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Assessment of Perceived Effects and Levels of Indoor Air-Quality Among Intensive Care Units' Personnel in Osun State Tertiary Institutions

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ABSTRACT

This study assessed the knowledge, perceived effects, and levels of indoor air quality (IAQ) among 107 ICU healthcare personnel in two tertiary institutions in Osun State, Nigeria (OAUTHC, Ile-Ife and UNIOSUNTH, Osogbo). The objectives were to assess knowledge of IAQ, ascertain perceived effects of poor IAQ on staff and patients, determine physicochemical and microbiological contaminants, and identify perceived preventive strategies. A descriptive cross-sectional quantitative design was adopted. All 107 eligible ICU personnel were consecutively enumerated after purposive selection of the two tertiary institutions. Data were collected using a questionnaire adapted from Del Ponte et al. (2021) and BUCK BU23 air samplers for physicochemical and microbiological analysis, then analyzed in SPSS v28 using descriptive and inferential statistics (χ^2 and ANOVA) at $p < 0.05$. Results showed that 82.2% of respondents had good knowledge of IAQ, while only 19.6% exhibited good perceived awareness of its effects. Perceived physicochemical and microbial contamination was rated high by 92.5%, yet 92.5% rated existing preventive strategies as good. Key perceived contaminants were VOCs from cleaning agents (82.3%), high CO_2 (89.7%), airborne bacteria/viruses (88.8%), and fungal spores (81.6%). Preventive strategies strongly supported included regular HVAC maintenance (91.6%), HEPA filtration (87.9%), non-toxic cleaning agents (89.7%), and staff training (93.4%). Hypothesis testing revealed no significant relationship between socio-demographic characteristics and knowledge ($p > 0.05$) or perceived effects (except education level, $p = 0.019$), and no significant association between knowledge and perceived effects of poor IAQ ($\chi^2 = 0.655$, $p = 0.418$). Despite high IAQ knowledge and contamination recognition among ICU personnel, a critical gap persists in perceived health effects and practical application. The study recommends that Osun State Ministry of Health and hospital boards immediately mandate annual IAQ training and install real-time monitoring systems in all tertiary ICUs.

Keywords: *Indoor Air Quality, Knowledge, Perceived Effects, Intensive Care Units, Tertiary Institutions*

INTRODUCTION

The indoor air quality (IAQ) is a crucial health and safety determinant, especially in health-care settings like Intensive Care Units (ICUs) where vulnerable patients with respiratory issues depend on clean air to recover and avoid complications (Anh et al., 2024; Tanveer et al., 2024; Morawska et al., 2022). Poor IAQ in crowded ICUs can adversely affect patients' conditions, highlighting the need for proper IAQ management to protect both patients and healthcare providers (Fonseca et al., 2022). IAQ refers to the air quality within enclosed spaces, such as hospitals, and is assessed based on its cleanliness and health implications (Nimra et al., 2021). Poor IAQ, caused by factors like inadequate ventilation, cleaning solvents, medical equipment emissions, and microorganisms, can lead to serious health issues for both patients and staff, including respiratory illnesses, allergies, and infections (Yadav et al., 2023; Mousavi et al., 2021; Raju et al., 2020). Healthcare workers exposed to polluted air may experience

symptoms like headaches, fatigue, and respiratory problems, impacting their health and productivity (Ackley et al., 2024). Therefore, understanding healthcare providers' knowledge of IAQ, sources of contaminants, and preventive measures is essential for improving health outcomes and controlling healthcare-associated infections (HAIs) (Ackley et al., 2024; Saini et al., 2020; Ibrahim et al., 2021).

