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Isolation Room Design: Indoor Environmental Quality, Theoretical Perspectives, and Future Considerations

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ABSTRACT
Isolation rooms are critical healthcare facilities designed to contain infectious respiratory diseases through negative-pressure systems and environmental controls. In Indonesia, their design is guided by the *Pedoman Teknis Ruang Isolasi* (2014), which outlines standards for ventilation, lighting, acoustics, thermal comfort, and air quality. However, these regulations primarily emphasise infection control, with limited consideration of patients' psychological and social well-being. This study aims to review Indonesian isolation room standards and evaluate them through the lens of *Indoor Environmental Quality (IEQ)* and environmental psychology theories, including the healing environment framework, Canter's place theory, and person–environment fit. A Post-Occupancy Evaluation (POE) approach is proposed as the methodological bridge between regulatory compliance and patient experience. The findings indicate that while current standards ensure functional safety, they lack integration with patient-centred design elements that contribute to comfort, resilience, and recovery. The paper highlights the potential of incorporating smart technologies and adaptive systems to enhance flexibility and psychosocial support. These insights have significant implications for interdisciplinary collaboration in revising future standards, ensuring that isolation rooms not only safeguard against infection but also foster environments conducive to healing and well-being.

Keywords: Isolation rooms; Indoor Environmental Quality (IEQ); Healing environment; Place theory; Person–Environment Fit; Post-Occupancy Evaluation (POE)

INTRODUCTION

Isolation rooms are specialised healthcare facilities designed to accommodate patients with infectious respiratory diseases (Al Khatib, Samara, & Ndiaye, 2024). They function using negative-pressure systems to ensure that contaminated air is contained within the space, thereby preventing the spread of pathogens to other hospital areas (Al-Benna, 2021; Qian & Zheng, 2018). In Indonesia, the design and operation of isolation rooms are governed by the Pedoman Teknis Ruang Isolasi Tahun 2014 (Technical Guidelines for Isolation Rooms Year 2014), issued by the Ministry of Health. These guidelines provide technical standards for both new construction and renovation, covering aspects such as ventilation, lighting, acoustics, and thermal conditions. Given the multiple modes of transmission, namely close contact, droplets, and airborne particles, effective isolation is critical in mitigating the spread of diseases such as tuberculosis, avian influenza, swine influenza, MERS, and COVID-19 (Setiati & Azwar, 2020).

Indoor Environmental Quality (IEQ) has been consistently linked to both physical health and psychological well-being in healthcare environments (Brambilla, Del Pio, Morosini, & Capolongo, 2020). Factors such as lighting, acoustics, thermal comfort, and air quality not only determine the technical performance of hospital spaces but also shape patient perceptions, moods, and recovery trajectories (Ackley et al., 2024). For instance, access to natural light has been shown to improve circadian rhythm regulation and reduce stress, while adequate acoustic control minimises sleep disturbances and enhances patient comfort (Amoatey et al., 2022; Huisman et al., 2012).

Similarly, maintaining stable thermal conditions and ensuring clean indoor air contribute directly to physical recovery and the reduction of hospital-acquired complications (Frontczak & Wargocki, 2011; Uścinowicz et al., 2023). In isolation rooms, where patients often spend prolonged periods in confined conditions, the quality of the indoor environment becomes even more critical, as suboptimal conditions can exacerbate anxiety, discomfort, and feelings of confinement (C. C. Andrade & Devlin, 2015). Thus, linking IEQ to well-being provides an essential foundation for understanding how technical standards in hospital design can be expanded to include patient-centred outcomes.

Despite their importance, current standards emphasise infection control and technical compliance, while the psychological and social dimensions of patient experience in isolation rooms remain underexplored (Lei, Lau, Yuan, & Qi, 2022). This creates a significant gap in understanding how such environments impact patient well-being, particularly since isolation rooms are inherently restrictive and may contribute to stress, anxiety, or feelings of confinement. Addressing this issue requires a broader perspective that integrates human-centred design and environmental psychology theories (Muhamad, Zaki, Hagishima, Ali, & Razak, 2023). Accordingly, the aim of this paper is to review Indonesian standards for isolation rooms with a focus on Indoor Environmental Quality (IEQ) (Norouzianpour, Eshraghi Samani, & Mousazadeh, 2022). The objective is to critically examine these standards through the lens of healing environment theory, place theory, person–environment fit, and Post-Occupancy Evaluation (POE), in order to develop insights that support more holistic, patient-centred design approaches.

