Concentration of Particulate Matter and Air Humidity in Pediatric Intensive Care Unit

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Abstract. Human activities are predominantly conducted indoors, making it equally important to ensure good indoor air quality as it is to maintain outdoor air quality. The quality of indoor air is partly determined by the levels of $PM_{2.5}$ (particles with an aerodynamic diameter ≤2.5μ m) and PM_{10} (particles with an aerodynamic diameter ≤ 10 μm) and humidity. The Pediatric Intensive Care Unit (PICU) is a space that must maintain high air quality because it is continuously occupied by pediatric patients and healthcare personnel 24 hours a day, 7 days a week. In this study, the indoor air quality in the PICU Arifin Achmad General Hospital (AAGH) in Riau Province, Indonesia, was observed using a descriptive observational study with a longitudinal and time-series design. The results of this study demonstrated that the $PM_{2.5}$ levels decreased from 9.25 μg/m³ in the morning to 3.3 μg/m³ in the afternoon, whereas PM_{10} levels decreased from 17.7 μg/m³ in the morning to 7.8 μg/m³ in the afternoon. Additionally, the air humidity increased from 60.7% in the morning to 61.4% in the afternoon. In conclusion, the observations from this study indicated an increase in air humidity from morning to afternoon and the normal particulate matter levels.
Keywords: Indoor air quality, $PM_{2.5}$, PM_{10}, air humidity.

1 Introduction

The PICU is a room that is continuously occupied by both critically ill pediatric patients and the healthcare professionals on duty. Patient management in the PICU is conducted by a multidisciplinary team including pediatric intensivists, nurses, respiratory therapists, and other specialists [1]. The air quality in the PICU is very important for both accelerating the patients healing process and ensuring the comfort of patients and healthcare staff. Infection prevention and maintaining a clean environment are crucial in such a room. The ingress and egress of patients and healthcare personnel in the PICU room will also impact the air quality within the space [2],[3],[4]. One of the determining factors for the quality of air in the ICU room is the level of $PM_{2.5,}$ PM_{10} and humidity [5],[6].

Variations in $PM_{2.5}$ and PM_{10} levels in the PICU can originate from occupant activities, medical procedures, cleaning activities, the ventilation system, patient visitors, as well as construction and renovation activities within the building. Sources of humidity in the ICU

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room can include occupant respiration, medical procedures, cleaning activities, the Air Conditioner (AC) system, and external weather conditions [7].

There are numerous diseases associated with increased levels of $PM_{2.5}$ and PM_{10}, particularly those related to respiratory tract diseases. The pathogenesis involves inflammatory processes in the endothelial lining of the respiratory tract and alveoli. Some of the diseases associated with air quality include Chronic Obstructive Pulmonary Disease (COPD), asthma, cardiovascular diseases, lung cancer, acute respiratory infections, allergies, and rhinitis. Repeated and continuous exposure to $PM_{2.5}$ and PM_{10} can reduce lung function and decrease the quality of life for both patients and healthcare workers [8], [9].

Humidity levels also significantly influence indoor air quality, and there are several diseases associated with increased humidity. The optimal indoor humidity range is 30% to 60%. Proper humidity levels can reduce the incidence of infections and medical complications for patients and healthcare workers. Maintaining appropriate humidity levels can decrease bacterial and fungal growth, prevent respiratory tract irritation, avoid dryness of the skin and mucous membranes, and keep medical and electronic equipment in optimal condition. [7], [10], [11], [12].

In the PICU, both patients and healthcare providers strive to manage critical illnesses. Poor air quality in the PICU can exacerbate patient conditions and diminish the performance of healthcare personnel. To date, no air quality assessments based on $PM_{2.5}$ and PM_{10} levels, as well as humidity, have been conducted in the PICU of AAGH in Riau Province. It is expected that by understanding the air quality conditions in the PICU, the necessary measures for improvement can be identified [13],[14],[15],[16].