This study aims to identify specific microbiological and physicochemical pollutants in ICUs, including particulate matter, gaseous chemicals, and biological agents like bacteria and viruses, which pose significant risks to ICU patients (Tran et al., 2020; Xiao et al., 2022; Carrazana et al., 2023). Poor IAQ is a major source of HAIs, and inadequate environmental control can exacerbate air contamination (Naziya, 2021; Habboush et al., 2023; Negi et al., 2023; Frazer-Williams et al., 2024). Identifying pollutant sources will help address IAQ issues (Bouza et al., 2022). Additionally, the study will determine recognized protective measures, such as enhanced ventilation, high-efficiency air filters (HEAF), and better infection control practices, to improve IAQ in ICUs (Jackson & Cairns, 2021; Grange et al., 2020; Ibrahim et al., 2022). Engaging healthcare professionals in these efforts is crucial for success (Ibrahim et al., 2024).

1.2 Statement of Problem

IAQ significantly impacts the health of patients and healthcare providers in ICUs, with poor air quality linked to respiratory diseases, allergies, and increased susceptibility to HAIs (Movahedi et al., 2023; Grange et al., 2020). Immunocompromised ICU patients are particularly vulnerable to adverse effects from polluted indoor air, leading to longer hospital stays and higher costs (Holden et al., 2023). Healthcare workers also suffer from reduced productivity and health due to exposure to indoor pollutants (Ackley et al., 2024; Schwab Jensen et al., 2022).

Enhancing IAQ is critical to preventing HAIs caused by bacterial and fungal spores (Mousavi et al., 2021; Beyamo et al., 2019). While previous studies have examined IAQ's impact on health and pollutant presence (Fonseca et al., 2022; Nimra et al., 2021), there is a lack of research specifically addressing healthcare professionals' awareness and perceptions of IAQ in ICUs. In Nigeria, studies have generally focused on IAQ in broader healthcare settings or other environments, often overlooking the specific needs of ICUs (Abulude et al., 2018; Adamu et al., 2023). Although IAQ monitoring has been emphasized, healthcare workers' knowledge remains under-researched (Ibrahim et al., 2021). A specific gap exists regarding the knowledge and perceptions of healthcare providers in Osun State concerning IAQ in ICUs. Previous studies in the region, such as Akinleye et al. (2023), focused on other populations and did not address ICU settings or healthcare workers' awareness. Furthermore, limited research exists on the specific contaminants affecting IAQ in Osun State ICUs. This study aims to bridge these gaps by assessing the knowledge, perceived effects, and levels of IAQ among ICU personnel in Osun State tertiary institutions, thereby informing measures to improve IAQ and ensure safety for staff and patients.

1.3 Objectives of the Study

The aim of the study is to assess the level of knowledge, perceived effects and levels of IAQ among intensive care unit personnel in Osun state tertiary institutions.

The specific objectives are to:

1. assess the knowledge level of healthcare personnel on IAQ in ICUs of tertiary institutions in Osun State;
2. ascertain the perceived causes and effects of poor IAQ on patients and healthcare personnel in ICUs;
3. determine the physicochemical and microbiological contaminants of IAQ in ICUs; and
4. determine the perceived preventive strategies to improve IAQ in ICUs of tertiary institutions in Osun State.

1.4 Research Questions

1. What is the knowledge level of healthcare personnel on IAQ in ICUs of tertiary institutions in Osun State?
2. What are the perceived causes and effects of poor IAQ on patients and healthcare professionals in ICUs of tertiary institutions in Osun State?
3. What is the physicochemical and microbiological contaminants of IAQ in ICUs of tertiary institutions in Osun State?

4. What are the perceived preventive strategies to improve IAQ in ICUs of tertiary institutions in Osun State?

1.5 Hypotheses

The following hypotheses are formulated to assist the study;

$H_0$1. There is no significant relationship between participants' socio-demographic profiles and their knowledge of IAQ.

$H_0$2. There is no significant relationship between participants' socio-demographic profiles and perceived effects of poor IAQ in ICUs.

$H_0$3. There is no significant relationship between knowledge of the healthcare personnel and perceived effects of IAQ in ICUs of tertiary institutions in Osun State.

