to carboxyhemoglobin formation, which prevents oxygen uptake. At moderate levels, CO exposure can lead to angina, impaired vision, and cognitive decline, with severe exposure posing a risk of death.[13]

Studies show that elevated CO2 levels can increase allostatic load, contributing to SBS symptoms like dry eyes, dizziness, and cognitive impairment, especially at concentrations above 1,000 ppm. However, in this study, CO and CO2 levels were within recommended limits, and no significant link was found between these gases and SBS symptoms. This could be due to the study's narrow focus on CO and CO2 alone, without considering other environmental factors that may also affect SBS.[14]

5. Conclusion

This study explored the relationship between indoor chemical air quality (CO and CO2 levels) and Sick Building Syndrome (SBS) symptoms among employees at the Plaju and Alang-Alang Lebar Health Centers in Palembang. Of 74 respondents, 48.6% experienced SBS symptoms. All rooms met the CO and CO2 standards, with CO levels under 7 ppm and CO2 levels under 560 ppm. The most common SBS symptoms were eye irritation and headaches. No significant correlation was found between CO, CO2, age, gender, or length of service with SBS symptoms, suggesting that factors other than indoor air chemical quality may contribute to SBS in these settings. This study was conducted over a short period and at different times. Additionally, potential bias in the respondents' answers may have occurred due to a lack of understanding or insufficient oversight while completing the questionnaire.

References

1. Permenkes RI. Peraturan Menteri Kesehatan No 2 Tahun 2023. Kementerian Kesehatan Republik Indonesia.
2. Ika Vera Marlina N, Setiani O, Joko T, Studi Magister Kesehatan Lingkungan P, Kesehatan Masyarakat F. Literature Review : Hubungan Kualitas Udara Indoor terhadap Kejadian Sick Building Syndrome pada Pekerja Perkantoran. Jurnal Serambi Engineering. 2023 Aug 10;8(3).
3. Drastyana SF, Ambag SC, Widya Ningrum LD, Sutha DW. The Impact Of Sick Building Syndrome And Physical Air Quality On Staff Productivity In The Hospital’s Outpatient Room Of Rumah Sakit Umum Daerah Haji Indonesia. Jurnal

Kesehatan Lingkungan. 2024 Apr 29;16(2):144–52.
4. Ginanjar A. Sick Building Syndrome. Kemenkes. 2022.
5. Mawarni FM, Lestari M, Windusari Y, Andarini D, Camelia A, Nandini RF, et al. Keluhan Sick Building Syndrome di Gedung PT. X. Jurnal Kesehatan Lingkungan Indonesia. 2021 Feb 3;20(1):39–46.
6. Baudet A, Baurès E, Guegan H, Blanchard O, Guillaso M, Le Cann P, et al. Indoor air quality in healthcare and care facilities: Chemical pollutants and microbiological contaminants. Atmosphere (Basel). 2021 Oct 1;12(10).
7. Boonphikham N, Singhakant C, Kanchanasuta S, Patthanaissaranukool W, Prechthai T. Indoor Air Quality in Public Health Centers: A Case Study of Public Health Centers Located on Main and Secondary Roadsides, Bangkok. Environ Nat Resour J. 2022 Sep 1;20(5):527–33.
8. Mendell MJ, Chen W, Ranasinghe DR, Castorina R, Kumagai K. Carbon dioxide guidelines for indoor air quality: a review. Journal of Exposure Science & Environmental Epidemiology 2024 34:4. 2024 Jun 13;34(4):555–69.
9. Salthammer T. Carbon monoxide as an indicator of indoor air quality. Vol. 4, Environmental Science: Atmospheres. Royal Society of Chemistry; 2024. p. 291–305.
10. Gladyszewska-Fiedoruk K. Survey Research of Selected Issues the Sick Building Syndrome (SBS) in an Office Building. Environmental and Climate Technologies. 2019 Nov 1;23(2):1–8.
11. Qayyum S, Tariq S, Younas F. Sick Building Syndrome And Job Performance In Women Factory Workers. Journal of Postgraduate Medical Institute. 2020 Jul 14;34(1).
12. Aziz N, Adman MA, Suhaimi NS, Misbari S, Alias AR, Aziz AA, et al. Indoor Air Quality (IAQ) and Related Risk Factors for Sick Building Syndrome (SBS) at the Office and Home: A Systematic Review. In: IOP Conference Series: Earth and Environmental Science. Institute of Physics; 2023.
13. Environment Protection Agency. Carbon Monoxide's Impact on Indoor Air Quality. US EPA. 2023.
14. Lowther SD, Dimitroulopoulou S, Foxall K, Shrubsole C, Cheek E, Gadeberg B, et al. Low level carbon dioxide indoors—a pollution indicator or a pollutant? A health-based perspective. Vol. 8, Environments - MDPI. MDPI; 2021.
15. Chuang KJ, Lee CY, Wang S Te, Liu IJ, Chuang HC, Ho KF. The Association between Indoor Carbon Dioxide Reduction by Plants and Health Effects. Indoor Air. 2023;2023.
16. Salthammer T. Carbon monoxide as an indicator of indoor air quality. Environmental Science: Atmospheres. 2024 Feb 14;4(3):291–305.
17. NIOSH. Carbon Monoxide. CDC. 2018.
18. Thach TQ, Mahirah D, Dunleavy G, Nazeha N, Zhang Y, Tan CEH, et al. Prevalence of sick building syndrome and its association with perceived indoor environmental quality in an Asian multi-ethnic working population. Build Environ. 2019 Dec 1;166.
19. Bardi NK, Fachrin SA, Arman, Tussaadah N. Faktor Yang Berhubungan Dengan Keluhan Sick Building Syndrome Pegawai PLN

UIW Sulserabar Kota Makassar. WOPHJ. 2021;2(2):264–72.
20. Hou J, Sun Y, Dai X, Liu J, Shen X, Tan H, et al. Associations of indoor carbon dioxide concentrations, air temperature, and humidity with perceived air quality and sick building syndrome symptoms in Chinese homes. Indoor Air. 2021 Jul 1;31(4):1018–28.
21. Wilson NM, Calabria C, Warren A, Finlay A, O'Donovan A, Passerello GL, et al. Quantifying hospital environmental ventilation using carbon dioxide monitoring – a multicentre study. Anaesthesia. 2024 Feb 1;79(2):147–55.
22. Laurent MR, Frans J. Monitors to improve indoor air carbon dioxide concentrations in the hospital: A randomized crossover trial. Science of the Total Environment. 2022 Feb 1;806.
23. Chou YA, Wang ZY, Chang HC, Liu YC, Su PF, Huang YT, et al. Indoor CO2 monitoring in a surgical intensive care unit under visitation restrictions during the COVID-19 pandemic. Front Med (Lausanne). 2023;10.