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Indoor VOC Exposure and SBS Symptoms in a Humid Tropical Region (A Case Study of Mako Polrestabes Surabaya)

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Abstract.

Indoor air quality is crucial to supporting employee health, particularly in colonial-heritage buildings adapted for modern office use. This study aims to analyze the relationship between exposure to Volatile Organic Compounds (VOCs) and the incidence of Sick Building Syndrome (SBS) among employees at the Surabaya Police Headquarters Building. The study employed an observational analytical approach with a cross-sectional design. TVOC concentrations were measured in seven work units, while SBS symptoms were identified using a structured questionnaire. The results showed a significant correlation between TVOC concentrations and the intensity of SBS symptoms. The validity of SBS symptoms at the study site was reinforced by the WHO's "golden criteria," where respondents' health complaints decreased dramatically immediately after leaving the building. Furthermore, architectural findings indicate that limited room dimensions significantly contribute to pollutant stagnation, with larger rooms proving more effective at passively dispersing VOC emissions. This conclusion confirms that spatial configuration and control of emission sources are crucial preventive interventions in the revitalization of heritage buildings to maintain their health and functionality.

Keywords: Volatile Organic Compounds; Sick Building Syndrome; indoor air quality; office buildings; employees.

1. Introduction

Work activities of employees at the Mako Polrestabes Surabaya Building are mostly carried out in enclosed rooms with prolonged exposure, making indoor air quality (IAQ) an important factor affecting health. One of the contaminants frequently found in the work environment is Volatile Organic Compounds (VOCs) originating from building materials, furniture, cleaning products, and office operational activities. Exposure to VOCs can cause various non-specific complaints such as eye, nose, and throat irritation, headaches, fatigue, and concentration disorders, which are common symptoms of Sick Building Syndrome (SBS). This condition has the potential to reduce work comfort and employee productivity. The Mako Polrestabes Surabaya Building has historical and architectural value as a Dutch colonial heritage building. The character of this heritage building is generally preserved, with modern functions incorporated without completely overhauling the ventilation system. This inadequate ventilation system, coupled with intensive room use, can lead to the accumulation of VOCs indoors. This study aims to conduct an in-depth analysis of the relationship between VOC exposure intensity and the incidence of SBS among employees at the Mako Polrestabes Surabaya Building, and to evaluate architectural spatial factors that influence air quality.

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2. Literature Review

2.1 Volatile Organic Compounds (VOC)

Volatile Organic Compounds (VOCs) are a group of organic compounds characterized by high vapor pressure, allowing them to evaporate readily into the air at room temperature. This physical characteristic makes VOCs one of the primary pollutants that most frequently contaminate Indoor Air Quality (IAQ). These compounds are passively released into the air continuously, creating an accumulation of invisible gas that is often unnoticed by building occupants during their daily activities.

In the office environment, VOC emission sources are highly diverse and closely integrated with work facilities. According to Kencanasari et al. (2020), office workers are highly vulnerable because they are constantly exposed to emissions from modern interior materials. These pollutant sources include architectural elements such as wall paint, floor coverings, and carpets, as well as processed wood furniture, which often contains formaldehyde residue. Apart from passive materials, the operation of office electronic devices, such as printers and printer ink, also contributes significantly to the release of these organic compounds into the air. Further study by Abdurrasyid et al. (2025) highlights that poor air circulation will exacerbate this condition, where air contaminated by carcinogenic chemical compounds has the potential to cause long-term health damage.

2.2 Sick Building Syndrome (SBS)

The accumulation of Volatile Organic Compounds (VOCs) emissions in enclosed spaces has been identified as a primary catalyst triggering Sick Building Syndrome (SBS). Conceptually, SBS is a condition where building occupants or workers experience a series of health problems closely related to the air quality in their work environment. When chemical pollutants such as VOCs are trapped and accumulate in the breathing zone, this condition slowly creates an unhealthy environment and threatens the comfort and productivity of its occupants.