LITERATURE REVIEW

2.2 Conceptual Review of Air Quality

Air quality defines the cleanliness of the air, determined by pollutant concentrations. It is crucial for health and environmental well-being (WHO, 2022). Poor air quality, characterized by pollutants like particulate matter (PM), nitrogen dioxide (NO2), and volatile organic compounds (VOCs), poses significant health and environmental risks (UNEP, 2021). While international agreements and technological advancements aim to improve air quality (Bae et al., 2023; EPA, 2022), challenges persist globally. Indoor Air Quality (IAQ) refers to air quality within and around buildings, impacting occupant health and comfort (Astuti, 2024). Poor IAQ, often worse than outdoor air in poorly ventilated spaces, causes immediate symptoms and long-term diseases (Deng et al., 2024; EPA, 2021). Monitoring IAQ in healthcare settings is critical for vulnerable populations (Fonseca et al., 2022; Baqer et al., 2023; WHO, 2009). In Intensive Care Units (ICUs) there is need for high IAQ standards to prevent infections and aid recovery (EPA, 2021; Huang et al., 2021). Poor IAQ in ICUs increases the risk of nosocomial infections like ventilator-associated pneumonia (Kumar et al., 2016; Dharan & Pitter, 2002). Despite efforts, maintaining IAQ is challenging due to various pollutant sources (Boswell & Fox, 2006). Adherence to guidelines and maintenance of HVAC systems are essential (Fajemilehin et al., 2018; Elsaid & Ahmed, 2021; NESREA, 2021).

Poor Air Quality have high Health Impacts**,** air pollution is a major global health risk, causing millions of premature deaths annually (WHO, 2021). Vulnerable groups and certain occupations are at higher risk (Holgate et al., 2020). Air Quality Indices (AQI) help communicate air quality levels (Tan et al., 2021). In Nigeria, rapid urbanization and industrial activities contribute to poor air quality in major cities (Daramola & Makinde, 2024; Oyetunde et al., 2024). The Impact of Poor IAQ on Patient Outcomes in ICUs leads to increased nosocomial infections (Luongo et al., 2019; Morawska et al., 2020), exacerbation of respiratory conditions (Zhang & Batterman, 2019; Mousavi et al., 2019), impaired immune response (Chen et al., 2021), and psychological/cognitive effects (Allen et al., 2019). Indoor Air Pollution Sources include VOCs, PM, biological agents, and radon (Emetere et al., 2024; POST, 2023). Sources range from building materials and combustion to human activities and outdoor infiltration (Lewis, 2023; Harrison et al., 2019). Indoor air pollution significantly contributes to respiratory diseases and deaths globally (WHO, 2018; Thomas & Boma, 2023).

2.2 Knowledge of Healthcare Professionals

Healthcare professionals' knowledge of IAQ in ICUs is vital but often lacking (Fonseca et al., 2022; Liao et al., 2020). Gaps in training and awareness hinder effective IAQ management (Kordzadeh et al., 2021; Taggart et al., 2022). Studies in Nigeria reveal significant knowledge gaps among healthcare workers (Akinyemi et al., 2020; Adeniyi et al., 2019). Perceived causes of poor IAQ include inadequate ventilation, chemical usage, biological contaminants, and outdoor pollution infiltration (Akinyemi et al., 2020; Fonseca et al., 2022; Nkosi et al., 2021). Effects include increased HAIs, respiratory issues, cardiovascular problems, and psychological stress for both patients and staff (Fonseca et al., 2022; Groot et al., 2023; Orellano et al., 2020). Contaminants in ICUs Physicochemical contaminants (PM, VOCs, CO2, CO, NO2) and microbiological contaminants (bacteria, viruses, fungi) compromise IAQ in ICUs (Vahidmoghadam et al., 2023; Baudet et al., 2021; Kumar et al., 2022). Strategies include enhanced ventilation/filtration (HEPA filters), air purification (UVGI), humidity control, routine monitoring, source

control (low-emission materials), and staff training (Baqer et al., 2023; Fonseca et al., 2022; Gola et al., 2019).

