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Indoor Air Quality at Fitness Centers in Surabaya

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ABSTRACT

Background: Indoor air quality reflects the condition of air parameters within enclosed spaces and can be defined as the state of air that influences the comfort and health of its occupants. Globally, poor indoor air quality has been associated with 3.8 million deaths, with Southeast Asia accounting for 1.5 million cases. In Indonesia, as one of the countries in this region, 36.5% of deaths have been linked to inadequate indoor air quality. Fitness centres represent a type of enclosed environment that may pose health risks to users if pollution sources are not properly managed. **Object:** This study aimed to describe the indoor air quality of a fitness centre in Surabaya. The research was conducted in a closed-design fitness centre, where physical parameters (temperature, illumination, humidity, ventilation rate, noise, PM10, and PM2.5), chemical parameters (SO2, NO2, and O3 gases), and biological parameters (airborne bacterial count) were measured. **Methods:** The results were compared with the Environmental Health Quality Standards based on the Regulation of the Minister of Health of the Republic of Indonesia No. 2 of 2023. **Results:** The findings indicated that illumination (53 lux), PM2.5 (30 µg/m3), and airborne bacterial count (786.5 CFU/m3), exceeded the permissible limits, whereas temperature (18.75oC), humidity (54% RH), ventilation rate (0.22 m/s), PM10 (40 µg/m3), noise (54 dBA), sulfur dioxide (7.42 µg/m3), nitrogen dioxide (7.345 µg/m3), and ozone (3.105 µg/m3) met the required standards. **Conclusion:** It is recommended that the management improve lighting through additional or replacement lamps, restrict outdoor air inflow at the entrance on the first floor, and employ mechanical ventilation to control airborne bacterial levels.

Keywords: Indoor Air Quality, Fitness Centre, Air Pollutants

BACKGROUND

Air is a vital element for life, so collective efforts to maintain and improve its quality are a prerequisite for public health. In the context of buildings, indoor air quality is defined as the condition of air parameters that affect the comfort and health of occupants, including temperature, humidity, gaseous and particulate pollutants, as well as microorganisms. Considering that the modern population spends 80–90% of its time indoors, exposure to indoor air significantly contributes to daily health risks, making ventilation management and emission source control crucial (Dimitroulopoulou et al., 2023; D. Zhang et al., 2022). Recent epidemiological evidence confirms that exposure to indoor pollutants contributes to complaints of Sick Building Syndrome (SBS) and respiratory disorders, particularly in buildings with inadequate ventilation and sources of volatile organic compounds (VOCs) emissions in the interior. Cross-building findings indicate a significant correlation between total VOC concentrations and SBS symptoms, emphasizing the importance of effective source control and air management (Freihat & Al-kurdi, 2023; Sazif et al., 2024).

The burden of disease due to air pollution remains high globally, with a significant contribution from household air pollution, which often forms part of an individual's total exposure to fine particles and harmful gases (World Health Organization, 2024). Symptoms of Sick Building Syndrome (SBS) include headaches, eye irritation, nasal and throat irritation, nausea, flu, pneumonia, other viral diseases, and indirectly (the effects occur after several years) include lung diseases, heart diseases, cancer, and even death (Ritchie & Roser, 2014). Recent evidence shows that improvements in ventilation and pollutant control in indoor spaces correlate with a decrease in SBS symptoms among office workers, emphasizing the importance of building-based interventions (Mansor et al., 2024). In line with the latest global findings, air pollution including indoor exposure has been proven to cause various health disruptions in humans, particularly in the productive age group, and is recognized as one of the main risk factors for premature death and disability. This condition underscores the importance of indoor air quality control in various activity contexts (A'yun & Umaroh, 2022; GBD 2021 HAP Collaborators, 2025).

The popularity of fitness centers in urban areas is increasing along with the shift towards a healthy lifestyle through indoor exercise such as fitness centers, but the characteristics of indoor spaces with mechanical ventilation, high user density, and intense physical activity can increase the concentration of particulates and reactive gases (Karaiskos et al., 2023). One of the fitness places in Surabaya that has 187 members who engage in activities in the same location. The types of activities carried out in this fitness center include yoga, flyhigh yoga, pilates, zumba, step, body language, aerobics, bootcamp training, kettlebell, muay thai, and various functional training activities. These various activities are conducted in an enclosed space that uses air conditioning as artificial ventilation.

