INDOOR ENVIRONMENTAL QUALITY IN PUBLIC HEALTH FACILITIES IN GHANA: A STUDY ON THE CURRENT STATE AND CHALLENGES

Abstract

Traditional methods of managing IEQ in public health facilities in Ghana tend to be reactive rather than proactive, often relying on manual interventions that may not adequately address the complex interplay of factors affecting the indoor environment. This study aimed to investigate the indoor environmental quality in public health facilities through automation technologies, emphasizing Esikado District Hospital and Shama Health Centre.

This study employed a mixed-methods research design incorporating qualitative and quantitative approaches.Analyses including descriptive statistics and documentation analyses were conducted to assess the existing legal framework.

The study revealed that there were no existing legal frameworks or regulations to govern IEQ standards in Ghana hence hospitals had to rely on international guidelines to maintain IEQ at the facilities assessed. Both hospitals had their CO_2 (400 ppm &270 ppm) and Air particulate (8.2µg/m³ for PM2.5& 4.2µg/m³ for PM2.5) within the acceptable limits according to international guidelines.

The study concludes that regulations and legal frameworks must be formulated in the country to enforce healthcare facilities better to comply with acceptable IEQ limits in their facilities.Implementing IEQ-controlling automation technologies will go a long way in improving overall facility management and indirectly influencing patient recovery.

Keywords: - Automation technologies, Indoor Environmental Quality, legal frameworks

1. INTRODUCTION

Indoor Environmental Quality (IEQ) is a fundamental aspect of healthcare delivery, significantly influencing patients' and healthcare workers' health, comfort, and overall well-being. In Ghana, public health facilities face considerable challenges in maintaining optimal IEQ, primarily due to factors such as overcrowding, outdated infrastructure, and inadequate resources (Asare, 2016). These challenges are compounded by the country's tropical climate, which contributes to fluctuating indoor conditions, including high temperatures, humidity, and poor air quality, all of which can exacerbate health problems and hinder recovery (Boateng, 2019).

Despite the critical importance of IEQ, many public health facilities in Ghana continue to rely on manual and often inadequate methods for monitoring and managing the indoor environment. Traditional approaches, such as using fans or opening windows for ventilation, are reactive and insufficient to address the complex and dynamic nature of indoor environmental conditions, particularly in settings with high patient turnover and limited space (Mensah, 2020). The absence of real-time monitoring and control mechanisms further exacerbates the risks associated with poor IEQ, including the spread of airborne infections, prolonged patient recovery times, and decreased staff productivity (Kaluarachchi et al., 2018).

Automation technologies, including sensors and smart systems, offer a promising solution to these challenges by enabling continuous, real-time monitoring and proactive management of key IEQ parameters, such as air quality, temperature, and humidity (Smith & Jones, 2020). However, the adoption of these technologies in Ghanaian public health facilities remains limited. Key barriers include high initial costs, a lack of technical expertise, and the need for customization to suit the specific environmental and operational contexts of these facilities (Agyeman, 2021). Moreover, there is a significant gap in research concerning the effectiveness and practicality of implementing such technologies in low-resource settings like Ghana.

Given the critical role of IEQ in healthcare outcomes and the potential of automation technologies to address existing challenges, there is an urgent need to assess the current state of IEQ in Ghanaian public health facilities and explore the feasibility and impact of integrating automation technologies for its improvement. This research seeks to address this gap by evaluating the effectiveness of automation technologies in enhancing IEQ in selected public health facilities across Ghana. The study aims to provide evidence-based recommendations for policymakers and healthcare administrators on how to implement these technologies effectively, thereby improving the health and well-being of both patients and healthcare workers in Ghana.

2. PREVIOUS RESEARCH

2.1Global Standards and Guidelines for IEQ in Healthcare

Numerous international standards delineate the design and management protocols for Indoor Environmental Quality (IEQ) within healthcare establishments. Within the United States, the American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE) has formulated specific IEQ guidelines tailored for healthcare contexts, encapsulated in ASHRAE Standard 170. This standard delineates the fundamental criteria on temperature, humidity, ventilation, and filtration within healthcare facilities (ASHRAE, 2013). These guidelines are frequently regarded as exemplary practices and are extensively implemented to ensure the maintenance of safe indoor environments in hospitals.

