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Research article

Evaluation of Physical Parameter Environment in the Hemodialysis Unit Based on Hospital Environmental Health Standards

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ABSTRACT

Background: The physical environmental quality of a hemodialysis unit plays an important role in supporting safe and comfortable healthcare services, as well as preventing and controlling infections. This study aimed to evaluate the physical environmental parameters of the hemodialysis unit based on the Environmental Health Quality Standards (SBMKL), in accordance with Regulation of the Minister of Health of the Republic of Indonesia Number 2 of 2023.
Methods: This study employed a quantitative descriptive design to evaluate the physical environmental conditions of the treatment and isolation rooms in the hemodialysis unit. The parameters measured included air temperature, relative humidity, lighting, noise levels, Air Changes per Hour (ACH), and air pressure using calibrated instruments. The data were analyzed descriptively by comparing the measurement results with the Environmental Health Quality Standards (SBMKL).
Results: The results showed that the mean air temperatures in the treatment and isolation rooms were 26.3°C and 26.5°C, respectively; relative humidity was 61.1% and 59.3%; lighting intensity was 262.8 lux and 273.2 lux; noise levels were 63.4 dB and 58.0 dB; Air Changes per Hour (ACH) were 21.6 and 19.5 times/hour; and air pressure was 1.5 Pa in both rooms. The lighting and ACH parameters met the applicable standards at all measurement points (100%), whereas air pressure did not meet the standard at any measurement point (0%). Relative humidity and noise levels showed higher compliance in the isolation room than in the treatment room. However, air temperature did not meet the applicable standards in either room.
Conclusion: Based on results the concluded that quality environment physical hemodialysis unit Not yet fully fulfill SBMKL. Evaluation integrated all physical parameters required as indicator performance HVAC system for support quality service, prevention infection, and safety patient.

INTRODUCTION

Hospitals are healthcare facilities that must provide a safe, comfortable, and healthy environment for patients, healthcare workers, and visitors. In addition to providing quality medical services, hospitals are responsible for maintaining environmental quality to prevent the environment from becoming a source of health risks and disease transmission (ASHRAE et al., 2021). An inadequate physical environment can compromise patient safety, increase the risk of healthcare-associated infections (HAIs), and

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adversely affect the comfort and performance of healthcare workers in delivering services (World Health Organization, 2024). Therefore, the implementation of hospital environmental health is an important component of the healthcare quality management system. In Indonesia, hospital environmental health is regulated through Regulation of the Minister of Health of the Republic of Indonesia Number 2 of 2023 concerning the Implementing Regulation of Government Regulation Number 66 of 2014 on Environmental Health. This regulation establishes various environmental parameters that must be fulfilled to ensure the safety and quality of healthcare services (Ministry of Health, 2023).

The hemodialysis unit is a specialized healthcare service with environmental characteristics that differ from those of other hospital units. It serves patients with chronic kidney disease, who generally have impaired immune function and require regular therapy over a prolonged period. These conditions make hemodialysis patients more vulnerable to adverse health effects resulting from an inadequate physical environment, including the risk of healthcare-associated infections and discomfort during treatment (Centers for Disease Control and Prevention, 2024). In addition to patients, healthcare workers in hemodialysis units are also exposed to a work environment that requires optimal control of physical environmental factors to ensure occupational safety. Therefore, maintaining the physical environmental quality of hemodialysis units in accordance with applicable standards is essential to support effective healthcare delivery while minimizing potential health risks. Evaluation of the physical environmental conditions in these units is an important component of hospital environmental health programs that are oriented toward patient safety and quality improvement (Nguyen et al., 2020).

Various studies have shown that many hospitals continue to face challenges in meeting physical environmental standards in specialized service areas. Some studies have reported room temperatures exceeding recommended limits, relatively high noise levels resulting from healthcare activities and medical equipment, and inadequate lighting in certain service areas (Aryani et al., 2025). These conditions may reduce patient comfort, affect the performance of healthcare workers, and increase the risk of adverse health effects when exposure persists over an extended period. However, most previous studies have focused on only one or two environmental parameters or have evaluated hospital treatment rooms in general. Consequently, information regarding the comprehensive physical environmental conditions of hemodialysis units, particularly treatment and isolation rooms, remains relatively limited (Akova et al., 2020). This limitation indicates the need for a comprehensive evaluation of physical environmental parameters in hemodialysis units as a basis for decision-making and efforts to improve healthcare service quality and hospital environmental health management (Wu et al., 2023).

Evaluation of physical environmental parameters is not only intended to determine compliance with hospital environmental health standards but also to provide a basis for developing appropriate environmental risk-control strategies. The results of such evaluations can assist hospital management in identifying parameters that do not meet applicable standards, thereby enabling accurate and sustainable corrective actions. In addition, information regarding physical environmental conditions can contribute to quality improvement programs, patient safety initiatives, and hospital accreditation processes that require compliance with environmental health standards (Ministry of Health, 2023). Through comprehensive evaluation, hospitals can improve the quality of their service environments and support the delivery of safe, effective, and patient-centered healthcare. Therefore, research evaluating physical environmental parameters in hemodialysis units is strategically important for supporting the sustainable implementation of hospital environmental health standards (Ministry of Health, 2023).