Research related to indoor air quality in fitness centers is still relatively scarce. This has adverse effects because a person engaging in physical activities at a fitness center for a period of time is at risk of exposure to various pollutants, including various gases such as SO2, NO2, O3, CO, CO2, formaldehyde, mold, bacteria, and others. Therefore, the researcher is interested in studying the indoor air quality of fitness centers.

RESEARCH METHODS

Study design

This research is a descriptive study conducted through observations in the field, namely a fitness center in Surabaya.

Sample

The object of this research is the indoor air used by fitness centre members during exercise activities. The sampling was conducted using non-probability sampling techniques with purposive sampling methods based on inclusion criteria, namely fitness centres located in Surabaya, having a minimum of 100 active members, and providing various types of physical activities such as cardio workouts, functional training, and yoga. These criteria were chosen to ensure that the research location represents fitness centres with high activity intensity and the potential for exposure to various air pollutants.

The observed parameters include three main categories. Physical parameters encompass temperature, lighting, humidity, ventilation rate, noise level, and concentrations of particulate matter PM10 and PM2.5. Chemical parameters consist of the concentrations of sulfur dioxide (SO2), nitrogen dioxide (NO2), and ozone (O3). Meanwhile, biological parameters are measured through air germ counts using the total plate count method. All measurements are conducted based on the Environmental Health Quality Standards (EHQS) outlined in the Ministry of Health Regulation No. 2/2023 Concerning the Implementation of Government Regulation Number 66/2014 Concerning Environmental Health where each parameter is defined with operational definitions, measurement methods, units, and standard quality threshold values as references for assessing air quality.

Instruments and Measurement

This research utilizes a standardized set to ensure the accuracy and reliability of indoor air quality measurement results. The physical parameters observed include temperature, humidity, and air flow velocity using a thermometer, hygrometer, and Mastercool 52236 digital anemometer – Airflow + Psychrometer. The light level was determined using a luxmeter (Lutron LX-1102), while the noise intensity was measured with a sound level meter (Svantex 973). The concentrations of particulate PM10 and PM2.5, were determined using a dust sampler (Tisch 1-887-263-7610). Chemically, the levels of sulfur dioxide (SO_2), nitrogen dioxide (NO_2), and ozone (O_3) were analyzed using spectrophotometry with an INSCIENCE PRO US 1012 spectrophotometer. As for the biological indicator in the form of airborne microbial count, it was obtained through the Total Plate Count (TPC) method using the MAS 100-Eco device.

Data analysis

The data analysis used is descriptive and presented in the form of tables and narratives for each measurement result of physical, chemical, and biological parameters. The measurement results are based on the Environmental Health Quality Standard references listed in Ministry of Health Regulation No. 2/2023 Concerning the Implementation of Government Regulation Number 66/2014 Concerning Environmental Health, so that each parameter can be systematically compared with the applicable threshold values to assess the suitability level of indoor air quality against environmental health standards

RESULTS AND DISCUSSION

Physical Parameters of Indoor Air Quality in Fitness Centers in Surabaya

The physical parameters analyzed include temperature, lighting, humidity, ventilation rate, PM10, PM2.5, and noise. Measurements were taken at two points, namely the 1st floor and the 2nd floor, then the results were averaged and evaluated based on the Ministry of Health Regulation No. 2/2023 Concerning the Implementation of Government Regulation Number 66/2014 Concerning Environmental Health.

Table 1.
Results of Physical Air Parameter Measurements in Fitness Centers in Surabaya in 2023

No	Parameter	Permissible Limit (EHQS)*	Result 1	Result 2	Result Mean	Status
1.	Temperature	18-30°C	18	19,5	18,75	Within standard
2.	Illumination	Minimun 60 lux	56	50	53	Non-compliant
3.	Humidity	40-60% RH	58	50	54	Within Standard
4.	Ventilation Rate	0.15-0.25 m/s	0,2	0,24	0,22	Within Standard
5.	PM10	70 µg/m3	56	24	40	Within Standard
6.	PM2.5	25 µg/m3	35	25	30	Non-compliant

No	Parameter	Permissible Limit (EHQS)*	Result			Status
			1	2	Mean	
7.	Noise	60 dBA	58	50	54	Within Standard

Note: *) Ministry of Health Regulation No. 2/2023 Concerning the Implementation of Government Regulation Number 66/2014 Concerning Environmental Health

Chemical Parameters of Indoor Air Quality in Fitness Centers in Surabaya

The chemical parameters analyzed include the concentrations of SO_2, NO_2, and O_3. Air samples were taken at two locations using a midget impinger, and then the measurement results were compared with indoor air quality standards.