In Europe, EN 15251, a standard established by the European Committee for Standardization (CEN), delivers guidance on IEQ across a variety of building typologies, encompassing healthcare facilities. It articulates recommendations concerning thermal comfort, air quality, illumination, and acoustic levels to safeguard patient safety and welfare (CEN, 2007). Furthermore, the Health Technical Memoranda (HTMs) disseminated by the National Health Service (NHS) of the United Kingdom provide comprehensive requirements for the oversight of ventilation systems in hospitals, underscoring the imperative of infection control through suitable air quality measures (NHS, 2017 cited in Roadnight & Followell, 2021).

The World Health Organization (WHO) has also instituted a compendium of guidelines expressly designed to regulate IEQ to curtail the transmission of airborne infections in healthcare settings. These directives prioritize the optimization of ventilation, the diminution of pollutant concentrations, and the regulation of microbial contamination to mitigate the propagation of infectious diseases (WHO, 2016 cited in Dimitroulopoulou et al., 2023).

In Ghana, the Ghana Health Service (GHS) alongside local building regulations offers some degree of guidance regarding environmental control within healthcare facilities; however, there remains a paucity of comprehensive IEQ standards integrated into the healthcare infrastructure (GHS, 2018 cited in Ayanore et al., 2022). The assimilation of international standards, such as those promulgated by ASHRAE and the WHO, is imperative for enhancing indoor air quality and optimizing patient outcomes in Ghanaian public health institutions.

The administration of IEQ within healthcare facilities constitutes a pivotal determinant of patient health, recovery trajectories, and the overarching quality of care rendered. By conforming to global standards and guidelines, healthcare providers can alleviate the hazards associated with suboptimal indoor environments, including Healthcare-Associated Infections (HAIs) and respiratory ailments. Nevertheless, in regions such as Ghana, the execution of these standards necessitates investment in infrastructural development and the incorporation of contemporary automation technologies to effectively monitor and regulate IEQ parameters. As healthcare facilities undergo continuous evolution, the emphasis on upholding superior IEQ standards will persist as a critical component in delivering safe and efficacious care.

2.2 Key Parameters of IEQ

The fundamental parameters that delineate Indoor Environmental Quality (IEQ) within healthcare facilities encompass temperature, humidity, ventilation, air quality, lighting, noise, and microbial control. These factors necessitate rigorous management to establish a secure and conducive atmosphere.

Temperature: The regulation of an appropriate thermal environment is imperative for ensuring patient comfort and physiological equilibrium. ASHRAE (2013) advocates for temperature maintenance within the range of 20°C to 24°C in areas designated for patient care. Deviations from this prescribed range may hinder patient recovery by inducing thermal discomfort, potentially escalating metabolic stress (Alfa & Öztürk, 2019).

Humidity: The management of humidity is essential to curtail microbial proliferation and avert respiratory complications. ASHRAE (2013) posits that the relative humidity within healthcare environments should be sustained between 30% and 60%. Elevated humidity levels promote the growth of mould and bacteria, whereas diminished humidity can lead to the desiccation of mucous membranes, thereby increasing patients' susceptibility to infections.

Ventilation: Sufficient ventilation is instrumental in the removal of airborne contaminants, encompassing pathogens, particulate matter, and chemical emissions. In healthcare environments, ventilation systems are required to supply an adequate quantity of outdoor air to dilute indoor pollutants and ensure air cleanliness. ASHRAE Standard 170 (2013) mandates that operating rooms achieve a minimum of 20 air changes per hour, with four of those changes consisting of fresh air, to mitigate infection risks.

Air Quality: The presence of airborne pollutants, such as carbon dioxide (CO_2), particulate matter (PM2.5), and volatile organic compounds (VOCs), poses a significant threat to air quality within hospitals. The WHO (2016) has established exposure limits for PM2.5 at 12 $\mu g/m^3$ over 24 hours. Increased levels of PM are correlated with heightened respiratory and cardiovascular health issues, while VOCs, frequently released from construction materials, cleaning agents, and medical apparatus, can induce irritation, headaches, and chronic health complications (Azimi & Stephens, 2013).

Lighting: Effective lighting is critical for both clinical procedures and the well-being of patients. Sufficient natural lighting has been evidenced to enhance mood, diminish stress, and accelerate recovery rates, while inadequate lighting may elevate the likelihood of medical errors (Osibona et al., 2021). Inpatient accommodations, a minimum illuminance level of 300 lux is advised, whereas surgical theatres necessitate considerably higher illuminance, reaching up to 10,000 lux (Eijkelenboom&Bluyssen, 2022).

