

Analysis of Indoor Air Pollutants in the Simulator Building at Politeknik Ilmu Pelayaran Semarang

Iksiroh El Husna^{*1}, Yan El Rizal Unzilattirrizqi Dewantoro¹, Anissofiah Azise Wijnurhayati¹, Widya Putri Idayatma¹

¹Program Studi Nautika, Politeknik Ilmu Pelayaran Semarang
Jl. Singosari Raya no.2A Kota Semarang, Kode Pos 50242, Indonesia

*E-mail: Anissofiah@pip-semarang.ac.id

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Abstrak

Polusi udara dalam ruang saat ini menjadi suatu permasalahan yang serius, karena telah menjadi penyebab 4,5 juta kematian setiap tahunnya. Ruang simulator kapal merupakan salah satu ruangan tertutup yang memungkinkan terpapar polusi udara dalam ruang. Tujuan penelitian adalah untuk mengukur dan menganalisis kualitas udara dalam ruangan di beberapa lokasi terpilih di ruang simulator kapal. Penelitian ini menggunakan metode *mix method* dengan perpaduan antara metode kuantitatif dan metode kualitatif dengan pendekatan *case control* dan bersifat observasional analitik dengan objek ruang simulator. Kualitas parameter fisik suhu, intensitas cahaya, dan jumlah mikroorganisme masih dibawah baku mutu yang dipersyaratkan Peraturan Menteri Kesehatan No. 1077 Tahun 2011. Sedangkan parameter kelembaban tidak memenuhi baku mutu kelembaban udara dalam ruang yaitu sebesar 40% Rh – 60% Rh. Kata kunci: PIP Semarang, polusi udara dalam ruang, simulator kapal.

Abstract

Analysis of Indoor Air Pollutants in the Simulator Building at Politeknik Ilmu Pelayaran Semarang. Indoor air pollution has become a serious issue, contributing to 4.5 million deaths annually. The ship simulator room is an enclosed space that may be exposed to indoor air pollution. This study aims to measure and analyze the indoor air quality in selected locations within the ship simulator room. The research used a mixed-method approach, combining both quantitative and qualitative methods with a case-control approach. It is observational and analytical in nature, focusing on the simulator room. The physical parameters of temperature, light intensity, and microorganism count were found to be below the quality standards required by the Regulation of the Minister of Health Number 1077 of 2011. However, the humidity level did not meet the indoor air humidity standard, which is set at 40% Rh – 60% Rh.

Keywords: indoor air pollution, PIP Semarang, ship simulator.

1. Introduction

Indoor air quality can be defined as the result of interactions between location, temperature, building systems, construction techniques, contaminant sources, building equipment, humidity, processes, activities within the space, external sources, and other workers [1]. Air pollution does not only occur outdoors; indoor air pollution can also pose a significant threat. In fact, indoor air pollution can have a greater impact on the health of occupants compared to outdoor air pollution. This is because approximately 80 to 90 percent of people spend their time or engage in activities indoors, such as in homes, offices, and other indoor spaces [2][3]. According to the United States Environmental Protection Agency (US EPA) (2020), exposure to indoor air pollution can be twice to 5 times, or even up to 100 times, higher than exposure to outdoor air pollution [4]. The World Health Organization (WHO) (2020) stated that air pollution causes 3 million deaths annually, with only 0.2 million of these caused by outdoor air pollution, while the remaining 2.8 million are attributed to indoor air pollution. Indoor air quality refers to the condition of air within a building, which is suitable for human activities and comfort. The definition and standards for indoor air quality typically rely on acceptable ventilation for indoor air quality (ventilation of acceptable indoor air quality) [4].