Although it does not specify the exact criteria for air quality in intensive care rooms, the World Health Organization (WHO) stipulates that the 24-hour $PM_{2.5}$ levels should not exceed 25 $\mu g/m^3$ and that indoor humidity should be maintained between 30-50%. In 2019, poor air quality was estimated to cause nearly seven million premature deaths and more than 200 million years of healthy life lost globally. The Regulation of the Minister of Environment and Forestry Number P.7/MENLHK/SETJEN/KUM.1/2/2019 concerning National Ambient Air Quality Standards specifies that the $PM_{2.5}$ level is 65 $\mu g/m^3$ over a 24-hour period and the PM_{10} level is 150 $\mu g/m^3$ over a 24-hour period [17],[18], [19].

AAGRH of Riau Province, serving as a referral center for 12 districts and cities in Riau Province, is committed to delivering quality health services and fostering a better environment through active participation in the Green Hospital program organized by the Ministry of Environment and Forestry. One of the key objectives of this program is to control and enhance indoor air quality and comfort [20], [21], [22].

The PICU room at AAGH in Riau Province, located on the first floor of the main building, has the characteristics of a closed room with glass windows covered by roller blinds. This room consists of eight patient beds, each equipped with a monitor, ventilator, and other apparatus according to the Ministry of Health standards. The room is equipped with several AC, including two ceiling-mounted AC units and three wall-mounted AC units. Currently, there is no research focused on PM concentration and air humidity in the PICU room. Therefore, this study aims to evaluate the concentration of PM and air humidity in the PICU room at AAGH in Riau Province, as important parameters in determining indoor air quality. [23], [24].

2 Method

This research on the concentration of PM and air humidity in the PICU room was conducted at AAGH, Riau Province. The study started with a survey at the research location, followed by tool testing, and primary and secondary data collection. It adopts a

descriptive observational study with a longitudinal and time-series design, measuring the concentrations of $PM_{2.5}$, PM_{10}, and air humidity in the morning (07:00-08:00 West Indonesia Time/WIB), afternoon (14:00-15:00 WIB), and evening (21:00-22:00 WIB) over a period of 14 consecutive days. The timing for measuring and recording PM levels and humidity was conducted simultaneously. The time pattern utilized was adjusted according to the shift changes of healthcare personnel during the morning, afternoon, and night shifts. Observations and recordings of PM levels and air humidity are conducted daily, both on weekdays and during weekends. Typically, the number of visitors coming for visits on weekends is higher compared to weekdays. During weekdays, the number of healthcare workers in the morning is generally greater than those on duty during the afternoon and night shifts.

Measurements were conducted at 17 locations within the PICU. The exact points of measurement can be seen in Figure 1. During the measurement process, factors influencing PM concentrations and air humidity in the PICU were identified. The instruments used in this study included the CEM DT-96 Mini Particle Counter to measure $PM_{2.5}$ and PM_{10} levels, as well as air humidity.

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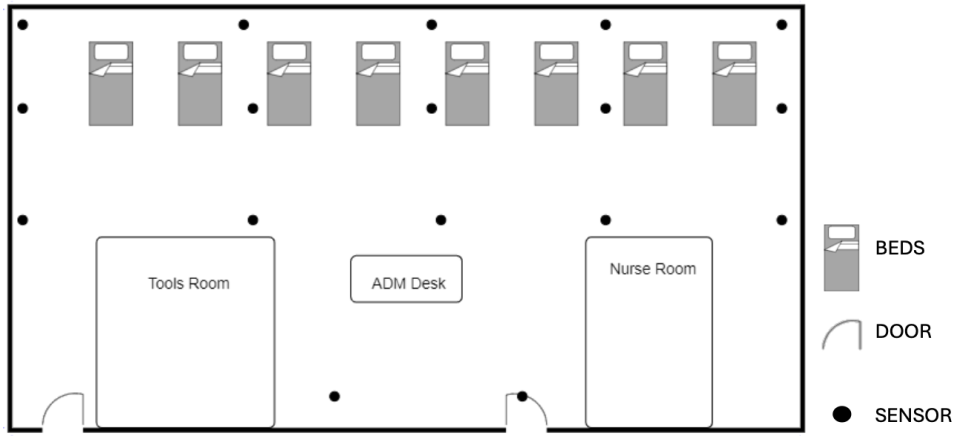