2.3 Types of Automation Technologies

Several automation technologies have been conceptualized and implemented to monitor and enhance Indoor Environmental Quality (IEQ) within healthcare environments, encompassing:

Sensors: Sensors serve as the cornerstone for real-time monitoring of IEQ parameters, including temperature, humidity, carbon dioxide concentrations, and particulate matter (PM2.5). Contemporary sensors exhibit high sensitivity, capable of detecting minute fluctuations in environmental conditions, and are frequently integrated within Internet of Things (IoT) ecosystems for perpetual data acquisition (Sunny et al., 2023). These sensors possess the capability to initiate automatic modifications in heating, ventilation, and air conditioning (HVAC) systems to uphold predetermined environmental standards, thereby ensuring both patient comfort and safety.

Internet of Things (IoT): IoT technology facilitates the intercommunication of interconnected devices, thereby offering a holistic perspective of indoor environments. Within healthcare institutions, IoT frameworks interlink multiple sensors, permitting real-time data collection regarding air quality, temperature, and illumination levels (Jia et al., 2019). By harnessing IoT capabilities, hospitals can establish intelligent environments wherein systems dynamically adjust in response to environmental fluctuations, thereby diminishing the necessity for manual intervention and enhancing overall operational efficiency.

Building Management Systems (BMS): BMS constitutes a centralized control mechanism that amalgamates various building subsystems, inclusive of HVAC, lighting, and security. In healthcare institutions, BMS assumes a pivotal role in managing and optimizing energy consumption while ensuring compliance with IEQ standards. Contemporary BMS platforms integrate automation algorithms and sensor feedback to modify settings in real time, thereby enhancing air quality and safeguarding patient safety (Mariano-Hernández et al., 2021). Through BMS, hospitals can automate the regulation of critical systems, guaranteeing consistent conditions that fulfil both regulatory mandates and comfort specifications.

Data Analytics Platforms: Data analytics platforms aggregate and scrutinize extensive volumes of data derived from sensors and IoT devices, enabling facility managers to derive insights into patterns and trends associated with IEQ. By employing sophisticated algorithms, these platforms can forecast potential shifts in environmental conditions and prompt pre-emptive adjustments in HVAC or air filtration systems (Calvillo et al., 2016). Predictive analytics further facilitate energy-efficient operations by optimizing system performance and curtailing unnecessary energy consumption.

2.4 Challenges and barriers to implementing IEQ automation in healthcare facilities

Indoor Environmental Quality (IEQ) automation technologies possess the capacity to markedly enhance healthcare outcomes by fine-tuning environmental parameters within hospitals and various healthcare environments. Nevertheless, the integration of these technologies frequently encounters multiple impediments, including financial, technical, and infrastructural challenges.

In developing nations, these concerns are exacerbated by supplementary hurdles such as inconsistent power supply and inadequate internet connectivity.

2.4.1 Common Barriers to Adopting Automation in Healthcare Facilities

The implementation of Indoor Environmental Quality (IEQ) automation technologies within healthcare environments encounters numerous challenges, even in nations that possess robust and advanced healthcare infrastructures.

Financial considerations represent a considerable impediment for numerous healthcare institutions contemplating the adoption of IEQ automation. The deployment and assimilation of sophisticated automation technologies, including sensors, Internet of Things (IoT) devices, Building Management Systems (BMS), and HVAC automation frameworks, necessitate considerable capital expenditure (Silva et al., 2023). The financial implications of these systems encompass not only the initial acquisition of apparatus but also the continual maintenance, software enhancements, and potential upgrades to pre-existing infrastructure. Numerous hospitals, especially those operating within public health systems, may find it difficult to rationalize these expenditures amidst competing priorities such as patient care and the procurement of medical apparatus.

Another significant barrier is the requisite technical proficiency, as the effective execution of automation systems demands a workforce possessing specialized knowledge in both healthcare and building automation. A considerable number of healthcare facilities are deficient in personnel who are sufficiently trained to oversee and operate these systems, particularly within settings where the emphasis is placed on medical care rather than technological oversight (Dixit et al., 2019). The assimilation of automation systems into healthcare operational protocols can prove challenging in the absence of requisite training and expertise, resulting in operational inefficiencies and suboptimal utilization of the technology.