Indoor air pollution has become a serious issue, as it has been the cause of 4.5 million deaths annually [5]. Globally, indoor air pollution has contributed to strokes (34%), heart disease (26%), chronic obstructive pulmonary disease (22%), pneumonia (12%), and lung cancer (6%) [6]. Indoor air pollution, especially in households, can originate from various sources such as building materials and construction, poor ventilation, furniture, cooking appliances, cleaning products, natural gases like radon, humidity, and mold [7]. Some indoor air pollutants that pose health risks include carbon monoxide (CO), aerosols, and biological pollutants, making indoor air quality a significant concern for human health [8][9]. The primary factors affecting indoor air quality are inadequate or poor ventilation and low ambient air quality. Ventilation serves as a means for fresh air circulation to neutralize indoor air pollution. Inadequate ventilation can lead to poor air circulation indoors and promote the growth of disease vectors, which may cause health issues, particularly acute respiratory infections (ARIs) [10]. The analysis of indoor air pollutants involves several aspects, such as identifying types of air pollutants, monitoring exposure levels, assessing health impacts, and developing mitigation strategies for air pollution [1].

The occupants of a building, whether intentionally or unintentionally, often play a role in determining the quality and quantity of indoor air. Thus, all activities and operations within the building or room can influence air quality. Good indoor air quality reduces the likelihood of illness, while poor air circulation or polluted air can lead to serious health effects on individuals who spend time in space, as the pollutants can enter the body based on their concentration in the room. The primary focus of controlling indoor air pollution should be on addressing hazardous sources, as they are key to minimizing or eliminating the potential dangers of pollution. This approach involves several factors, including selecting safer materials through substitution, isolating potential hazards, incorporating additional technical features for equipment and instruments in the room, and redesigning work circulation processes, as well as introducing new equipment and instruments [11].

This study aims to measure the quality parameters of temperature, humidity, light intensity, and the number of microorganisms in the air within the simulator room based on the Indonesian Ministry of Health Regulation Number 1077 of 2011, and to analyze the risk factors of temperature, humidity, light intensity, and microorganism levels in the air in relation to health. The simulator room is an enclosed space where exposure to indoor air pollution is possible [12]. It is a facility used for ship simulation, designed as a practical laboratory for cadets to apply theoretical knowledge gained in the classroom. Instructors or lecturers present problems for cadets to solve while navigating the simulated ship at sea.

The importance of practical activities in this room requires individuals to spend the majority of their time in an indoor environment. Exposure to indoor air pollutants has a significant impact on human health and workplace efficiency, which necessitates an analysis of indoor air pollutants in the simulator building at Politeknik Ilmu Pelayaran Semarang.

2. Methodology

This study used a mixed-method approach, combining both quantitative and qualitative methods with a case-control design. It was observational and analytical in nature, focusing on the simulator room as the object of study. The data collected for this research included both primary and secondary data. The following are the primary and secondary data used in this study:

Table 1. Primary Data on Physical, Chemical, and Biological Factors

Parameter	Variable	Data Collection Tool	Reference
Physical Air	Temperature	Thermometer	SNI 16-7061-2004
	Humidity	Humidity Meter	SNI 16-7061-2004
	Light Intensity	Lux Meter	SNI 7062-2019
Biological Air	Microorganism Count	Agar Media	-

Temperature measurement follows SNI 16-7061-2004, which pertains to work climate measurement (heat) using the wet-bulb and globe temperature index. The air temperature within a room is measured using a thermometer. Humidity measurement is based on SNI 16-7061-2004 regarding Work Climate Measurement (Heat) with Parameters of Wet-Bulb and Globe Temperature Index. Light intensity measurement follows SNI 7062-2019 regarding Light Intensity Measurement in the Workplace. Light intensity within a room is measured using a lux meter. For microorganism (germ) sampling, equipment and materials for preparing media are required to serve as a medium for collecting germ counts.

The method used for germ sampling is the passive exposure plate method (setting plate) where the agar media is exposed directly to the air [13]. The agar media is placed at the sampling point for one hour. After the germ sampling is completed, the media is placed in a cool box with ice packs and transported to the laboratory. Subsequently, the media is incubated for 48 hours at 37°C using an incubator. After incubation, the bacterial colonies formed are counted using a colony counter.