Fig. 1. PICU Room Layout Diagram

Performance Evaluation of the mini particle counter CEM DT-96 is based on the Circular Letter of the Head of the Government Goods/Services Procurement Policy Institute concerning procedures for managing electronic catalogs after the inclusion of goods/services in the electronic catalog No. 11 of 2022 with Product number SKU 69726628. The Performance Evaluation by the Commitment Making Officer is an accumulation of the assessments given by the PPK for each completed order. CEM Instruments is a company based in China. They are known for manufacturing a wide range of measuring instruments and electronic devices, including particle counters such as the CEM DT-96. CEM products are commonly used in various industrial, laboratory, and environmental applications. The CEM DT-96 Particle Counter is a compact particle counting device featuring a 2.0 color TFT LCD screen that provides rapid, user-friendly, and precise measurements for particle count and mass concentration. Additionally, it offers ambient temperature and relative humidity measurements.

During the observation period, the number of patients and healthcare personnel on duty for each shift will be recorded. Similarly, the activities performed by healthcare personnel on patients using medical equipment, such as patient inhalation procedures, intubation,

resuscitation, recording of patient temperature, or any actions related to the management of PICU patients, will also be documented.

The analytical method employed was descriptive analysis. All collected data were recorded on research forms and subsequently transferred to Microsoft Excel. For each measured parameter, the average, maximum, and minimum values were calculated. The data were presented in both textual and tabular formats as required. The average values for each shift will be compared across morning, afternoon, and night shifts

3 Results and Discussion

The measurement results indicated that $PM_{2.5}$ concentrations ranged from 0 μg/m^3 to 62 μg/m^3, with average levels of 9.25 μg/m3 in the morning, 6.4 μg/m^3 during the day, and 3.3 μg/m^3 at night. However, it is noteworthy that at certain times and locations, $PM_{2.5}$ concentrations peaked at 62 μg/m^3, which exceeds the established threshold, as shown in Table 1 below.

Table 1Results of $PM_{2.5}$ Concentration Measurements

Time	$PM_{2.5}$ concentration (μg/m^3)		Maximum concentration (μg/m^3)
	Average	Maximum	
Morning	9.25	41	35
Afternoon	6.40	62	35
Evening	3.32	26	35

The measurement results showed that PM_{10} concentrations ranged from 0 μg/m^3 to 98 μg/m^3, with average levels of 17.7 μg/m3 in the morning, 13 μg/m3 during the day, and 7.8 μg/m^3 at night. However, it is noteworthy that at certain times and locations, PM_{10} concentrations peaked at 98 μg/m3, which exceeds the established threshold. The detailed PM_{10} concentration measurement results are presented in Table 2.

Table 2Results of PM_{10} Concentration Measurements

Time	PM10 concentration (μg/m^3)			Maximum concentration (μg/m^3)
	Average	Minimum	Maximum	
Morning	17.71	2	69	70
Afternoon	13.05	1	98	70
Evening	7.81	0	46	70

The measurement results for air humidity indicated that values ranged from 50% to 70.3%, with average levels of 60% in the morning, 60.7% during the day, and 61.4% at night.