Limitations in infrastructure further exacerbate challenges, particularly in older healthcare establishments that may not be architecturally suited to support contemporary automation systems. Retrofitting pre-existing structures to incorporate the essential wiring, sensors, and control mechanisms can prove both financially burdensome and disruptive to hospital operations (Demirdöğen et al., 2020). In certain instances, the inherent physical constraints of the building's architecture may render it difficult or unfeasible to implement comprehensive automation without extensive renovations.

Resistance to change constitutes yet another obstacle to the integration of IEQ automation in healthcare environments. Healthcare professionals and administrators may exhibit reluctance towards the adoption of new technologies due to apprehensions regarding reliability, user-friendliness, or the potential for disruptions to established operational workflows. Research has indicated that resistance to change is frequently fuelled by uncertainty and trepidation regarding the unknown, particularly in high-stakes settings such as healthcare (Buchanan et al., 2007). Surmounting this resistance necessitates not only illustrating the advantages of automation but also providing sufficient training and support to ensure that healthcare personnel feel at ease with the utilization of the technology.

2.4.2 Specific Challenges in Developing Countries like Ghana

In nations classified as developing, such as Ghana, the impediments to the integration of Indoor Environmental Quality (IEQ) automation within healthcare facilities are particularly salient due to a convergence of infrastructural, financial, and technological limitations.

A significant challenge pertains to the reliability of electrical power supply. Healthcare establishments in Ghana and analogous developing regions frequently encounter recurrent power interruptions, which can severely disrupt the functioning of automation systems dependent on a stable power source. In the absence of reliable power infrastructure, even the most sophisticated automation technologies become ineffective, as they cannot function continuously to oversee and regulate IEQ parameters (Bedeley&Palvia, 2014). While the utilization of backup generators or uninterruptible power supplies (UPS) can alleviate some repercussions of power failures, these alternatives introduce additional financial burdens and complexities to the deployment of automation technologies.

The issue of internet connectivity constitutes another considerable obstacle in developing nations, where dependable, high-speed internet services are not consistently accessible. Numerous contemporary automation systems, especially those that leverage Internet of Things (IoT) technologies, necessitate internet connectivity to operate efficiently (Abdulmalek et al., 2022). In the rural sectors of Ghana, internet access may be sporadic or non-existent, thereby complicating the implementation of automation systems that depend on real-time data acquisition and remote surveillance. This predicament is exacerbated by the reality that healthcare facilities in these locales frequently possess limited financial resources to allocate towards internet infrastructure or to cover ongoing connectivity expenses.

Financial limitations represent arguably the most substantial hindrance to the adoption of IEQ automation in developing nations. Public health systems in countries such as Ghana are frequently characterized by inadequate funding, resulting in constrained resources for infrastructural enhancements or technological advancements. The considerable expenses associated with automation systems, coupled with the necessity for continuous maintenance and support, render it challenging for these healthcare facilities to substantiate investments in IEQ automation when more pressing priorities, such as the procurement of medical supplies and the recruitment of personnel, prevail (Silva et al., 2023). Furthermore, public health budgets in developing countries are often constrained by prevailing economic challenges, leaving scant opportunities for the adoption of new technologies deemed non-essential.

3. RESEARCH METHOD

This study employed a mixed-methods research design, incorporating both qualitative and quantitative approaches. This design is chosen to address the complex, multifaceted nature of indoor environmental quality (IEQ) in public health facilities and the potential for its enhancement through automation technologies (Marques &Pitarma, 2019). The mixed-methods approach allows for a comprehensive exploration of the research objectives, combining the strengths of both qualitative and quantitative methodologies (Almeida et al., 2017).

Legal Framework Assessment (Qualitative): A qualitative document analysis was conducted to address the first objective of identifying the legal framework of IEQ. This involved reviewing relevant legislation, regulations, and guidelines from Ghanaian and international sources, including the Environmental Protection Agency (EPA) and other pertinent agencies.

IEQ Parameter Assessment (Quantitative): Assessing current IEQ parameters was approached through quantitative methods:

a. Collection of numerical data on indoor air quality, thermal comfort, acoustic levels and lighting conditions using specialized measurement equipment.
b. Statistical analysis of the collected data to establish baseline conditions at Esikado Hospital and Shama Health Centre.