Based on the foregoing, compliance with physical environmental standards in hemodialysis units is an important aspect of ensuring healthcare service quality, patient safety, and the health and safety of healthcare workers. However, information regarding compliance with physical environmental standards in hemodialysis units remains limited, particularly studies that simultaneously evaluate multiple environmental parameters in an integrated manner (Rodríguez et al., 2025). This condition highlights the need for a comprehensive evaluation of the physical environmental quality of hemodialysis units as a basis for improving hospital environmental management systems. The results of this study are expected to provide useful scientific information for hospital managers in maintaining and improving the quality of the healthcare environment in accordance with applicable regulations. Therefore, this study aimed to evaluate the physical environmental parameters of the hemodialysis unit based on the Hospital Environmental Health Standards.

METHODS

This study employed a quantitative descriptive design and was conducted in the hemodialysis unit of a hospital in Tulungagung, Indonesia. The unit consisted of a treatment room and an isolation room. Data were collected through direct measurement of physical environmental parameters, including air temperature, relative humidity, lighting intensity, noise level, Air Changes per Hour (ACH), and air pressure. Measurements were conducted monthly over a six-month period, from June to November 2025, in both the treatment and isolation rooms of the hemodialysis unit, following the applicable procedures for hospital environmental measurements.

Air temperature and relative humidity were measured using a digital thermo-hygrometer, while lighting intensity was measured using a digital lux meter. Noise levels were measured using a Sound Level Meter (SLM) and expressed in A-weighted decibels (dBA). The Air Changes per Hour (ACH) was calculated based on the measured air velocity obtained using a hot-wire anemometer, combined with the ventilation cross-sectional area and room volume, to determine the number of air changes per hour. Air pressure was measured using a differential pressure meter (micromanometer) to determine the pressure difference between the hemodialysis room and the surrounding area.

All measurement instruments were calibrated in accordance with the applicable procedures before data collection. The measurement procedures for each parameter referred to relevant Indonesian national standards, including SNI 6390:2020 for building air-conditioning systems, SNI 6197:2020 for building lighting systems, and SNI 7231:2009 for noise-level measurement methods (Badan Standardisasi Nasional, 2020; Standar Nasional Indonesia, 2020; SNI Noise Measurement, 2009)

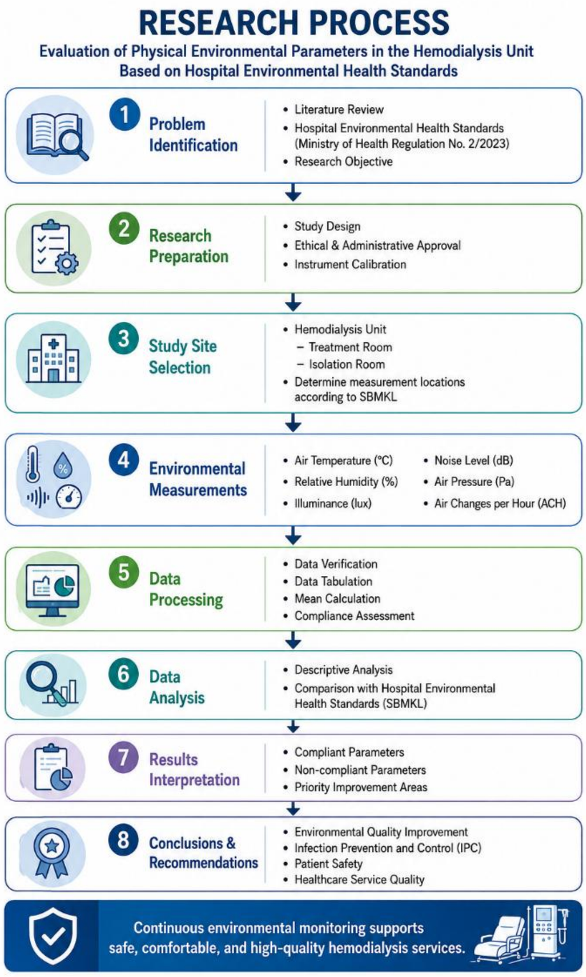

Figure 1. Process for Evaluating Physical Environmental Parameters in the Hemodialysis Unit Based on Hospital Environmental Health Standards.

The research process began with problem identification through a literature review and an examination of the Environmental Health Quality Standards (SBMKL) stipulated in Regulation of the Minister of Health of the Republic of Indonesia Number 2 of 2023. The subsequent stages included research preparation, which involved developing the research design, obtaining the necessary permits, and calibrating the measurement instruments. Measurements were conducted in the treatment and isolation rooms of the hemodialysis unit and included six physical environmental parameters: air temperature, relative humidity, lighting intensity, noise level, air pressure, and Air Changes per Hour (ACH). The measurement data were subsequently verified, tabulated, and analyzed descriptively by comparing the results with the applicable SBMKL. The findings were then interpreted to identify parameters that met or did not meet the established standards. Based on these findings, conclusions and recommendations were formulated to support improvements in physical environmental quality, infection prevention and control, patient safety, and healthcare service quality in the hemodialysis unit.

The interpretation of the measurement results was based on Regulation of the Minister of Health of the Republic of Indonesia Number 2 of 2023 concerning the Implementing Regulation of Government Regulation Number 66 of 2014 on Environmental Health, which serves as the reference standard for hospital environmental health quality. The measurement data were analyzed descriptively by presenting the minimum, maximum, and mean values and comparing the results for each environmental parameter with the applicable hospital environmental health standards. The analysis results were presented in tables and narrative descriptions to provide a comprehensive overview of the physical environmental conditions of the hemodialysis unit.