Table 2.
Results of Air Chemistry Parameter Measurements in Fitness Centers in Surabaya in 2023

No	Parameter	Permissible Limit (EHQS)*	Result			Status
			1	2	Mean	
1.	SO_2 Gas	20 µg/m3	18	19,5	18,75	Within standard
2.	NO_2 Gas	40 µg/m3	56	50	53	Non-compliant
3.	O_3 Gas	100 µg/m3	58	50	54	Within Standard

Note: *) Ministry of Health Regulation No. 2/2023 Concerning the Implementation of Government Regulation Number 66/2014 Concerning Environmental Health

Biological Parameters of Indoor Air Quality in Fitness Centers in Surabaya

The biological quality of the air is evaluated through the calculation of the total microbial count using the Total Plate Count (TPC) method, with the measurement results presented to depict the microbiological condition of the fitness center.

Table 3.
Results of Air Quality Parameter Measurements in a Fitness Center in Surabaya in 2023

No	Parameter	Permissible Limit (EHQS)*	Result			Status
			1	2	Mean	
1.	Airbone Bacterial Count	700 CFU/m3	698	875	786.5	Non-compliant

Note: *) Ministry of Health Regulation No. 2/2023 Concerning the Implementation of Government Regulation Number 66/2014 Concerning Environmental Health

Physical Parameters of Indoor Air Quality in Fitness Centers in Surabaya

Measurements of physical parameters show that the average room temperature is at 18.75oC with a relative humidity of 54%. This value is still within the range of thermal comfort and microbiological control (ideal temperature 20–24oC, humidity 30–60%) (Peixoto et al., 2023), Although the temperature approaches the lower limit, this can potentially cause slight discomfort for some users. This result is in line with previous research showing that the temperature in sports environments often falls within the comfort threshold due to limited ventilation systems and the use of mechanical air conditioning (Szulc et al., 2023). Meanwhile, the noise level was recorded at 54 dBA, still below the tolerance limit of 60 dBA for fitness facilities, thus not causing significant disturbances to the concentration or comfort of users (Peixoto et al., 2023).

The room's lighting only reaches 53 lux, well below the minimum recommendation for physical activity (60 lux), which could potentially cause visual fatigue and reduce sports performance. The lighting in the fitness area utilizes a combination of natural and artificial light, where natural rays not only create a bright and refreshing atmosphere but also reduce the use of lamps during the day. Although environmentally friendly LED lights have been installed, their quantity has proven insufficient on the second floor, especially in the 40 m2 gymnastics area, calculations show that approximately 40 W of power is needed for the intensity to reach the minimum of 60 lux according to sports room lighting standards. The lack of lighting risks reducing participants' focus, which in extreme situations may trigger injuries or visual disturbances. Therefore, the implementation of adequate lighting, both in increasing the number of energy-efficient LED lights and in designing lighting layouts that maximize daylighting, becomes very important, in line with the recommendations for lighting design in modern fitness facilities to enhance user safety and performance (299 Lighting, 2023; RRR Lighting, 2024). Other conditions that are in line with recent research emphasize the importance of adequate lighting to support physical performance while also maintaining eye health (Peixoto et al., 2023).

The concentration of fine particulate matter (PM2.5) was recorded at 30 µg/m3 , exceeding the threshold value of the Environmental Quality Standard of 25 µg/m3 (24-hour average) with measurements on the first floor being higher (35 µg/m3) compared to the second floor (25 µg/m3), due to the first floor being open without barrier doors. Additionally, visitors coming in from outside may potentially bring PM2.5 particles from traffic or open areas into the room, thereby increasing the overall particle load. The contribution of higher visitor activity in the morning may also be a factor that exacerbates the high concentration of PM2.5 indoors. Cleaning activities in the morning, especially sweeping or mopping, can capture dust from the floor and cause a temporary increase in fine particles in the air (Tian et al., 2021). Physiologically, solid particles with a diameter of Physiologically, solid particles with a diameter of the lungs, potentially disrupting gas exchange and increasing the risk of respiratory infections. Sources of particles in fitness areas can include fibers from clothing, floor dust, carpet residues, and construction materials such as fiberglass or asbestos from air conditioning ducts (Environmental Protectiont Agency (EPA), 2025; Tian et al., 2021). Therefore, effective solutions include installing doors or door curtains as the primary barrier against road pollution, and improving the airtightness of entrances to reduce the infiltration of external particles. Other physical parameters such as temperature, humidity, ventilation rate, PM10, and noise still comply with the standard environmental health quality for indoor air.