The data analysis phase in this study begins with categorizing the primary data obtained. The primary data, such as temperature, humidity, light intensity, and carbon monoxide (CO), are compared to the requirements set forth in the Indonesian Ministry of Health Regulation Number 1077 of 2011. The germ sample data collected earlier are recalculated using the following formula [14]:

$$\text{Number of Germs (CFU/m}^3\text{)} = \text{Conversion: } 1 \text{ colony CFU/m}^3 = 35.32 \text{ CFU/m}^3 \quad (1)$$

$$X = \sum fx / \sum f$$

$$\sum y = \text{CFU/m}^3 \times X$$

$$X = \text{Average result of colonies}$$

$$\sum fx = \text{Number of colonies in the petri dish}$$

$$\sum f = \text{Number of petri dishes}$$

$$\sum y = \text{Number of colonies in the room (CFU/m}^3\text{)}$$

Using Excel software for calculations, the data on the number of germs in the air within the room are obtained and then compared to the requirements set forth in the Indonesian Ministry of Health Regulation Number 1077 of 2011. After all primary data have been adjusted according to the regulations, the results are analyzed.

3. Results and Discussion

Sources of pollutants in a room, such as cigarette smoke, dust, chemicals, and emissions from electronic equipment, can increase the concentration of pollutants in enclosed spaces. Without adequate ventilation, these pollutants can accumulate and reach unhealthy levels [15]. A smaller closed simulation room with a higher number of occupants can accelerate pollutant accumulation. Human activities, such as breathing and sweating, can also increase humidity in an enclosed space [16]. Measurements are conducted on key parameters such as particulate concentration, carbon dioxide levels, humidity, and air temperature [17][18]. The data obtained are then analyzed to assess air quality and influencing factors.

3.1 Temperature

Based on the results of air temperature measurements conducted in the Agum Gumelar Simulator Room and the Integrated Navigation System (INS) Room, the data can be seen in the following figure.

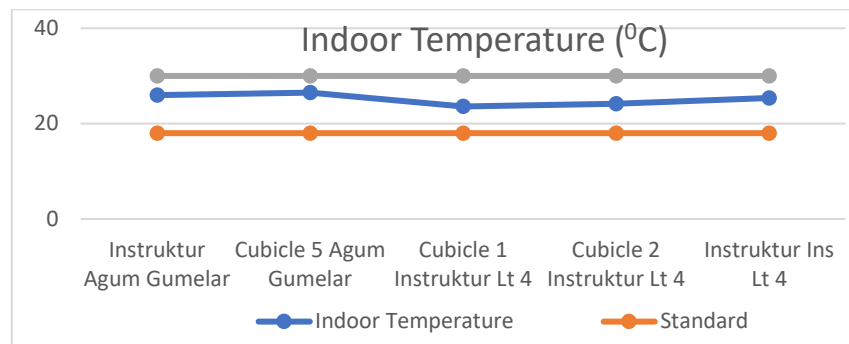


Figure 1. Results of Indoor Temperature Measurements
(Source: Data Analysis, 2024)

Based on the temperature measurement results shown in Figure 1, it can be observed that the indoor temperatures in the simulator rooms, both with and without windows, equipped with air conditioning, meet the Quality Standards as stipulated by the Ministry of Health Regulation Number 1077 of 2011, which sets the acceptable range between 18°C and 30°C. Field measurements at the PIP Semarang simulator rooms revealed that the air temperature ranged between 23.6°C and 26.5°C.

Temperature is one of the most significant environmental factors influencing microbial growth. The previous studies have confirmed that temperature can have a substantial effect on microbial growth rates, metabolite production, and enzyme activity [19][20]. Based on the temperature measurements above, it can be concluded that the simulator room temperatures at PIP Semarang comply with the applicable regulations.