RESULTS

Environmental Health Quality Standards Physical Parameters Hospital Environment Based on Minister of Health Regulation Number 2 of 2023

No	Parameter	SBMKL
1	Temperature	22-23 ^{o}C
2	Humidity	40-60%RH
3	Lighting	> 100 Lux
4	Noise	< 65 dB
5	*Air Changes per Hour* (ACH)	≥ 6 ACH
6	Air Pressure	+2.5 Pa

Table 2. Measurement of Physical Air Parameters in the Hemodialysis Treatment Room

Measurement (Month)	Measurement of Physical Air Parameters					
	Temperature(^{o}C)	Humidity (%RH)	Lighting (Lux)	Noise (dB)	ACH	Air Pressure (Pa)
1	26.1*	63.8*	343	68*	22.66	1.7*
2	26*	65*	268.4	63.2	20.1	1.5*
3	25.4*	61.7*	235	68*	20.41	1.6*
4	26.8*	59.3	244	60.7	20.18	1.7*
5	25.5*	57.4	251.5	55	21.44	1.7*
6	28.1*	60.4*	235	66.4*	24.48	1.3*

Description: * Measurement results exceed the Environmental Health Quality Standards (SBMKL)

Based on Table 2, the results of the physical environmental parameter measurements in the hemodialysis treatment room over the six-month study period showed that several parameters did not meet the Environmental Health Quality Standards (SBMKL). Air temperature ranged from 25.4 to 28.1°C, with five of the six measurements exceeding the prescribed standard. Relative humidity ranged from 57.4% to 65.0% RH, with four measurements exceeding the specified limit and therefore not meeting the standard. Lighting intensity ranged from 235 to 343 lux, and all measurements met the SBMKL requirements. Noise levels ranged from 55.0 to 68.0 dB, with four measurements exceeding the applicable quality standard. Air Changes per Hour (ACH) ranged from 20.10 to 24.48 times/hour, and all measurements met the prescribed standard. Meanwhile, air pressure ranged from 1.3 to 1.7 Pa;

however, none of the measurements met the required air-pressure standard for the hemodialysis treatment room.
The results indicate that lighting intensity and ACH consistently met the SBMKL requirements, whereas air temperature, relative humidity, and noise levels showed partial non-compliance. Air pressure demonstrated the most consistent non-compliance and therefore requires particular attention and corrective measures to achieve the applicable hospital environmental health standards.

Table 3. Measurement of Physical Air Parameters in the Hemodialysis Isolation Room

Measurement (Month)	Measurement of Physical Air Parameters					
	Temperature (°C)	Humidity (%RH)	Lighting (Lux)	Noise (dB)	ACH	Air Pressure (Pa)
1	25*	57.2	218	60	20	1.3*
2	25.7*	63.1*	209	58.7	18.77	1.3*
3	25.9*	65.6*	217	50	20.08	1.3*
4	25*	56.1	231	63.2	22.18	1.3*
5	24.8*	56	219.6	57.4	21.52	1.3*
6	29*	58.0	214	58.7	14.4	1.3*

Description: * Measurement results exceed the Environmental Health Quality Standards (SBMKL)

Based on Table 3, the results of the physical environmental parameter measurements in the hemodialysis isolation room over the six-month study period showed that some parameters met the Environmental Health Quality Standards (SBMKL), whereas others did not meet the established requirements. Air temperature ranged from 24.8 to 29.0°C, with all measurements falling outside the prescribed standard range. Relative humidity ranged from 56.0% to 65.6% RH, with two measurements exceeding the standard limit, while the remaining four measurements met the requirements. Lighting intensity ranged from 209 to 231 lux, and all measurements met the SBMKL requirements. Noise levels ranged from 50.0 to 63.2 dB, with five measurements meeting the applicable quality standard and only one measurement exceeding the standard. Air Changes per Hour (ACH) ranged from 14.4 to 22.18 times/hour, and all measurements met the established standard. Meanwhile, air pressure remained relatively constant at 1.3 Pa throughout the measurement period; however, none of the measurements met the required air-pressure standard according to the SBMKL.
Lighting intensity and ACH consistently met the applicable standards. Relative humidity and noise levels met the standards in most measurements, whereas air temperature and air pressure consistently failed to meet the requirements. Therefore, corrective measures and environmental control strategies are needed to improve air temperature and pressure conditions and ensure compliance with hospital environmental health standards in the hemodialysis isolation room

Table 4. Analysis Results Statistics Descriptive Physical Parameters Environment in the Hemodialysis Unit

Parameter	Room	Minimum	Maximum	Average	SBMKL	Interpretation
Temperature (°C)	Maintenance	25.4	28.1	26.30	22–23	Does not meet the
	Isolation	24.8	29.0	25.90	22–23	Does not meet the
Humidity (%RH)	Maintenance	57.4	65.0	61.10	40–60	Some meet
	Isolation	56.0	65.6	59.33	40–60	Some meet
Lighting (Lux)	Maintenance	235	343	262.82	>100	Fulfil
	Isolation	209	231	218.27	>100	Fulfil
Noise (dB)	Maintenance	55.0	68.0	63.38	<65	Some meet
	Isolation	50.0	63.2	58.00	<65	Fulfil
Air Changes per Hour (ACH)	Maintenance	20.10	24.48	21.55	≥6	Fulfil
	Isolation	14.40	22.18	19.49	≥6	Fulfil
Air Pressure (Pa)	Maintenance	1.5	1.7	1.58	+2.5	Does not meet the
	Isolation	1.3	1.3	1.30	+2.5	Does not meet the

Based on Table 4, the overall physical environmental conditions in the hemodialysis treatment and isolation rooms showed a relatively similar pattern. The mean air temperature was 26.3°C in the treatment room and 25.9°C in the isolation room, both of which exceeded the Environmental Health Quality Standard (SBMKL) range of 22–23°C. The mean relative humidity was higher in the treatment room (61.1% RH) than in the isolation room (59.3% RH). Although the mean value in the isolation room was within the standard, measurements exceeding the maximum limit of 60% RH were still observed in both rooms.