The 2014 regulation was introduced to standardise the requirements for constructing new isolation rooms or renovating existing ones (Pedoman Teknis Ruang Isolasi, 2015). Regarding lighting, the guideline states that isolation rooms should have both natural and artificial sources, along with emergency lighting. Natural daylight should be maximised based on the building's orientation and design. Artificial lighting must follow recognised standards, with attention to energy efficiency, glare reduction, and the minimisation of unnecessary reflections. Emergency lighting must be able to automatically activate and provide sufficient illumination for basic medical procedures.

Artificial lighting systems should include accessible controls, either manual or automated, positioned near the user (Tekin, Corcoran, & Gutiérrez, 2022). General overhead lighting is recommended, installed in recessed ceiling fixtures to reduce dust accumulation. Efficient fluorescent or LED lamps are preferred, with luminaires designed to optimise light output. The required illuminance level is 250 lux, with a colour rendering index in category 1 or 2, and the colour temperature should fall within the cool white range (3,300 K–5,300 K). In terms of acoustic comfort, the guideline sets the maximum allowable noise level inside isolation rooms at 45 dBA.

Thermal parameters specify an indoor temperature between 22–25 °C, relative humidity of 60%, and an air exchange rate of 12 ACH. These conditions are managed by the mechanical air-conditioning system, which also filters airborne contaminants and maintains negative pressure.

Finally, regarding indoor air quality, the Indonesian Hospital Environmental Health Regulation No. 7 of 2019 specifies that sulphur dioxide (SO_2) levels must not exceed 125 µg/m³, nitrogen dioxide (NO_2) must remain under 200 µg/m³, and volatile organic compounds (VOCs) should be limited to 3 ppm. Additionally, the use of materials that do not emit odours is recommended to help maintain a healthy indoor environment (Zhao, Zhan, & Xu, 2022).

The concept of the healing environment emphasises that hospital spaces should not only serve functional and safety needs but also actively contribute to patient well-being and recovery (Huisman et al., 2012). Research highlights those factors such as access to natural light, acoustic comfort, thermal regulation, and air quality can significantly influence both physical and psychological health outcomes. For isolation rooms, which are inherently restrictive spaces, designing with a healing environment mindset could help reduce stress, feelings of confinement, and anxiety among patients (C. C. Andrade & Devlin, 2015). Moreover, patients cared in isolation rooms that embody healing environment principles are more likely to experience higher satisfaction, stronger perceptions of control, and enhanced overall well-being, all of which can positively influence treatment adherence and recovery trajectories.

In parallel, Canter's Place Theory explains that the meaning of a place arises from the interaction between its physical attributes, the activities it accommodates, and the social context, suggesting that isolation rooms should be designed not only as medical facilities but also as environments that foster patients' needs and a sense of comfort for patients (C. Andrade et al., 2012). Complementing this perspective, the Person–Environment Fit Theory proposes that well-being is enhanced when there is congruence between individual needs and environmental resources, underscoring the importance of aligning isolation room design with patients' physical comfort, emotional resilience, and perceptions of safety (van Vianen, 2018). Together, these frameworks provide a holistic theoretical foundation for evaluating and improving isolation room environments in ways that balance safety, functionality, and patient-centred care.

Post-Occupancy Evaluation (POE) provides a practical tool for operationalising these theoretical perspectives by systematically assessing how isolation rooms perform once they are in use (Preiser et al., 2015). While the healing environment framework highlights the importance of supportive environmental features, and place theory and PE Fit theory emphasise the interaction between people and their surroundings, POE allows these concepts to be tested against real experiences of patients and staff. For example, POE can identify whether lighting, acoustics, thermal comfort, and air quality meet both regulatory standards and the psychological needs of occupants, thereby revealing possible gaps between design intentions and lived realities. Insights gained from POE can not only validate theoretical frameworks but also inform evidence-based design strategies, ensuring that future isolation rooms foster safety, healing, and a stronger alignment between environmental conditions and human well-being (Bayer, 2020).