3.2 Humidity

The results of the humidity measurements taken in the Agum Gumelar Simulator Room and the Integrated Navigation System (INS) Room can be seen in Figure 2 below.

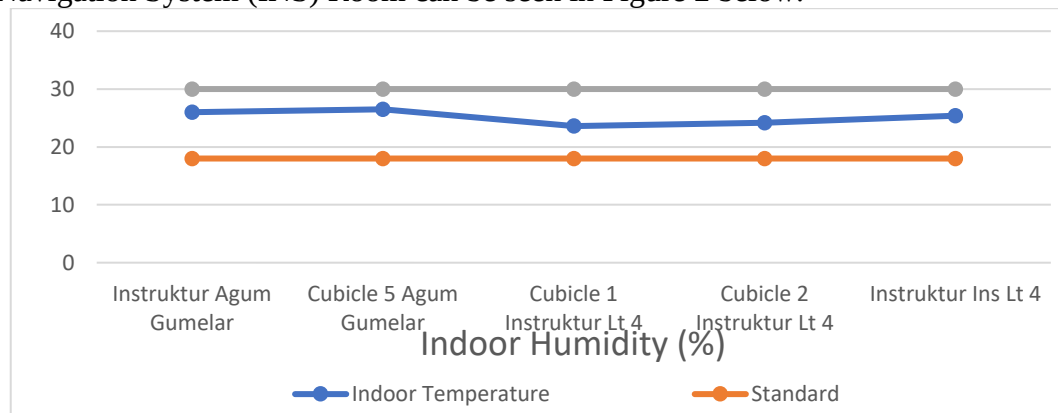


Figure 2. Results of Indoor Humidity Measurements
(Source: Data Analysis, 2024)

Based on the humidity measurement results shown in the Table and Graph above, it can be observed that none of the tested rooms meet the indoor air humidity standards as regulated by the Ministry of Health Regulation Number. 1077 of 2011, which stipulates a range of 40% Rh – 60% Rh. The measurements indicate that the Agum Gumelar Instructor Room had the highest humidity at 73%, Cubicle 1 on the 4th floor Instructor Room had 76%, Cubicle 5 in Agum Gumelar had 70%, the Instructor Room INS on the 4th floor had 68%, and Cubicle 2 on the 4th floor Instructor Room had 66%. This suggests that the simulator rooms tested at PIP Semarang have high humidity levels that do not conform to the required standards.

High humidity in a room can lead to a weakened immune system, making occupants more susceptible to diseases, particularly infections, as humidity can enhance the survival of microorganisms [21]. Therefore, humidity is a crucial factor influencing indoor air quality. Both excessive and insufficient humidity can promote the growth and proliferation of pathogenic microorganisms, posing health risks to the occupants [22].

3.3 Lighting

The results of light intensity measurements taken in the Agum Gumelar Simulator Room and the Integrated Navigation System (INS) Room can be seen in Figure 3 below.

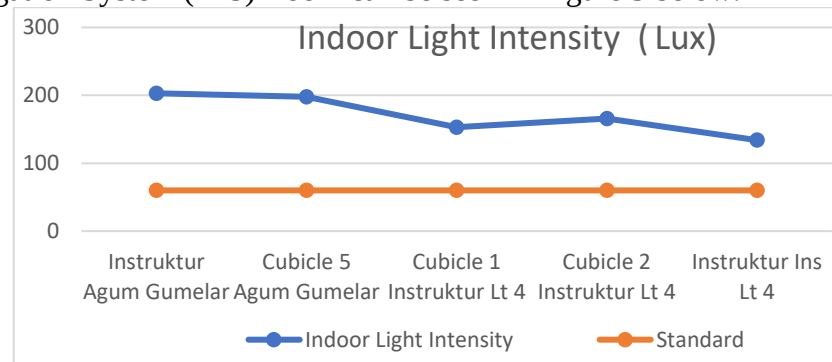


Figure 4.5. Graph of Indoor Light Intensity Measurements
(Source: Data Analysis, 2024)