2.3 WHO Guidelines on Indoor Air Quality

The World Health Organization (WHO) provides detailed regulations on indoor air quality for the public. These regulations were set based on the intensive scientific research conducted to reduce or minimize indoor exposure to any indoor air pollutants (WHO, 2021). WHO has threshold limits for a number of indoor air pollutants that reduce the chances of developing health risks. For instance, the WHO benzene guideline for long-term exposure is 0.5 mg/m³. It is one of the established carcinogenic components (WHO, 2024). According to WHO (2021), air exchange and filtration adequate ventilation and filtration need to be kept in operation to ensure high indoor air quality. Specific proposed guidelines for ventilation rate, also use of high-efficiency filters to eliminate contaminants from space air. Humidity levels in indoor spaces must be managed and any water damage or leaks must be addressed immediately to prevent the growth of mold and other microbial contaminants. This also prevents adverse respiratory effects and allergic reactions. The WHO considered particular health institution settings where the population might be vulnerable to poor indoor air quality, such as ICU patients. The standards of air quality in these institutions are aimed at the highest level.

2.4 Theoretical Framework

The study utilizes Bronfenbrenner's Ecological Systems Theory (EST) to understand the multi-layered influences on IAQ in ICUs, considering microsystem, mesosystem, exosystem, macrosystem, and chronosystem factors (Bronfenbrenner & Morris, 2006; Tsoulou et al., 2021). This framework supports a holistic analysis of IAQ management.

2.5 Gaps in Knowledge

Existing literature highlights a lack of comprehensive studies on healthcare professionals' knowledge and perceptions of IAQ specifically in ICUs within Osun State, Nigeria. Furthermore, there is limited data on specific physicochemical and microbiological contaminants in these settings. This study aims to bridge these gaps.

RESEARCH METHOD

3.1 Research design

The research design involved procedures of collecting, analyzing, interpreting and reporting data. In other words, the research design set the procedure on the required data, the methods applied to collect and analyze the data, and how all of these were able to answer the research questions (Tesfaye, 2018)**.** The research design that was adopted for this study is descriptive cross-sectional and experimental design. Quantitative approach was employed to gather comprehensive insights to assess the knowledge, perceived effects and levels of indoor air-quality among intensive care units' personnel in Osun state tertiary institutions. The experimental design involved collection, examining and analyzing the air sample taken from each ICU at the same time which revealed the current state of indoor air and associated physicochemical variables within the ICUs.

3.3. Study Setting

The study was carried out in two selected Osun state tertiary health institutions; Obafemi Awolowo University Teaching Hospital Ile-Ife (OAUTHC) and University of Osun Teaching Hospital Osogbo (UTH).

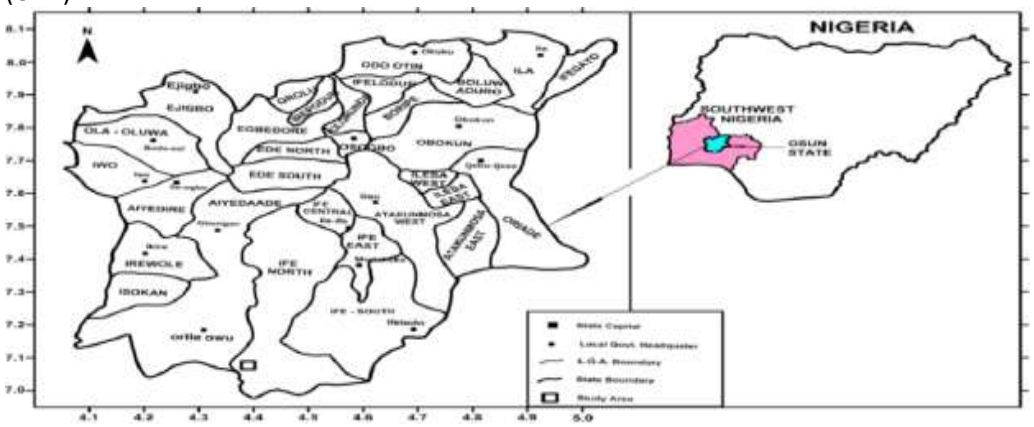

Figure 1: The map of Osun-State, Nigeria.