The clinical manifestations of SBS generally present as nonspecific physical complaints. Mansor et al. (2024) and Zainal et al. (2019) noted that office workers often report symptoms such as extreme fatigue, dizziness or headaches, and irritation of the ocular mucosa and upper respiratory tract. This syndrome is diagnosed by a very distinct characteristic pattern: the severity of symptoms will continue to increase with the duration of workers' stay inside the building, but these complaints will gradually subside or even improve on their own as soon as they leave the building.

The risk of exposure and the incidence of SBS become much more complex when it occurs in the context of historical or heritage buildings. Old buildings that undergo functional adaptation to modern office spaces often involve partial layout changes. Unfortunately, these interior modifications are often carried out without comprehensive air circulation calculations. As a result, ventilation limitations in these historical structures fail to disperse pollutants effectively, ultimately leading to a high incidence of SBS among their occupants.

3. Research Methods

This research employed an observational, analytical approach using a cross-sectional design. The research location was in the enclosed office area of the Mako Polrestabes Surabaya

Building, which includes seven main work units, namely: Ruang Aspri Wakapolrestabes, Ruang Kasubbag Progar, Ruang SDM Dalpers, Ruang SDM-Binkar, Ruang Satren, Ruang Watpers, and Ruang Sium.

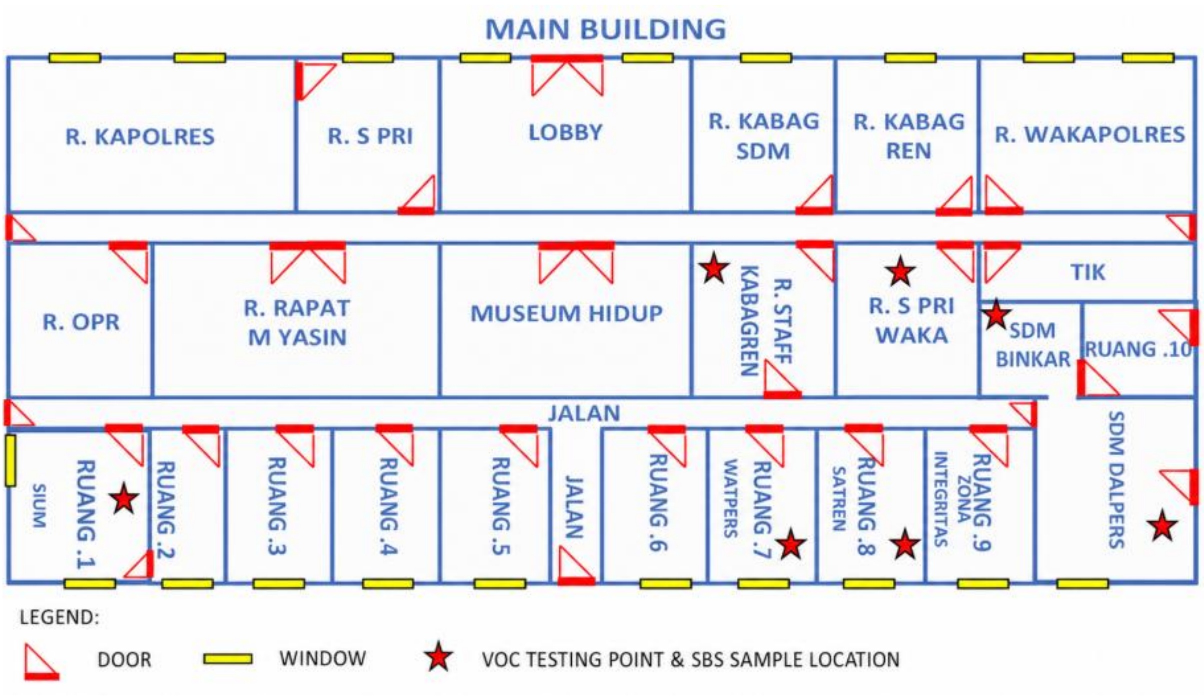

Figure 1. Map of Mako Polrestabes Building and Testing Location

The data collection stages were carried out using two main instruments:

1. **IAQ (Indoor Air Quality) Measurement:** Total VOC (TVOC) concentrations were comprehensively measured using an Air Quality Detector in each room during peak hours. Physical environmental parameters, including room temperature and humidity, were also recorded simultaneously using a Hygrometer.
2. **Room Dimension Measurement:** The room dimensions, namely length, width, and height of the room, were measured comprehensively using a measuring tool such as a laser meter in meters.
3. **SBS Questionnaire:** Subjective health complaint data from employees were collected through a structured questionnaire with a validated rating scale to record the frequency and intensity of symptoms.