Research settings: This study was conducted at two healthcare facilities in Ghana: Esikado Hospital and Shama Health Centres. These locations were carefully selected to provide a comprehensive view of indoor environmental quality (IEQ) challenges and opportunities in Ghanaian public health facilities.

Data collection procedure: Data collection was carried out with the active involvement of stakeholders and data collection experts. The procedure was implemented in the following stages; Environmental monitoring equipment was strategically installed in facilities to continuously collect data over a defined period (two weeks or more). This equipment recorded key indoor environmental quality parameters.Document analysis was conducted off-site using a predefined checklist. This analysis focused on reviewing relevant documents related to indoor environmental quality.

4 RESULTS AND DISCUSSION

4.1 Legal framework and regulations of indoor environmental quality by the EPA and other agencies of Ghana

A review of 12 regulations and legal frameworks available in Ghana indicates that IEQ-acceptable limits are not included in the documents. This implies that formulators of the regulations and frameworks have not yet considered the importance of IEQ in hospital settings. The table below highlights the regulations and legal frameworks that were reviewed.

Table 1: Table showing the legal frameworks and regulations relating to IEQ in Ghana

Regulation/Legal Framework	**IEQ Parameters**		
	Air quality	**Thermal comfort**	**Lighting**
Environmental Protection Agency Act, 1994 (Act 490)	Does not provide guidelines for the recommended acceptable limit for IEQ.	Does not provide guidelines for the recommended acceptable limit for IEQ.	Does not provide guidelines for the recommended acceptable limit for IEQ.
Factories, Offices and Shops Act, 1970 (Act 328)	Does not provide guidelines for the recommended acceptable limit for IEQ. Emphasises the need for good ventilation but does not relate to air quality.	Does not provide guidelines for the recommended acceptable limit for IEQ.	Emphasises effective and sufficient lighting but does provide acceptable limits for lighting in indoor areas. Does not provide guidelines for the recommended acceptable limit for IEQ.
Labour Act, 2003 (Act 651)	Does not provide guidelines for the recommended acceptable limit for IEQ.	Does not provide guidelines for the recommended acceptable limit for IEQ	Does not provide guidelines for the recommended acceptable limit for IEQ
Public Health Act, 2012 (Act 851)	Does not provide guidelines for the recommended acceptable limit for IEQ.	Does not provide guidelines for the recommended acceptable limit for IEQ.	Does not provide guidelines for the recommended acceptable limit for IEQ.
National Building Regulations, 1996 (LI 1630)	Provides guidelines for how ventilations should be created in buildings but does not provide clear guidelines on the acceptable limits on air pollutants inside the building	Not included in this regulation	Provides guidelines on how lighting should be in rooms etc but does not clearly define lighting for hospital settings. The acceptable limit for lighting in hospitals not defined.
Occupational Health and Safety Policy and Guidelines for the Health Sector 2010	Does not provide guidelines for the recommended acceptable limit for IEQ.	Does not provide guidelines for the recommended acceptable limit for IEQ.	Does not provide guidelines for the recommended acceptable limit for IEQ.
Environmental Sanitation Policy of Ghana (Revised 2010)	Does not provide guidelines for the recommended acceptable limit for IEQ.	Does not provide guidelines for the recommended acceptable limit for IEQ.	Does not provide guidelines for the recommended acceptable limit for IEQ.
Health Institutions and	Does not provide	Does not provide	Does not provide

Facilities Act, 2011 (Act 829)	guidelines for the recommended acceptable limit for IEQ.	guidelines for the recommended acceptable limit for IEQ.	guidelines for the recommended acceptable limit for IEQ.
Fire Precaution (Premises) Regulations, 2003 (LI 1724)	Does not provide guidelines for the recommended acceptable limit for IEQ.	Does not provide guidelines for the recommended acceptable limit for IEQ.	Does not provide guidelines for the recommended acceptable limit for IEQ.
Ghana Building Code (GS 1207	Does not provide guidelines for the recommended acceptable limit for IEQ.	Does not provide guidelines for the recommended acceptable limit for IEQ.	Does not provide guidelines for the recommended acceptable limit for IEQ.
Environmental Sanitation Policy 2009	Does not provide guidelines for the recommended acceptable limit for IEQ.	Does not provide guidelines for the recommended acceptable limit for IEQ.	Does not provide guidelines for the recommended acceptable limit for IEQ.
National Environmental Policy-2012	Does not provide guidelines for the recommended acceptable limit for IEQ.	Does not provide guidelines for the recommended acceptable limit for IEQ.	Does not provide guidelines for the recommended acceptable limit for IEQ.