3.4 Study Population

The study population for this study was the total group of healthcare personnel who work in the ICUs of selected tertiary institutions. They were doctors, nurses, anesthesiologists, perfussionists and health attendants working in the Intensive Care Units of OAUTHC, and UTH. Therefore, the total participants from the two selected institutions were 107. The table1 below shows the record of the participants according to statistics of November, 2024.

Units / Departments	**Type of Healthcare Professionals**	**Total Population**		
		OAUTHC	UTH	Total
Intensive Care Unit	Nurses	27	14	
	Anesthesiologists	25	20	
	Health Attendants	13	8	
Total		**65**	**42**	**107**

Table 1: Participants Population according to statistics of November, 2024

3.5 Sample Size

A total enumeration approach was employed to select a sample of 107 ICU healthcare personnel based on specific inclusion criteria. Given the small population size, this method ensured that the knowledge, perceptions, and experiences of every eligible participant were included. This comprehensive approach provided detailed and accurate insights into indoor air quality (IAQ) issues in ICUs.

3.6 Sampling Technique

Multistage sampling technique involving three stages was adopted to select respondents from the ICUs of the selected tertiary institutions in Osun State. The stages were:

First stage: The two tertiary health institutions in Osun State namely OAUTHC and UTH were consecutively chosen by the researcher.

Second stage: Purposive sampling technique was utilized to select the ICU in each of the tertiary healthcare institution.

Third stage: Consecutive sampling method was used by the researcher to select all the ICU staff of the two healthcare institutions with resultant total of 107 participants.

3.6 Eligibility criteria

Inclusion criteria

Inclusion criteria are defined as the key features of the target population that the investigators used to answer the research question. Typical inclusion criteria include demographic, clinical, and geographic characteristics (Montes de Oca *et al.,* 2017). The inclusion criteria for this study include; Anesthesiologists,

Nurses and health attendants who are working in the Intensive Care Units of Obafemi Awolowo University Teaching Hospital (OAUTHC) Ile-Ife and UNIOSUN Teaching Hospital, Osogbo and voluntarily consented to participate.

Exclusion criteria

Exclusion criteria are defined as features of the potential study participants who meet the inclusion criteria but present with additional characteristics that could interfere with the success of the study or increase their risk for an unfavorable outcome (Patino and Ferreira, 2018). Common exclusion criteria include characteristics of eligible individuals that make them highly likely to be lost to follow-up, misscheduled appointments to collect data, provide inaccurate data.

In this study, the exclusion criteria are stated as follows: healthcare providers not directly involved in the management of patients in the Intensive Care Units, individuals were temporarily absent from their respective units were reached electronically, healthcare personnel with less than 6 months working experience in the ICU and healthcare personnel unwillingness to participate in the study.

3.7 Instruments for data collection

The research instrument for this study was a structured adapted questionnaire that was designed by Del Ponte et al, (2021) as well as from relevant literature search. This instrument was used to measure the study variables (Polit and Beck, 2012).

Questionnaire

The questionnaire for this study consists of six sections based on the study objectives. This includes;

Section A: 1-7 obtained sociodemographic information, such as age, gender, profession, level of education, years of experience and specific facility individual was working with.

Section B: 1-10 provided information on the knowledge level of healthcare providers on IAQ in ICUs of Tertiary Institutions using Yes/No.

Section C: 11-20 drawn out information on the perceived causes and effects of poor indoor air quality on patients and healthcare personnel's in ICUs of tertiary institutions

Section D: 21-30 extracted data on the physicochemical and microbiological contaminants of indoor air quality in ICUs of tertiary institutions

Section E: 31-40 was used in determining the perceived preventive strategies to improve indoor air quality in ICUs of tertiary institutions.