The collected quantitative data were then analyzed using statistical correlation tests (Pearson and Spearman's Rank) to test the hypothesis and determine the significance of the relationship between the magnitude of TVOC exposure and the severity of SBS symptoms.

4. Results and Discussion

4.1 Intensity of VOC Exposure and SBS Characteristics

The field measurement results showed significant variations regarding TVOC concentrations in the seven workspaces of Mako Polrestabes Surabaya. Rooms with smaller areas or air volumes and suboptimal passive ventilation consistently showed higher TVOC

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accumulation than rooms with larger dimensions and smoother mechanical/natural air circulation. In terms of employee health, the prevalence of SBS complaints was alarming. The most dominantly felt symptoms included fatigue, headaches, and irritation of the eyes and upper respiratory tract. The validity of the questionnaire was demonstrated by the fulfillment of WHO's "golden criteria," in which the intensity of complaints decreased sharply and improved shortly after employees left their workspaces inside the building.

Table 1. Recapitulation of SBS and TVOC per Room

NO	RESPONDENT	ROOM	SYMPTOM SCORE									TOTAL SCORE	ROOM DIMENSIONS				TVOC	
			A	B	C	D	E	G	H	I	J		LENGTH	WIDTH	HEIGHT	AREA		
1	R1	ASPRI	1	1	2	2	0	1	0	0	0	7	3.87	8.46	6	32.74	0.120	mg/m3
2	R2		1	1	0	1	1	1	0	0	0	6	3.87	8.46	6	32.74	0.120	
3	R3		0	0	0	0	0	1	0	0	0	1	3.87	8.46	6	32.74	0.120	
4	R4		1	1	1	1	1	2	1	0	1	10	3.87	8.46	6	32.74	0.120	
5	R1	KASUBBAG PROGAR	0	0	1	0	0	1	2	1	0	6	6	8	6	48	0.311	mg/m3
6	R2		1	1	0	1	0	1	0	1	1	6	6	8	6	48	0.311	
7	R3		0	0	1	0	1	1	2	2	0	7	6	8	6	48	0.311	
8	R4		2	1	2	2	2	2	2	0	2	17	6	8	6	48	0.311	
9	R5		0	0	0	0	0	0	0	0	0	0	6	8	6	48	0.311	
10	R6		1	1	1	1	1	1	1	1	1	10	6	8	6	48	0.311	
11	R1	SDM-DALPERS	0	0	0	0	1	0	0	0	0	1	9	6	6	54	0.486	mg/m3
12	R2		0	0	1	1	0	1	0	0	0	3	9	6	6	54	0.486	
13	R3		2	1	1	1	1	2	2	1	1	13	9	6	6	54	0.486	
14	R4		0	0	0	0	1	0	1	2	0	4	9	6	6	54	0.486	
15	R5		1	1	1	1	1	0	1	0	0	6	9	6	6	54	0.486	
16	R6		2	1	2	1	2	1	1	1	2	14	9	6	6	54	0.486	
17	R7		1	1	1	1	1	1	2	0	0	9	9	6	6	54	0.486	
18	R8		2	1	2	1	2	2	1	1	1	15	9	6	6	54	0.486	
19	R9		0	0	0	0	1	0	1	0	0	2	9	6	6	54	0.486	
20	R10		1	1	1	2	1	1	2	0	1	11	9	6	6	54	0.486	
21	R11		1	1	1	1	1	1	0	0	0	7	9	6	6	54	0.486	
22	R1	SDM-BINKAR	0	0	0	0	0	0	0	0	0	0	4	4	6	16	0.337	mg/m3
23	R2		0	0	0	0	0	0	0	0	0	0	4	4	6	16	0.337	
24	R3		0	0	1	0	1	0	0	0	0	2	4	4	6	16	0.337	
25	R4		2	2	1	1	0	0	2	2	0	12	4	4	6	16	0.337	
26	R5		1	1	1	1	0	1	0	0	0	6	4	4	6	16	0.337	
27	R1	SATREN	0	0	0	1	0	0	0	0	0	1	3.8	6	6	22.8	0.208	mg/m3
28	R2		1	1	1	1	1	1	1	1	1	10	3.8	6	6	22.8	0.208	
29	R3		1	0	2	0	2	1	1	2	0	10	3.8	6	6	22.8	0.208	
30	R4		1	1	0	1	1	1	0	0	0	5	3.8	6	6	22.8	0.208	
31	R5		2	1	1	2	1	2	1	0	1	12	3.8	6	6	22.8	0.208	
32	R1	WATPERS	0	0	1	0	1	0	0	0	0	2	3.8	6	6	22.8	0.221	mg/m3
33	R2		0	0	0	0	0	0	0	0	0	0	3.8	6	6	22.8	0.221	
34	R3		0	0	0	0	1	0	0	0	0	1	3.8	6	6	22.8	0.221	
35	R4		0	0	0	0	0	1	1	0	0	3	3.8	6	6	22.8	0.221	
36	R5		0	0	0	0	1	0	1	0	0	2	3.8	6	6	22.8	0.221	
37	R6		1	1	0	1	1	0	1	0	0	5	3.8	6	6	22.8	0.221	
38	R7		2	1	1	2	1	1	1	0	1	12	3.8	6	6	22.8	0.221	
39	R8		1	1	1	1	0	1	1	0	0	6	3.8	6	6	22.8	0.221	
40	R9		2	1	2	2	1	1	1	1	1	15	3.8	6	6	22.8	0.221	
41	R1	SIUM	1	1	0	1	1	0	1	0	0	5	6	6.25	6	37.5	0.137	mg/m3
42	R2		2	1	1	2	1	2	1	0	1	12	6	6.25	6	37.5	0.137	
43	R3		1	1	1	1	0	1	1	0	0	6	6	6.25	6	37.5	0.137	
44	R4		2	1	2	2	1	2	1	1	1	15	6	6.25	6	37.5	0.137	
45	R5		0	0	0	1	0	0	1	0	0	2	6	6.25	6	37.5	0.137	
46	R6		1	1	1	1	1	1	1	1	1	10	6	6.25	6	37.5	0.137	