4.2 Current indoor environmental quality (IEQ) parameters (indoor air quality, thermal comfort, and lighting conditions) at Esikado Hospital and Shama Health Centre.

An indoor environmental quality test was conducted at both hospitals and the results were juxtaposed to internationally acceptable limits for IEQ since Ghana did not have any. The results at the Esikado District Hospital indicated that some parameters assessed were in acceptable ranges of the international guidelines (Temperature, Lighting, Humidity, $CO_2$and Airborne particulate). With the Shama Health Centre, all parameters assessed were within acceptable limits except for temperature, noise level and air change per hour in general areas. The table below highlights the results from the IEQ test at the facilities.

Table 2: Results from the IEQ test at both facilities

IEQ Parmeter	Acceptable Limit	Results	
		Esikado	Shama
Temperature	20°C-24°C	21	26
Lighting	General Areas- 300-500	350	289
	Operating Rooms- 1,000-20,000	15,000	N/A
Humidity	30-60%	48	54
Air Quality			
Air Change per hour	General Areas-6 changes per hour	0	0
	Operating Rooms-20 air changes per hour	12	N/A
CO_2 level	Below 1,000ppm	400ppm	270ppm
Airborne Particulate (PM2.5)	Less than 12µg/m³ for PM2.5	8.2µg/m³ for PM2.5	4.2µg/m³ for PM2.5
Noise Level	Daytime- Less than 45dB	48db	42
	Night time- Less than 35dB	28	23

Legal framework and regulations of indoor environmental quality by the EPA and other agencies of Ghana

Results from the study in the table above (tab..1) indicate that no IEQ regulations or legal frameworks are being formulated to directly tackle IEQ within the Ghanaian jurisdiction for health facilities or general public places. This presents a gloomy picture of how IEQ is not considered a focal issue with regard to public health in Ghana. This implies that workers in such facilities need to adopt international standards to keep the facility globally competitive. These findings also indicate that regulatory agencies do not have the legal backing to enforce facilities to IEQ parameters under acceptable limits since no law binds them to do so hence the laxity of enforcement. The adherence to the WHO guidelines affirms the statement of by WHO (2021) stating the implementation of natural or mechanical ventilation systems in healthcare settings to diminish the concentration of airborne pollutants and avert infection spread

Current indoor environmental quality (IEQ) parameters (indoor air quality, thermal comfort, acoustic level and lighting conditions) at Esikado Hospital and Shama Health Centre.

With the minute IEQ systems available to the facilities to manage the IEQ parameters, the results of the IEQ test indicated that some of the parameters assessed were within the acceptable limit by international institutions. The 21°C recorded at Esikado District Hospital was in line with the acceptable limit by ASHRAE but the 26°C recorded at Shama Health Centre was beyond the acceptable limit by ASHRAE. The results affirm studies by Alfa and Öztürk (2019) who opined that deviations from this prescribed range may hinder patient recovery by inducing thermal discomfort, potentially escalating metabolic stress. The survey indicated that respondents were okay with the temperature in the hospital and further opined that it was suitable for patient recovery. The results also affirm the study byLan et al. (2011) who revealed that sustaining moderate temperatures within the recommended range (20°C–24°C) correlates with enhanced staff performance and elevated satisfaction rates.

Concerning lighting, Esikado District Hospital was within the acceptable limit for lighting in both general rooms and the operating room however, Shama Health Centre was below the minimum acceptable limit. Shama Health Centre falling short of the acceptable limit could be attributed to it being a primary healthcare facility hence inadequate resources to maintain lighting in the Health Centre. Osibona et al. (2021) stated that sufficient natural lighting has been evidenced to enhance mood, diminish stress, and accelerate recovery rates, while inadequate lighting may elevate the likelihood of medical errors. The finding by Osibona et al. (2021) affirms the finding in this study where respondents were neutral on how the lighting conditions of the facilities enhanced their work.