Section F: 41-50 assessed the perceived state of indoor air quality in ICUs of Osun state tertiary institutions.

3.8 Validity and Reliability of the Iinstrument

Validity: The validity of the instrument, which refers to how well it measures the intended constructs, was ensured through multiple processes. Content validity was established by aligning the questionnaire with current literature and research aims. Construct validity was evaluated with the help of the researcher's supervisor to confirm that the instrument accurately assessed the intended concepts. Face validity was addressed by vetting the structured questionnaire with the supervisor, incorporating necessary corrections before administration to respondents.

Reliability: The reliability of the instrument reflects its consistency and dependability. It was assessed by analyzing collected data for internal consistency, using Cronbach's alpha to measure reliability. A value greater than 0.7 indicated that the instrument was reliable, minimizing the influence of chance factors or environmental conditions on the results**.**

3.9 Method for Data Collection

The researcher collected data for the study using structured adapted questionnaire, so also air samplers were used to collect air sample to identify contents experimentally. Following ethical approval from appropriate authorities, the researcher visited the participants at their duty post in each of the selected health institution between Mondays through Fridays at 10:00 am for four (4) weeks. Informed consent was obtained then the instrument were administered to them. Instructions on objectives of the

study and the questionnaire which took between 20-25 minutes were answered. Completed questionnaires were retrieved, coded, and analyzed.

Experimentally, the researcher obtained air samples with the use of automatic air sampler BU23 and agar solution containing petri dishes. The petri dishes were placed on a high pedestal in the ICU of each institution at10a.m and 4p.m of the first, third and fifth day of each week for a month. The automatic air sampler measures 11 parameters namely temperature, humidity, pressure, carbon dioxide, volatile organic compounds, alcohol specifically Polycyclic Aromatic Hydrocarbons (PAH), carbon monoxide, ammonia, nitrogen dioxide, and particulate matter ($PM_{2.5}$ and PM_{10}). The data obtained were thereafter sorted and cleaned using Microsoft Excel and analyzed for risk using AirQ+ World Health Organization-financed software that assesses for mortality risks of short- and long-term exposure to ambient air pollution. The microbiological air sample however, was taken in petri dishes containing chocolate, MacConkey and Saboraud dextrose agar for bacteria and fungi respectively from which microbes were incubated at 25^0C for 3-5days, microbial growths were isolated, identified using different biochemical tests then enumerated for airborne bacteria and fungi via DNA sequencing. 24 samples were obtained in all. The total number of colony forming units (CFU) for fungi and bacteria were determined after incubation then converted to organisms colony forming units per cubic meter (CFU/MM^3 X 10^2) using the formular $CFU/MM^3=(CFU/t \times K) \times 10^2$, where CFU=mean of colony forming unit, t=total sampling time expressed in minutes, k=a conversion factor from cubic feet to cubits meters (k=35.3).

3.9.1 Data Analysis

In this study, data collected was analyzed using Statistical Package for Social Sciences (SPSS) version 28. Descriptive statistics such as frequency counts, percentages, mean and standard deviation were used to summarize and present the results. Descriptive statistics of frequency distribution mean and standard deviation were used to analyze the data which provided answers to the research questions 1, 2, 3 and 4. The mean and standard deviation of some descriptive features of the respondents were calculated. Inferential analysis was used to make decisions about a population under study from samples of that population, commonly through hypothesis testing (Sheard, 2018). Therefore, the hypotheses was analyzed by using the chi-square test, to know if statistically significant at the level of $P \leq 0.05$; ANOVA or regression can be used also if suitable to explore significant relationships.