Previous research by Ulrich et al. synthesised evidence on how physical settings affect clinical outcomes and proposed the "healing environment" as a design paradigm in healthcare. While influential, most of the underlying studies concern general patient rooms, ICUs, or waiting areas; isolation rooms with negative pressure are rarely analysed as a distinct typology with unique psychosocial stressors (restricted mobility, limited social contact, staff PPE barriers). Consequently, the translation of healing-environment principles (e.g., daylight, views, perceived control) to high-containment spaces remains theoretically asserted but empirically thin. Second, Qian and Zheng (2018) examined ventilation strategies to mitigate airborne transmission and articulated airflow/pressure regimes for infection control. Their work is technically rigorous on containment (ACH, pressure differentials, filtration) but largely silent on patient-centred Indoor Environmental Quality (IEQ) outcomes (lighting, acoustics, thermal comfort) and on post-occupancy feedback from users. Complementary reviews—e.g., Amoatey et al. (2022) on hospital acoustics and Frontczak & Wargocki (2011) on thermal comfort—likewise address single IEQ dimensions and seldom integrate environmental-psychology theories or Indonesia's regulatory context.

This study aims to critically review Indonesia's isolation-room standards through the IEQ lens and environmental-psychology theories, and to outline a POE framework that couples regulatory performance (pressure, ventilation, filtration) with patient and staff experience (comfort, stress, perceived control). The expected benefits are practical: a set of patient-centred IEQ criteria and POE instruments that hospital planners and engineers can adopt during design, commissioning, and retrofit; strategic: inputs for regulators to refine standards so they integrate safety with well-being; and clinical: environments that better support recovery, reduce anxiety and sleep disturbance, and enhance staff performance and satisfaction.

METHOD

This study employed a descriptive qualitative approach supported by the narrative literature review method. Data were collected from official Indonesian regulations, such as the Technical Guidelines for Isolation Rooms (2014) and Minister of Health Regulation No. 7 of 2019, as well as from international journal articles obtained from databases like Scopus, ScienceDirect, Springer, and PubMed. Case studies from hospitals in Indonesia and Malaysia were also included. The inclusion criteria covered publications from 2008 to 2024 that addressed Indoor Environmental Quality (IEQ) in isolation rooms, including lighting, acoustics, thermal comfort, air quality, and psychological impacts. Thematic analysis was applied to identify patterns, which were then mapped using the Healing Environment framework, Place Theory, and Person–Environment Fit. A comparative analysis with WHO/ASHRAE standards was also conducted, while the Post-Occupancy Evaluation (POE) framework was used to connect regulatory compliance with real patient experiences.

RESULTS AND DISCUSSION

The results of the study show that the quality of ventilation and air in the isolation room is still the main issue. Regulations in Indonesia stipulate air exchange of 12 times per hour (ACH), a temperature of 22–25 °C, and a relative humidity of around 60%. However, a case study in one hospital in Jakarta showed that ACH rates only reached 9–10 times per hour, with CO_2 concentrations reaching 1,200 ppm, exceeding the WHO recommendation of <1,000 ppm. This condition not only decreases the effectiveness of infection control, but also increases patient discomfort complaints and medical personnel fatigue.

To clarify the position of Indonesian standards against international recommendations, the following is a comparison table of technical standards for isolation rooms:

Table 1. Comparison of Technical Standards for Indonesian Isolation Rooms vs WHO/ASHRAE

Parameters	Indonesian Standards	WHO/ASHRAE
Air Changes per Hour (ACH)	12	12
Room Temperature (°C)	22–25	21–24
Humidity (%)	60	40–60
CO_2 Max (ppm)	Non-specific	< 1000
Noise (dBA)	≤ 45	≤ 35–40
Lighting (lux)	≥ 250	≥ 300 (daylight preferred)

Source: Technical Guidelines for Isolation Rooms (2014), WHO, ASHRAE

Based on the table, Indonesia's standards in the ACH aspect are in line with WHO, but there are still gaps in other aspects. For example, lighting of at least 250 lux in Indonesia is lower than the international recommendation that emphasizes 300 lux with natural light preference. The same thing can also be seen in the noise aspect, where Indonesian standards are still looser than WHO/ASHRAE.