Humidity levels in both facilities were within the acceptable limits set by ASHRAE (2013). According to Alfa and Öztürk (2019), elevated humidity levels facilitate the proliferation of bacteria and mould, which can aggravate respiratory ailments and precipitate infections, particularly among patients with compromised immune defences. Conversely, diminished humidity levels can desiccate mucous membranes, rendering both patients and healthcare personnel increasingly vulnerable to infections (ASHRAE, 2013). Although the study did not investigate the impact of humidity on the wellness of patients or staff, humidity in the acceptable limit at both facilities could imply that low levels of bacteria will be recorded if test are carried out. Investigative studies during the COVID-19 pandemic by Morawska and Cao (2020) emphasized the significance of air filtration and ventilation in curtailing the virus's spread, revealing that hospitals which adopted advanced air filtration systems and upheld optimal ventilation protocols reported lower rates of transmission. This finding by Morawska and Cao (2020) could indirectly imply the low to zero cases detected at both facilities.

Regarding air quality, the acceptable limit for air changes per hour in both hospitals was not met by both facilities however, CO_2 and air particulate results were within the acceptable limits. The results from the air changes per hour did not meet the acceptable limits by ASHRAE's Standard 170 (2013) which mandates that operating rooms achieve a minimum of 20 air changes per hour, with four of those changes consisting of fresh air, to mitigate infection risks. Air particulate results at both facilities were within the acceptable limits stated by WHO (2016) whichestablished exposure limits for PM2.5 at 12 $\mu g/m^3$ over 24 hours.Azimi and Stephens (2013) indicated in their study that elevated levels of airborne contaminants and suboptimal ventilation may exacerbate respiratory ailments and facilitate the transmission of airborne pathogens.Allen et al. (2016) also demonstrated that enhancements in ventilation and the mitigation of CO_2 levels resulted in improved cognitive performance and decision-making accuracy among healthcare personnel, which is of utmost importance in high-pressure environments such as hospitals.A study conducted by Azimi and Stephens (2013) illustrated that hospitals equipped with deficient ventilation systems experienced heightened occurrences of healthcare-associated infections (HAIs) attributable to the concentration of pathogens present in the air.

With the acoustic level at both institutions, Shama Health Centre was within the acceptable noise level limits for both daytime and night. This could be linked to the location of the hospital since the area is a rural fishing-dominated community. The Esikado District Hospital, however, had its daytime noise level above the acceptable limit. This could be linked to the hospital being close to a cluster of schools and the main town centre. This can be confirmed as the noise level at night was within the acceptable limit by WHO.The WHO (2016) recommends that noise levels in patient rooms should be maintained below 35 dB(A) during nocturnal hours and below 45 dB(A) throughout the daytime. Research has indicated that noise levels within hospitals frequently surpass these recommended thresholds, particularly in emergency and intensive care units (Eijkelenboom&Bluyssen, 2022).

CONCLUSION

This study presents a unique opportunity for the health sector of Ghana, crucially the primary and secondary government health facilities to relook at the designs of future primary and secondary healthcare facilities. Findings from this study denote the deleterious nature of IEQ standards in government primary and secondary healthcare facilities. Although the facilities in this study one way or another met some of the international standards for IEQ, the lack of regulations, guidelines or legal framework to ensure strict adherence or implement mitigative measures to address IEQ issues were not present. Lack of regulation or legal framework meant facilities were not obliged to maintain IEQ parameters in the facilities hence the issues relating to IEQ were not fully focal to the management of these facilities.

References

Abdulmalek, S., Nasir, A., Jabbar, W. A., Almuhaya, M. A., Bairagi, A. K., Khan, M. A. M., & Kee, S. H. (2022). IoT-based healthcare-monitoring system towards improving quality of life: A review. In *Healthcare* (Vol. 10, No. 10, p. 1993). MDPI.

Agyeman, J. (2021). Challenges of integrating smart technologies in low-resource healthcare settings: The case of Ghana. Journal of Health Informatics in Developing Countries, 15(2), 85-92.

Alfa, M. T., & Öztürk, A. (2019). Perceived indoor environmental quality of hospital wards and patients' outcomes: A study of a general hospital, Minna, Nigeria. *Applied Ecology & Environmental Research*, *17*(4).