The lighting conditions were adequate in both rooms. The mean lighting intensity was 262.8 lux in the treatment room and 218.3 lux in the isolation room. All measurements exceeded the minimum lighting standard of 100 lux; therefore, both rooms met the SBMKL requirements for lighting intensity.

The mean noise level in the treatment room was 63.4 dB, which was higher than that in the isolation room (58.0 dB). Although the mean noise levels in both rooms were below the maximum limit of 65 dB, several measurements in the treatment room exceeded the applicable standard. Therefore, the treatment room only partially met the SBMKL requirements for noise, whereas all noise measurements in the isolation room remained within the prescribed limits.

The ventilation conditions, as indicated by the Air Changes per Hour (ACH), showed favorable results in both rooms. The mean ACH was 21.6 air changes per hour in the treatment room and 19.5 air changes per hour in the isolation room. Both values were substantially higher than the minimum requirement of ≥6 ACH, indicating that the ventilation systems in both hemodialysis rooms met the applicable hospital environmental health standards.

Meanwhile, the mean air pressure was 1.6 Pa in the treatment room and 1.3 Pa in the isolation room. Both values were below the required positive air-pressure standard of +2.5 Pa; therefore, neither room met the SBMKL requirement for air pressure.

Descriptive analysis showed that lighting intensity and ACH consistently met the hospital environmental health standards in both rooms, whereas air temperature and air pressure did not meet the applicable requirements. Relative humidity and noise levels generally showed better compliance in the isolation room than in the treatment room, although some measurements in both rooms remained outside the prescribed quality limits.

Table 5. Level of Compliance of Physical Air Parameters with Environmental Health Quality Standards in Hemodialysis Treatment Rooms and Isolation Rooms

Parameter	SBMKL	Treatment Room		Isolation Room	
		Fulfil n (%)	Does not meet the n (%)	Fulfil n (%)	Does not meet the n (%)
Temperature	22–23°C	0 (0.0)	6 (100)	0 (0.0)	6 (100)
Humidity	40–60%RH	2 (33.3)	4 (66.7)	4 (66.7)	2 (33.3)
Lighting	>100 lux	6 (100)	0 (0.0)	6 (100)	0 (0.0)
Noise	<65 dB	3 (50.0)	3 (50.0)	6 (100)	0 (0.0)
ACH	≥6 ACH	6 (100)	0 (0.0)	6 (100)	0 (0.0)
Air Pressure	+2.5 Pa	0 (0.0)	6 (100)	0 (0.0)	6 (100)

Based on Table 5, the compliance of physical environmental parameters with the Environmental Health Quality Standards (SBMKL) varied between the hemodialysis treatment and isolation rooms. Lighting intensity and Air Changes per Hour (ACH) demonstrated the highest level of compliance, with all measurements (100%) in both rooms meeting the applicable standards. These findings indicate that the lighting and mechanical ventilation systems in the hemodialysis unit were functioning in accordance with the established requirements.

In contrast, air temperature and air pressure demonstrated the lowest levels of compliance. All air temperature measurements (100%) in both the treatment and isolation rooms were outside the prescribed standard range. Similarly, all air pressure measurements (100%) failed to meet the required positive pressure standard of +2.5 Pa. These findings indicate that greater attention is required to improve temperature regulation and air-pressure control in order to achieve hospital environmental health standards.

For relative humidity, the isolation room demonstrated a higher level of compliance than the treatment room. A total of 66.7% of the relative humidity measurements in the isolation room met the SBMKL requirements, compared with only 33.3% in the treatment room. These findings suggest that humidity conditions were relatively better controlled in the isolation room, although some measurements still exceeded the maximum permissible limit.

Noise levels also differed between the two rooms. All noise measurements in the isolation room (100%) met the applicable standard, whereas only 50.0% of the measurements in the treatment room met the SBMKL requirements. This finding indicates that the acoustic environment was better controlled in the isolation room than in the treatment room, potentially due to differences in healthcare activities, patient numbers, and the use of medical equipment during hemodialysis procedures.

The evaluation showed that lighting intensity and ACH consistently met the SBMKL requirements at all measurement points in both rooms, whereas air temperature and air pressure did not meet the applicable standards at any measurement point. In addition, the isolation room demonstrated higher compliance with respect to relative humidity and noise than the treatment room. Therefore, the physical environmental conditions in the isolation room were generally more compliant with hospital environmental health standards than those in the treatment room.