To clarify the quantitative comparison, here is a bar graph showing the differences in key numerical parameters:

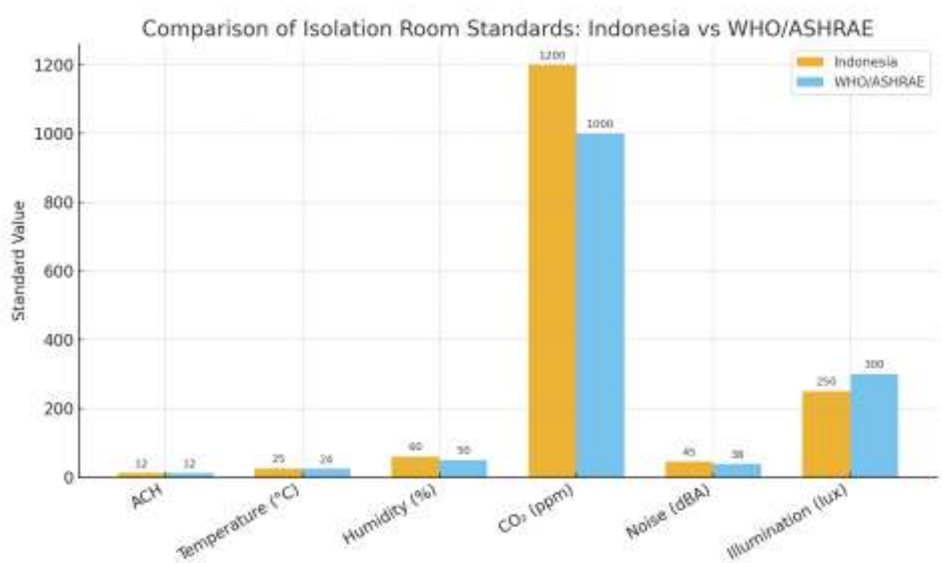

Figure 1. Comparison Chart of Technical Standards for Isolation Rooms Indonesia vs WHO/ASHRAE

The figure shows that although ACH is compliant, Indonesia's lighting standards and noise limits still lag behind international recommendations. The room temperature is also slightly higher (up to 25 °C) than the WHO standard (maximum 24 °C). Relative humidity in Indonesia is pegged at a single figure of 60%, while the WHO gives a more flexible range (40–60%).

This difference in standards has important implications. Insufficient lighting can reduce the therapeutic effect of natural light on the patient's recovery. High noise increases the risk of sleep disturbances and anxiety. Meanwhile, the humidity flexibility offered by international standards provides a better adaptation space to climatic conditions and patient needs. Therefore, the use of these tables and graphs strengthens the argument that Indonesia needs to update its isolation room regulations by taking into account international evidence so that the resulting design not only meets the technical aspects, but also better supports the physical and psychological health of patients.

Therefore, this study reinforces the argument that Indonesian standards require updating by integrating international evidence. By incorporating parameters that account not only for infection prevention but also for psychological and physiological well-being, isolation room design can evolve from purely technical compliance toward patient-centred, healing-oriented environments.

CONCLUSION

This study has examined Indonesian isolation room regulations (Pedoman Teknis Ruang Isolasi, 2014) in light of Indoor Environmental Quality (IEQ) and environmental psychology frameworks, showing that while current standards effectively address infection control through ventilation, lighting, acoustics, and thermal conditions, they consider the psychological and social dimensions of patient care. By applying the healing environment framework, Canter's place theory, person–environment fit, and Post-Occupancy Evaluation (POE), this research contributes a patient-centred perspective that bridges regulatory compliance with lived experience. Future research should expand this approach by empirically testing patient and staff perceptions through POE in operational facilities, assessing how smart technologies such as adaptive lighting, personalised thermal controls, and real-time air monitoring can enhance comfort and well-being, and exploring strategies for resilience and scalability in post-pandemic hospital design. These contributions will support the development of holistic, interdisciplinary design standards that integrate safety, functionality, and human-centred healing in isolation rooms.

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