Almeida, M. S., De Freitas, S. R., & Leite, C. (2017). The impact of indoor air quality on health in hospitals: A review. International Journal of Environmental Research and Public Health, 14(4), 354-371.

Asare, A. (2016). Health facility design and indoor environmental quality in Ghana: A case study of public hospitals in Accra. University of Ghana.

ASHRAE, A. (2013). Standard 170-2013 Ventilation of Health Care Facilities. *American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc, Atlanta*.

Ayanore, M., Asampong, R., Akazili, J., Awoonor-Williams, J. K., &Akweongo, P. (2022). Sub-national variations in general service readiness of primary health care facilities in Ghana: Health policy and equity implications towards the attainment of Universal Health Coverage. *Plos one*, *17*(6), e0269546.

Azimi, P., & Stephens, B. (2013). HVAC filtration for controlling infectious airborne disease transmission in indoor environments: Predicting risk reductions and operational costs. *Building and environment*, *70*, 150-160.

Bedeley, R., &Palvia, P. (2014). A Study of the Issues of E-Health Care in Developing Countries: The Case of Ghana. In *AMCIS*.

Boateng, E. (2019). Challenges of maintaining indoor air quality in Ghanaian hospitals. Ghana Medical Journal, 53(2), 123-131.

Buchanan, D. A., Fitzgerald, L., & Ketley, D. (2007). The sustainability and spread of organizational change. *Modernising healthcare. Abingdon: Routledge Taylor & Francis Group*.

Calvillo, Christian F., Alvaro Sánchez-Miralles, and Jose Villar. "Energy management and planning in smart cities." *Renewable and Sustainable Energy Reviews* 55 (2016): 273-287.

Demirdöğen, G., Işık, Z., &Arayici, Y. (2020). Lean management framework for healthcare facilities integrating BIM, BEPS and big data analytics. *Sustainability*, *12*(17), 7061.

Dimitroulopoulou, S., Dudzińska, M. R., Gunnarsen, L., Hägerhed, L., Maula, H., Singh, R., ... & Haverinen-Shaughnessy, U. (2023). Indoor air quality guidelines from across the world: An appraisal considering energy saving, health, productivity, and comfort. *Environment International*, *178*, 108127.

Dixit, M. K., Venkatraj, V., Ostadalimakhmalbaf, M., Pariafsai, F., & Lavy, S. (2019). Integration of facility management and building information modeling (BIM) A review of key issues and challenges. *Facilities*, *37*(7/8), 455-483.

Eijkelenboom, A., &Bluyssen, P. M. (2022). Comfort and health of patients and staff, related to the physical environment of different departments in hospitals: a literature review. *Intelligent Buildings International*, *14*(1), 95-113.

Kaluarachchi, Y., Jones, R., & Abeysekera, T. (2018). Advances in automation technologies for improving indoor environmental quality in healthcare facilities. Journal of Automation and Control Engineering, 6(1), 1-7.

Mariano-Hernández, D., Hernández-Callejo, L., Zorita-Lamadrid, A., Duque-Pérez, O., & García, F. S. (2021). A review of strategies for building energy management system: Model predictive control, demand side management, optimization, and fault detect & diagnosis. *Journal of Building Engineering*, *33*, 101692.

Mensah, K. (2020). Barriers to the adoption of smart technologies in healthcare facilities in Ghana. Journal of Health Informatics in Africa, 7(2), 45-56.

Osibona, O., Solomon, B. D., & Fecht, D. (2021). Lighting in the home and health: A systematic review. *International journal of environmental research and public health*, *18*(2), 609.

Roadnight, S., & Followell, A. (2022). Fundamentals Department Design of Operating. *Fundamentals of Operating Department Practice*, 57.

Silva, B. V., Holm-Nielsen, J. B., Sadrizadeh, S., Teles, M. P., Kiani-Moghaddam, M., &Arabkoohsar, A. (2023). Sustainable, green, or smart? Pathways for energy-efficient healthcare buildings. *Sustainable Cities and Society*, 105013.

Smith, J., & Jones, L. (2020). Automation and indoor environmental quality in healthcare: A review of current technologies and future directions. Journal of Healthcare Engineering, 45(3), 256-272.

Sunny, A. I., Zhao, A., Li, L., & Sakiliba, S. K. (2020). Low-cost IoT-based sensor system: A case study on harsh environmental monitoring. *Sensors*, *21*(1), 214.