The evaluation of physical environmental parameters in the hemodialysis unit demonstrated that the overall environmental quality did not fully comply with the Environmental Health Quality Standards (SBMKL). Lighting intensity and ACH were the only parameters that consistently met the applicable standards at all measurement points, indicating that the lighting and mechanical ventilation systems were functioning effectively. In contrast, air temperature and air pressure remained outside the prescribed standards at all measurement points, while relative humidity and noise levels showed variable compliance between the treatment and isolation rooms. Compared with the treatment room, the isolation room demonstrated better compliance with both relative humidity and noise requirements. These findings indicate that physical environmental management in the hemodialysis unit requires further optimization, particularly with respect to temperature, humidity, noise, and air-pressure control, to achieve full compliance with the applicable standards and support a safe, comfortable, and high-quality healthcare environment.

DISCUSSION

Air Temperature Parameters

The results showed that air temperature in the hemodialysis treatment room ranged from 25.4 to 28.1°C, with a mean of 26.3°C, whereas the isolation room ranged from 24.8 to 29.0°C, with a mean of 25.9°C. According to Regulation of the Minister of Health of the Republic of Indonesia Number 2 of 2023, the recommended air temperature for hemodialysis treatment rooms is 22–23°C. Therefore, all measurements in both rooms did not meet the Environmental Health Quality Standards (SBMKL). Although the deviation from the prescribed temperature range was relatively small, these findings indicate that room temperature control was not optimal and may affect thermal comfort during hemodialysis services (Ministry of Health, 2023).

These findings are consistent with a study on indoor environmental quality (IEQ) in several hospitals in Indonesia, which reported treatment-room temperatures ranging from 23.4 to 27.6°C, with many measurements exceeding the applicable national standards. The study identified temperature as one of the environmental factors requiring particular attention because it influences the perception of comfort among patients, healthcare workers, and visitors. In addition to temperature, noise and lighting were identified as important factors in improving hospital environmental quality (Aryani et al., 2025; Rabbani & Suharyani, 2026; Arlyani et al., 2026).

From a scientific perspective, air temperature is a major component of indoor environmental quality that affects thermal comfort, physiological conditions, and the effectiveness of healthcare services. Excessively high temperatures can increase the body's heat load, accelerate fluid loss through evaporation, and cause sensations of heat and discomfort among patients and healthcare workers. For patients undergoing hemodialysis for approximately 4–5 hours, suboptimal thermal conditions may increase fatigue and reduce comfort during treatment. Furthermore, room temperature interacts with relative humidity and ventilation systems, thereby influencing indoor air quality. Appropriate

temperature control can contribute to maintaining a stable indoor environment, limiting the growth of certain microorganisms, and supporting the effective operation of mechanical ventilation systems.
Thermal environmental conditions may be particularly important for patients undergoing hemodialysis because many of these patients have chronic kidney disease and may have greater physiological vulnerability. Previous research has indicated that variations in environmental temperature may be associated with changes in hemodynamic responses during hemodialysis. An inappropriate thermal environment may influence the body's response to ultrafiltration and contribute to discomfort and certain complications during treatment. Therefore, controlling room temperature is not only necessary to comply with regulatory requirements but also constitutes an important component of efforts to improve patient safety and comfort during hemodialysis therapy (Hartwig et al., 2021).
The findings of this study indicate the need for further evaluation of the Heating, Ventilation, and Air Conditioning (HVAC) system in the hemodialysis unit. Several factors may contribute to room temperatures exceeding the prescribed standards, including inadequate cooling capacity relative to room size, the number of patients and accompanying persons, heat generated by hemodialysis equipment, and frequent entry and exit of healthcare workers, which may increase air exchange with the outdoor environment. In addition, Indonesia's tropical climate may increase the cooling load and require more adaptive HVAC operation. Periodic evaluation of HVAC performance, regular maintenance of cooling equipment, and routine temperature monitoring are therefore important measures to ensure that indoor environmental conditions remain consistent with hospital environmental health standards (Ministry of Health, 2023).

Relative Humidity Parameters
The results showed that relative humidity in the hemodialysis treatment room ranged from 57.4% to 65.0% RH, with a mean of 61.1% RH, whereas the isolation room ranged from 56.0% to 65.6% RH, with a mean of 59.3% RH. According to Regulation of the Minister of Health of the Republic of Indonesia Number 2 of 2023, the required relative humidity for hemodialysis service rooms is 40–60% RH. The results indicated that most measurements in the treatment room exceeded the maximum permissible limit, whereas most measurements in the isolation room remained within the prescribed range. These findings indicate that compliance with the relative humidity standard was higher in the isolation room than in the treatment room, although measurements exceeding the prescribed limit were still observed in both rooms (Ministry of Health, 2023).
These findings are consistent with previous studies on indoor environmental quality (IEQ) in hospitals, which have reported that relative humidity frequently exceeds the recommended range, particularly in healthcare facilities located in tropical climates. Indoor relative humidity is influenced by several factors, including outdoor humidity, the effectiveness of mechanical ventilation systems, air-conditioning capacity, and occupant activities that generate heat and water vapor. Previous research has also identified humidity control as a challenge in maintaining hospital indoor air quality because it is influenced by interactions among outdoor environmental conditions, building characteristics, and HVAC systems. Therefore, periodic monitoring of relative humidity is an important component of hospital environmental health management (Pan et al., 2021; Wolkoff et al., 2021).
From a scientific perspective, relative humidity is an important environmental parameter that contributes to thermal comfort and indoor air quality. Excessively high humidity may promote the growth of fungi, bacteria, and other microorganisms on building surfaces and within ventilation systems. High humidity may also contribute to condensation on walls, ceilings, and ventilation ducts, potentially compromising indoor environmental quality. Conversely, excessively low humidity can cause dryness of the respiratory mucosa, eyes, and skin, thereby reducing occupant comfort. Therefore, maintaining relative humidity within an appropriate range is important for achieving a balance between thermal comfort, indoor air quality, and microbial control (Wolkoff et al., 2021).
In hemodialysis units, humidity control is particularly important because patients with chronic kidney disease undergo prolonged treatment sessions and may have increased vulnerability to infection. An environment with excessive humidity may facilitate microbial growth if it is not adequately controlled through effective ventilation, environmental cleaning, and facility maintenance. High humidity may also contribute to thermal discomfort among patients and healthcare workers during treatment. Therefore, maintaining appropriate relative humidity is an important component of efforts to establish a safe,