Based on the light intensity measurements shown in Table 4.3 and Figure 4.5 above, it is evident that all the tested simulator rooms have excellent light intensity conditions, meeting the indoor light intensity standards outlined in the Ministry of Health Regulation Number 1077 of 2011, which specifies > 60 Lux. The measurements revealed that the Agum Gumelar Instructor Room had the highest light intensity at 203 Lux, Cubicle 5 in Agum Gumelar had 198 Lux, Cubicle 1 in the 4th-floor Instructor Room had 153 Lux, Cubicle 2 in the 4th-floor Instructor Room had 166 Lux, and the Instructor Room INS on the 4th floor had 134 Lux. This indicates that the tested simulator rooms at PIP Semarang have excellent and appropriate light intensity levels in accordance with the standards set by the Ministry of Health Regulation No. 1077 of 2011, which is 60 Lux.

The research indicates no strong correlation between high light intensity (above 60 Lux) and increased indoor air pollution. Proper light intensity (greater than 60 Lux) does not directly cause an increase in pollutants or a decrease in indoor air quality [23][24]. However, other factors can influence indoor air quality, such as ventilation, humidity, occupant activities, and other pollution sources. High light intensity can raise room temperature, which in turn may affect air circulation and humidity, indirectly impacting indoor air quality [25].

3.1 Microbial Count

One of the parameters for indoor air quality is the microbial count, measured in Colony Forming Units per cubic meter (CFU/m³). The standard limit for indoor microbial count is generally <700 CFU/m³. Based on the results, the microbial count in the tested rooms was quite low, well below the standard, which is excellent and should be maintained. Factors contributing to the low microbial count include frequent cleaning and sanitation, effective air filtration systems, low human activity, and few sources of contamination within the rooms, as well as regular disinfection. Thus, each room will be equipped with one petri dish containing a reagent to capture the existing microbes. The results of the microbial count measurements in the Agum Gumelar Simulator Room and the Integrated Navigation System (INS) Room are shown in Table 2 below.

Table 2. Indoor Microbial Count Results

Room	Microbial Count (CFU/m ³)							Quality Standard
	Staphylococcus aureus	Staph.Epi-Der Midis	Streptococcus	E-Coli	Entero-bakter	Bacillus Subtilis	Acinetobacter	
Agum Gumelar Instructor	26	14	6	4	2	2	0	< 700 CFU/m ³
Cubicle 5								
Agum Gumelar	14	4	5	3	1	4	0	
Cubicle 1								
Instructor 4th Floor	7	4	3	0	0	2	2	
Cubicle 2								< 700 CFU/m ³
Instructor 4th Floor	3	7	0	2	0	1	1	
INS 4th Floor Instructor	6	7	6	2	0	1	1	

(Source: Data Analysis, 2024)

Based on research, the microbial count remains low. However, the presence of microorganisms suggests a potential source of indoor air pollution, which highlights the need to maintain the excellent room cleaning and sanitation standards already in place at the PIP Semarang simulator rooms. This is important because, regardless of the low count, microorganisms can still pose health risks. Studies have found that higher indoor microbial counts correlate with increased risks of respiratory infections among patients and medical staff. Airborne pathogenic microorganisms can cause infectious diseases, especially among vulnerable populations such as hospital patients. Controlling the indoor microbial count is essential for preventing nosocomial infections [26].

4. Conclusion

Based on the analysis and discussion of Indoor Air Pollutant Analysis at the PIP Semarang Simulator Building, it can be concluded that the physical parameters of temperature, light intensity, and microbial count remain below the required standards as outlined by Ministry of Health Regulation Number 1077 of 2011. However, the humidity parameter does not meet the indoor air humidity standards, which require 40% Rh – 60% Rh according to the same regulation.

Further research needs to be conducted by collecting data both before the room is used and after it has been utilized, allowing for an assessment of the differences in indoor air quality.

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