Table 3Air Humidity Measurement Results

Time	Air Humidity (%)			Quality Standard (%)
	Average	Minimum	Maximum	
Morning	60.06	50	64.4	40 - 60
Afternoon	60.78	56.3	65.9	40 - 60

Evening	61.47	57.7	70.3	40 - 60

The average concentrations of $PM_{2.5}$ and PM_{10} in the morning are higher than those during the day and night. The increased levels of $PM_{2.5}$ and PM_{10} have exceeded the thresholds set by the WHO. The WHO establishes the average hourly $PM_{2.5}$ level at 15 $\mu g/m^3$, while for PM_{10}, the level should not exceed 45 $\mu g/m^3$. The elevated levels of PM in the morning are likely due to the higher number of occupants on duty compared to the afternoon and evening. In the morning, it is the time for doctors from other departments to see patients. Visits from pediatric surgery, neurosurgery, and physiotherapy departments often occur in the morning. Additionally, several diagnostic procedures using mobile equipment, such as X-rays, are frequently conducted after the morning patient rounds rather than in the afternoon or evening. In the morning, multidisciplinary rounds frequently take place, especially for complex cases that require collaborative team efforts. A greater number of medical interventions and diagnostic procedures are performed in the morning compared to the afternoon and evening. Additionally, the number of nurses involved in shift handovers is higher in the morning.

The activities of medical residents, nursing students, and healthcare personnel undergoing orientation in the PICU are typically conducted in the morning. Additionally, families of patients are more likely to be present in the morning, making it the preferred time for explaining the patient's condition. The frequency of door openings and closings is higher, thereby increasing the likelihood of external air entering the PICU.

Factors affecting the concentrations of $PM_{2.5}$ and PM_{10} in the PICU include the number of occupants, such as patients, medical personnel, cleaners, and visitors, as well as activities like room cleaning, the use of ventilators, nebulizers, patient sputum suctioning, and other related activities. According to a study by Congrong He et al. conducted in the PICU of Royal Children's Hospital in Brisbane, Australia, the most dominant sources of indoor particles were identified as nebulization therapy and cleaning activities. Additionally, invasive tracheal suctioning performed by nurses is also hypothesized to be a significant source of indoor particles. Moreover, equipment such as air conditioners, computers, and printers can also contribute to PM levels in the PICU room. Contrarily, research by Alghamdi Waleed et al. in PICU rooms of two hospitals in Saudi Arabia discovered that the primary source of indoor PM contamination was infiltration from the outside, primarily due to the study being conducted during a sandstorm. In the current study, it is highly probable that the PM originated from indoor sources, as the PICU is an enclosed space.

To further elaborate, maintaining air quality within the recommended humidity range of 40-60% is critical for patient well-being in the PICU room. The observed humidity levels can sometimes exceed this guideline, reaching as high as 70.3%. Higher humidity levels can significantly impact patient comfort and foster an environment conducive to the growth of microorganisms, potentially elevating the risk of infections. Research supports that keeping indoor air humidity below 50% can mitigate the risk of airborne infections. On the flip side, if relative humidity levels dip to 40% or below, it could lead to adverse effects such as dryness of the skin, eye irritation, and respiratory tract irritation, all of which could cause significant discomfort for patients. Therefore, monitoring and maintaining appropriate humidity levels is integral to ensuring a healthy and comfortable environment in the PICU.

The observed air humidity levels at night in the PICU are higher compared to those in the morning and during the day. This phenomenon is likely influenced by factors such as temperature, lighting, and air circulation. Given that the PICU is a closed room with no ventilation to facilitate air flow, temperature and lighting levels are lower at night, contributing to increased humidity.

4 Conclusion

Based on the results of the research and analysis conducted, the following conclusions can be drawn: The air quality, as determined by the concentrations of $PM_{2.5}$ and PM_{10} in the PICU of AAGH, complies with the quality standards stipulated by Minister of Health Regulation Number 7 of 2019 concerning the Environmental Health of Hospitals in the Republic of Indonesia. Several factors influence PM concentration levels, including the number of occupants in the room comprising patients, medical personnel, and visitors as well as cleaning activities, utilization of medical equipment, and the presence of electronic devices such as computers and printers.

The air humidity in the PICU of AAGH in Riau Province exceeds the quality standards established by the Ministry of Health Regulation Number 7 of 2019 concerning Hospital Environmental Health in Indonesia. Factors contributing to air humidity levels include temperature, lighting, and air circulation.

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