comfortable, and supportive environment for healthcare delivery in hemodialysis units (Wolkoff et al., 2021).

The difference in compliance with relative humidity requirements between the treatment and isolation rooms may be associated with several factors, including differences in room size, the number of patients and healthcare workers, cooling capacity, and the effectiveness of mechanical ventilation in controlling indoor moisture. Although both rooms were equipped with mechanical air-conditioning systems, the isolation room demonstrated better compliance with relative humidity requirements. This finding suggests that humidity control in the isolation room was relatively more effective, with most measurements remaining within the range specified by the applicable standard (Ministry of Health, 2023). In contrast, the treatment room had greater service activity and a larger number of patients, potentially resulting in greater heat and moisture generation and consequently affecting indoor humidity. Therefore, the hospital should periodically evaluate HVAC performance, particularly in treatment areas, through routine cooling-system maintenance, optimization of dehumidification functions, and regular humidity monitoring to ensure that environmental conditions remain within the prescribed standards.

Lighting Parameters

The results showed that lighting intensity in the hemodialysis treatment room ranged from 235 to 343 lux, with a mean of 262.8 lux, whereas the isolation room ranged from 209 to 231 lux, with a mean of 218.3 lux. According to Regulation of the Minister of Health of the Republic of Indonesia Number 2 of 2023, the minimum lighting intensity requirement for hemodialysis service rooms is 100 lux. All measurements in both rooms exceeded the minimum standard, resulting in a compliance rate of 100%. These findings indicate that the lighting systems in the hemodialysis unit met the applicable hospital environmental health requirements and provided adequate illumination to support healthcare activities (Ministry of Health, 2023).

These findings are consistent with previous studies on hospital environmental quality, which have identified lighting as an important factor in creating a safe, comfortable, and productive healthcare environment. Appropriate lighting intensity can improve the accuracy of healthcare workers when performing medical procedures, facilitate observation of patients' conditions, and reduce the risk of errors associated with inadequate visibility. Adequate lighting also contributes to patients' visual comfort during treatment and helps create a more conducive healthcare environment. Therefore, lighting is an important component in the assessment of physical environmental quality in hospitals (Davis et al., 2020; MacCunn et al., 2020).

From a scientific perspective, lighting standards are not intended solely to meet visual requirements but may also influence the health and well-being of room occupants. Insufficient lighting can cause visual fatigue, reduce concentration, and potentially increase the risk of errors during medical procedures. Conversely, excessive lighting may cause glare, visual discomfort, and eye fatigue, particularly when light is unevenly distributed. Therefore, lighting-system management should consider not only lighting intensity but also light distribution, direction, color rendering index (CRI), and color temperature to optimally support healthcare activities.

In hemodialysis units, adequate lighting is particularly important because treatment involves various clinical procedures requiring a high degree of accuracy, including vascular access placement, monitoring of patient conditions, adjustment of hemodialysis machines, and observation of clinical changes during therapy. In addition to supporting healthcare-worker performance, adequate lighting contributes to patient comfort during treatment sessions, which may last approximately 4–5 hours. A well-lit environment may reduce visual discomfort and contribute to patients' perceptions of healthcare service quality (Rodríguez et al., 2025).

The results showed that mean lighting intensity was higher in the treatment room (262.8 lux) than in the isolation room (218.3 lux), although both rooms met the applicable standards. This difference indicates some variation in lighting intensity between the rooms; however, all measurements remained adequate to support healthcare activities. Unlike the air temperature and air pressure parameters, which did not meet the applicable Environmental Health Quality Standards (SBMKL), lighting demonstrated 100% compliance in both rooms. These findings indicate that the lighting systems in the hemodialysis unit were generally well managed and capable of meeting the applicable environmental health requirements. Nevertheless, periodic maintenance remains necessary, including cleaning lighting fixtures and routinely measuring lighting intensity, to ensure that lighting quality remains compliant as equipment ages and room conditions change (Ministry of Health, 2023).

Noise Parameters

The results showed that noise levels in the hemodialysis treatment room ranged from 55.0 to 68.0 dB, with a mean of 63.4 dB, whereas the isolation room ranged from 50.0 to 63.2 dB, with a mean of 58.0 dB. According to Regulation of the Minister of Health of the Republic of Indonesia Number 2 of 2023, the maximum permissible noise level for hemodialysis service rooms is 65 dB. All measurements in the isolation room met the Environmental Health Quality Standards (SBMKL), resulting in a compliance rate of 100%. In contrast, only 50% of the measurements in the treatment room met the standard, as several measurement points exceeded the permissible threshold. These findings indicate that compliance with the noise standard was higher in the isolation room than in the treatment room (Ministry of Health, 2023).