No	Symptoms
A	Eye irritation/itching
B	Dry or sore throat after waking up
C	Runny or blocked nose
D	Irritation/sore throat
E	Difficutly breathing
F	Headache/dizziness when working
G	Easy fatigue or drowsiness
H	Difficulty concentrating
I	Nausea or loss of appetite
J	Dry or itchy skin

Description
0 = None
1 = Mild
2 = Moderate
3 = Frequent

1.3 Categorization of Scores and Interpretation

Total Score	SBS Category	Interpretation
0	No SBS	No or minimal symptoms reported. The indoor environment does not contribute to health complaints.
1 – 5	Mild SBS	Some mild symptoms that do not significantly interfere with productivity.
6 – 10	Moderate SBS	Symptoms may reduce comfort and productivity. An evaluation of IAQ (Indoor Air Quality) conditions is needed.
11 – 30	Severe SBS	Severe symptoms often occur. Other VOCs and IAQ factors may have a major contribution. Immediate control measures are required.

Table 2. Percentage of Employees Experiencing SBS

Division	n	No SBS (0)	Mild (1–5)	Moderate (6–10)	Severe (11–30)	% Experiencing SBS
ASPRI	4	-	1 (25.0%)	3 (75.0%)	-	100.0%
KASUBBAG PROGAR	6	1 (16.7%)	-	4 (66.7%)	1 (16.7%)	83.3%
SDM-DALPERS	11	-	4 (36.4%)	3 (27.3%)	4 (36.4%)	100.0%
SDM-BINKAR	5	2 (40.0%)	1 (20.0%)	1 (20.0%)	1 (20.0%)	60.0%
SATREN	5	-	2 (40.0%)	2 (40.0%)	1 (20.0%)	100.0%
WATPERS	9	1 (11.1%)	5 (55.6%)	1 (11.1%)	2 (22.2%)	88.9%
SIUM	6	-	2 (33.3%)	2 (33.3%)	2 (33.3%)	100.0%
TOTAL	46	4 (8.7%)	15 (32.6%)	16 (34.8%)	11 (23.9%)	91.3%