Chemical Parameters of Indoor Air Quality in Fitness Centers in Surabaya

The measurement results show that the average concentrations of sulfur dioxide (SO2), nitrogen dioxide (NO2), and ozone (O3) are 7.42 µg/m3 (threshold 20 µg/m3), 7.345 µg/m3 (threshold 40 µg/m3), and 3.105 µg/m3 (threshold 100 µg/m3) all of which are still well below the maximum limits set by Ministry of Health Regulation No. 2/2023 Concerning the Implementation of Government Regulation Number 66/2014 Concerning Environmental Health., (2023). Concerning Environmental Health. This condition is consistent with the results of indoor air quality studies in fitness centers and other health clubs, where pollutant gas levels generally remain low if activities are relatively free from gas emission sources such as chemicals or motorized equipment, and if natural or mechanical ventilation is adequate to ensure air circulation (Peixoto et al., 2023).

Research on indoor air quality is greatly influenced by ongoing activities and the types of materials used (A'yun & Umaroh, 2022). In fitness centers, most activities do not involve equipment or materials that have the potential to release hazardous gases, thus the risk of chemical pollution is relatively low. Furthermore, the natural ventilation system that is applied allows for more optimal air circulation, enabling clean air from outside to enter and helping to reduce the concentration of pollutants indoors. Therefore, this finding further reinforces the importance of integrating ventilation design and interior material management as a primary strategy in maintaining chemical air quality in indoor sports facilities.

Biological Parameters of Indoor Air Quality in Fitness Centers in Surabaya

Measurements indicate that the average Airborne Bacterial Count in the fitness center reaches 786 CFU/m3 exceeding the maximum limit of the Environmental Health Quality Standards (EHQS) of 700 CFU/m3 . This high number of bacteria is most likely caused by intense physical activity and increased sweating from users, which triggers the release of microbiological particles into the air. Similar studies show that human activity significantly increases bioaerosol concentration even in sports facilities, with bacteria levels at least doubling when the area is in use compared to when it is empty. Moreover, high occupancy density and suboptimal ventilation have also been shown to exacerbate this exposure (X. Zhang et al., 2024).

Air itself is not an ideal habitat for microorganisms, so microbes in the flying space are only temporary, usually carried by dust particles, cough droplets, or respiratory droplets. Good ventilation becomes crucial because rooms with a combination of natural and mechanical ventilation show lower bioaerosol concentrations even with high physical activity (Jabeen et al., 2023). Recent literature emphasizes that ventilation conditions and human density are the main determinants of high microbial concentrations in enclosed spaces, and efficient interventions can include increasing fresh air flow, HEPA filtration, and regulating the number of users to reduce biological exposure (Meadow et al., 2013). Research emphasizes that adequate ventilation regulation and controlling user density are key strategies to improve biological air quality while reducing the risk of respiratory infection transmission (Peixoto et al., 2023).

CONCLUSION

Research results indicate that the indoor air quality of fitness centers in Surabaya still has some limitations. Physical parameters that meet the standards include temperature, humidity, ventilation rate, noise, and PM10, while lighting and PM2.5 concentration were found to not meet the requirements. In terms of chemicals, levels of SO2, NO2, and O3 were recorded to be below the set thresholds, thus still meeting the standards. Conversely, in the biological aspect, the airborne bacteria count exceeds the threshold value, potentially increasing health risks for users. Based on these findings, it is recommended that management make technical improvements, including adding or replacing light fixtures with those of higher intensity, regulating air circulation by closing direct access from outside that could bring in pollutants, as well as optimizing the artificial ventilation system to maintain temperature and humidity stability while minimizing the growth of microorganisms.

CONFLICT OF INTEREST

The authors declare that there is no conflict of interest regarding the publication of this article. This study was conducted independently, without any financial, commercial, or personal relationships that could be construed as a potential conflict of interest. All data collection and analysis were performed objectively, and the authors received no specific grant or funding from any commercial or not-for-profit organization.

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