These findings are consistent with previous studies on hospital environmental quality, which have identified noise as one of the environmental parameters that frequently exceeds recommended standards, particularly in areas with high levels of healthcare activity. Sources of hospital noise may include conversations among healthcare workers and visitors, medical equipment alarms, treatment machines, mechanical ventilation systems, and patient movement. Previous research has also indicated that noise levels in treatment rooms may exceed recommended limits because of high service activity and the simultaneous use of multiple medical devices. Therefore, noise control remains an important challenge in hospital physical-environmental management (Andrade et al., 2021).

From a scientific perspective, noise is an environmental factor that can affect the comfort, health, and safety of room occupants. Exposure to noise exceeding recommended limits may interfere with communication, reduce healthcare-worker concentration, increase stress, and impair patient rest. In hospital environments, excessive noise may also affect sleep quality and induce physiological responses, such as increased blood pressure and heart rate, potentially affecting patient recovery. Therefore, noise control is important not only for compliance with environmental health standards but also for establishing a comfortable and safe healing environment for patients (Raghuwanshi et al., 2024).

In the hemodialysis unit, noise control is particularly important because patients may undergo treatment sessions lasting approximately 4–5 hours. During this period, a relatively quiet environment is desirable to improve physical and psychological comfort. Healthcare workers also require a controlled acoustic environment to monitor patients, operate hemodialysis equipment, and communicate effectively. Excessive noise may interfere with staff concentration and increase the risk of communication errors during healthcare delivery (Raghuwanshi et al., 2024).

The results showed that the isolation room achieved 100% compliance with the SBMKL noise standard, whereas the treatment room achieved only 50% compliance. This difference suggests that the acoustic environment in the isolation room was relatively better controlled than that in the treatment room. This may be associated with differences in room characteristics, including a smaller number of patients, lower activity levels, and more limited movement in and out of the room. In contrast, the treatment room generally has higher service activity and a greater variety of noise sources. Although the mean noise level in the treatment room remained below the maximum permissible limit, several measurements exceeded the standard, indicating the occurrence of intermittent or peak noise events.

Therefore, additional measures are needed to minimize excessive noise events. These measures may include routine maintenance of medical equipment, appropriate adjustment of alarm settings according to clinical requirements, installation of sound-absorbing materials where appropriate, and implementation of quiet-hospital policies. Effective acoustic management may improve patient and healthcare-worker comfort, support effective clinical communication, reduce the risk of information-transfer errors, and improve patient safety during hemodialysis services (Andrade et al., 2021).

Air Changes per Hour (ACH) Parameters

The results showed that Air Changes per Hour (ACH) in the hemodialysis treatment room ranged from 20.10 to 24.48 air changes per hour, with a mean of 21.6 ACH, whereas the isolation room ranged from 14.40 to 22.18 ACH, with a mean of 19.5 ACH. According to Regulation of the Minister of Health of the Republic of Indonesia Number 2 of 2023, the minimum air-exchange requirement for hemodialysis service rooms is ≥6 air changes per hour. All measurements in both rooms met and substantially exceeded this minimum requirement, resulting in a compliance rate of 100%. These findings indicate that the mechanical ventilation systems in the hemodialysis unit provided adequate air exchange in relation to the applicable environmental health requirements (Ministry of Health, 2023).

These findings are consistent with previous studies of indoor air quality in hospitals, which have identified adequate air-exchange rates as an important factor in maintaining healthcare-environmental quality. Ventilation systems capable of achieving adequate ACH can contribute to the dilution and removal of carbon dioxide, airborne particles, dust, and microorganisms, thereby potentially reducing the concentration of airborne contaminants. Adequate ventilation also contributes to occupant comfort and supports infection prevention and control (IPC) measures in healthcare facilities (Rodríguez et al., 2025).

Scientifically, Air Changes per Hour (ACH) represents the number of times the volume of air within a room is theoretically replaced within one hour. Higher ACH generally increases the rate at which indoor air is diluted and replaced, although the actual effectiveness of ventilation also depends on airflow distribution, filtration, outdoor-air fraction, and room configuration. Adequate air exchange can reduce the concentration of airborne contaminants through dilution ventilation, limit the accumulation of bioaerosols, and contribute to maintaining indoor air quality appropriate to the function of the room. Therefore, ACH is an important indicator for evaluating HVAC performance in healthcare facilities, particularly in areas where airborne contaminant control is important (Rodríguez et al., 2025).

In hemodialysis units, effective ventilation is important because patients undergo treatment for prolonged periods, and many patients with chronic kidney disease may have increased vulnerability to infection. Adequate ventilation not only contributes to thermal comfort but may also help reduce the concentration of airborne contaminants and support indoor air quality. Thus, compliance with ACH requirements constitutes one component of infection prevention and control, healthcare quality, and patient and healthcare-worker safety during hemodialysis services (Rodríguez et al., 2025).

The mean ACH was slightly higher in the treatment room (21.6 ACH) than in the isolation room (19.5 ACH), although both rooms substantially exceeded the minimum requirement. This difference indicates some variation in air-exchange rates between the rooms; however, all measurements remained well above the SBMKL minimum standard. Unlike the air temperature and air pressure parameters, which did not meet the applicable requirements, ACH demonstrated 100% compliance in both rooms. These findings indicate that the mechanical ventilation systems were capable of providing adequate air exchange within the hemodialysis unit (Ministry of Health, 2023).