4.2 Correlation of TVOC, SBS Symptoms, and Architectural Implications

Based on the results of the Pearson and Spearman Rank correlation tests (r and p-values), a positive and highly statistically significant correlation was found between room TVOC concentration and high reported SBS symptom scores. The Scatter Plot data (TScore vs TVOC) showed a clear linear trend that the increase in TVOC accumulation is directly proportional to the increase in the severity of employee health complaints. From an architectural perspective, the research found that the spatial configuration (length, width, and ceiling height that determine the total volume) is extremely crucial. Narrow rooms trap pollutants in the breathing zone, while large-volume rooms offer far more effective passive dispersion of VOC emissions. This confirms the importance of spatial evaluation in office space planning.

Table 3. Correlation Test Table (Pearson and Spearman Rank)

No.	Variable Relationship	Spearman Correlation (rho)	Spearman Interpretation	
1	T-score vs Item A (Eye irritation/itching)	0.899	Very Strong	Positive
2	T-score vs Item B (Dry or sore throat after waking up)	0.758	Strong	Positive
3	T-score vs Item C (Runny or blocked nose)	0.809	Very Strong	Positive
4	T-score vs Item D (Irritation/sore throat)	0.720	Strong	Positive
5	T-score vs Item E (Perceiving odors not otherwise evident)	0.610	Strong	Positive
6	T-score vs Item F (Headache/dizziness when working)	0.794	Strong	Positive
7	T-score vs Item G (Easy fatigue or drowsiness)	0.840	Very Strong	Positive
8	T-score vs Item H (Difficulty concentrating)	0.758	Strong	Positive
9	T-score vs Item I (Nausea or loss of appetite)	0.469	Moderate	Positive
10	T-score vs Item J (Dry or itchy skin)	0.722	Strong	Positive
11	Item A (Eye irritation/itching) vs Item B (Dry or sore throat after waking up)	0.889	Very Strong	Positive
12	Item A (Eye irritation/itching) vs Item D (Irritation/sore throat)	0.782	Strong	Positive
13	Item C (Runny or blocked nose) vs Item F (Headache/dizziness when working)	0.679	Strong	Positive
14	Item F (Headache/dizziness when working) vs Item H (Difficulty concentrating)	0.711	Strong	Positive
15	Item G (Easy fatigue or drowsiness) vs Item H (Difficulty concentrating)	0.670	Strong	Positive
No.	**Variable Relationship**	**Pearson Correlation (r)**	**Spearman Interpretation**	
16	T-score vs TVOC	0.045	Very Weak	Positive
17	Length vs TVOC	0.782	Strong	Positive
18	Width vs TVOC	-0.296	Weak	Opposite
19	Area vs TVOC	0.604	Strong	Positive

5. Conclusion and Recommendations

5.1 Conclusion

This study concludes that there is a significant relationship between the intensity of indoor Volatile Organic Compounds (VOC) exposure and the incidence of Sick Building

Syndrome (SBS) among employees at the Mako Polrestabes Surabaya Building. The higher the VOC concentration trapped in the room, the higher the intensity of the SBS symptoms experienced. The room volume configuration acts as a passive determinant for VOC dispersion. Colonial buildings converted into modern offices must balance the need for room adaptation with the movement of fresh air volume to minimize the stagnation of chemical pollutants.

5.2 Recommendations

As a preventive measure, improved office spatial management is recommended. Optimization of room dimensions is needed to reduce occupancy density per cubic meter, segregation of emission sources from materials and electronic devices, and improvement of exhaust ventilation systems in small rooms so that air changes per hour (ACH) are achieved, without damaging the historical value of the facade and the main structure of the building.

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