However, adequate ACH alone is not sufficient to ensure optimal physical environmental quality. This is demonstrated by the continued non-compliance of the air-temperature and air-pressure parameters despite all ACH measurements exceeding the required minimum. These findings indicate that a ventilation system may provide a high air-exchange rate while still requiring improvement in temperature control, humidity management, differential pressure, and airflow distribution. Therefore, HVAC evaluation should not focus solely on ACH but should consider the integration of all physical environmental parameters to achieve safe and comfortable indoor conditions for patients and healthcare workers (Aryani et al., 2025).

Accordingly, the hospital should conduct periodic HVAC maintenance, ventilation-performance testing, equipment calibration, and comprehensive evaluation of physical environmental parameters. Such an integrated approach can help ensure that the HVAC system not only meets air-exchange requirements but also effectively controls temperature, humidity, air pressure, and airflow distribution. These measures are important for supporting healthcare service quality, patient safety, and infection prevention and control in the hemodialysis unit (Ministry of Health, 2023).

Air Pressure Parameters

The results showed that air pressure in the hemodialysis treatment room ranged from 1.3 to 1.7 Pa, with a mean of 1.5 Pa, whereas the isolation room ranged from 1.4 to 1.6 Pa, also with a mean of 1.5 Pa. According to the standard applied in this study, the required differential air pressure for the hemodialysis room is ≥+2.5 Pa. All measured values in both rooms were below the prescribed requirement, resulting in a compliance rate of 0%. These findings indicate that the HVAC system had not achieved the required differential pressure conditions (Ministry of Health, 2023).

These findings are consistent with previous studies of hospital ventilation systems, which have identified differential air pressure as one of the parameters that can be difficult to maintain consistently because it is affected by several factors, including HVAC capacity, the balance between supply and exhaust air, door-opening frequency, and air leakage within the building envelope. An imbalance between incoming and outgoing airflow may result in inadequate differential pressure even when the ventilation system provides a relatively high air-exchange rate. Therefore, evaluation of differential air pressure is an important component of comprehensive HVAC performance assessment (Yang et al., 2023).

From a scientific perspective, differential air pressure is an operational parameter used to influence the direction of airflow between adjacent spaces and thereby help control the movement of airborne contaminants. Pressure differentials are generated by balancing supplied and exhausted air. Positive pressure is generally used for rooms that require protection from contaminants entering from surrounding areas, whereas negative pressure is typically used for isolation rooms intended to prevent airborne infectious contaminants from escaping into adjacent areas. The appropriate pressure relationship therefore depends on the intended function and infection-control requirements of the room.

In the hemodialysis unit, maintaining appropriate differential pressure is important as part of overall environmental control. Inadequate pressure differentials may alter airflow patterns and potentially increase the movement of particles and other airborne contaminants between adjacent areas. Although differential pressure is not the sole determinant of indoor air quality, it is an important component of ventilation control and may contribute to a safer environment for patients and healthcare workers during hemodialysis services (Chaira et al., 2023).

The results showed that the mean air pressure in both the treatment and isolation rooms was approximately 1.5 Pa, indicating that neither room met the minimum pressure requirement. In contrast to lighting and ACH, which demonstrated 100% compliance, air pressure demonstrated 0% compliance in both rooms. These findings indicate that the ventilation system was capable of providing adequate air exchange but had not achieved the required differential pressure. Therefore, HVAC performance cannot be evaluated solely on the basis of ACH; its ability to maintain appropriate pressure relationships must also be assessed. These findings further support the need for comprehensive HVAC evaluation incorporating multiple physical environmental parameters simultaneously (Chaira et al., 2023; Rodríguez et al., 2025).

In addition to HVAC capacity, low differential pressure may be associated with operational and building-related factors, including frequent door opening, leakage through door or window gaps, imbalance between supply and exhaust airflow, and inadequate HVAC maintenance. Therefore, the hospital should consider conducting Testing, Adjusting, and Balancing (TAB) of the ventilation system, inspecting the room envelope for air leakage, calibrating differential-pressure sensors, and routinely monitoring pressure differentials. These measures can support compliance with applicable environmental health requirements and strengthen infection prevention and control, patient safety, and healthcare service quality in the hemodialysis unit (Yang et al., 2023).

CONCLUSION

The results of this study confirmed that the physical environmental quality of the hemodialysis unit did not fully meet the Environmental Health Quality Standards (SBMKL) based on Regulation of the Minister of Health of the Republic of Indonesia Number 2 of 2023. Lighting intensity and Air Changes per Hour (ACH) met the applicable standards at all measurement points, whereas air temperature and air pressure did not meet the prescribed requirements. Meanwhile, relative humidity and noise levels showed varying degrees of compliance, with the isolation room demonstrating better overall conditions than the treatment room. These findings indicate that the physical environmental quality of the hemodialysis unit requires further optimization, particularly with regard to air temperature, relative humidity, noise, and air pressure.

This study further demonstrates that the evaluation of physical environmental quality in a hemodialysis unit should not be based solely on compliance with individual parameters but should consider the interaction among environmental parameters as indicators of overall Heating, Ventilation, and Air Conditioning (HVAC) system performance. Although ACH values met and substantially exceeded the minimum standard, this condition was not accompanied by compliance with all physical environmental parameters. Therefore, the hospital should conduct comprehensive.

CONFLICTS OF INTEREST

No conflicts of interest were disclosed by the writers of this work

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