3.10 Ethical Consideration

Approval to conduct the study was obtained from the Research and Ethics Committee of ABUAD with protocol number: ABUADHREC/25/04/2025/671, OAUTHC, Ile-Ife with Protocol Number: ERC/2025/05/02 and UTH, Osogbo with Protocol Number: UTH/REC/2025/05/1203. Then, permission was taken from the department head of each hospital. Each respondent's autonomy was respected, as the study respondents were adequately informed of the process, purposes and objectives of the study. Only respondents who are willing to participate in the study were used for the study without coercing anyone to take part in the research. Additionally, a consent forms were filled and duly signed by the respondents Confidentiality, privacy, anonymity and the respondents' right to withdraw from the study at any time without any negative consequences was ensured.

RESULTS AND DISCUSSION

4.1 Socio-Demographic Data of the Respondents

Table 1 presents the sociodemographic characteristics of the respondents. The respondents were predominantly young to middle-aged ICU healthcare workers: 49.5% aged 25–34 years, 26.2% aged 35–44 years, 60.7% female, and mostly bachelor's degree holders (59.8%). A smaller proportion held diplomas/certificates (19.6%), master's (7.5%), or PhD (2.8%) qualifications. Despite a generally good awareness of the importance of indoor air quality (IAQ), significant knowledge gaps persist, particularly regarding specific pollutants (e.g., VOCs) and monitoring technologies (Mohammed et al., 2023; Fonseca et al., 2022; Vieira et al., 2020; Abdel-Fattah et al., 2021). More experienced respondents (typically 30–50 years) demonstrated better IAQ awareness, confirming that clinical exposure over time improves recognition of IAQ issues (Vieira et al., 2020). However, even experienced staff lacked in-depth knowledge of pollutants and management strategies due to inadequate formal training (Kordzadeh et al.,

2021; Akinyemi et al., 2020). A striking 79.4% of respondents had never received formal training on indoor air quality (IAQ) management, 57.9% were unaware of any specific IAQ standards or guidelines for healthcare settings, and 77.6% confirmed that their intensive care units lacked any form of IAQ monitoring devices (Dascalaki et al., 2019; Mohammed et al., 2023; Mousavi et al., 2020; Vieira et al., 2020).

Table 1: Sociodemographic data of respondents

		N	%
Age of respondents	25-34	53	49.5
	35-44	28	26.2
	45-54	17	15.9
	55 and above	9	8.4
Gender of respondents	Male	42	39.3
	Female	65	60.7
Highest level of education	Diploma/Certificate	21	19.6
	B.sc	64	59.8
	M.sc	8	7.5
	Ph.D	3	2.8
	Others	11	10.3
Years of experience	<1	3	2.8
	1-5	19	17.8
	6-10	26	24.3
	11-15	19	17.8
	>15	40	37.4

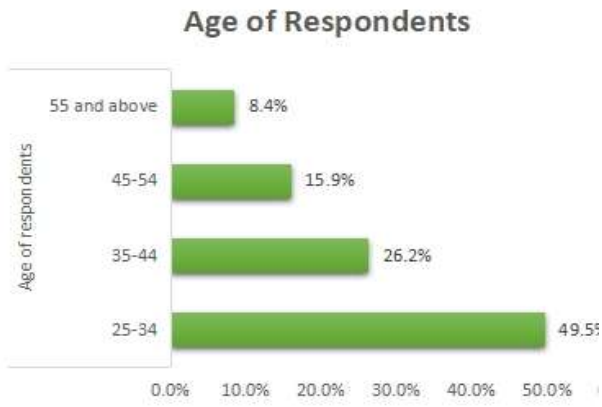

Figure 1: Bar Chart showing the age distribution of respondents

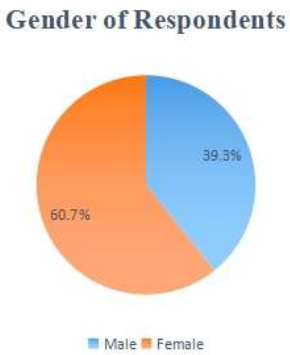

Figure 2: Pie Chart showing the gender distribution of respondent

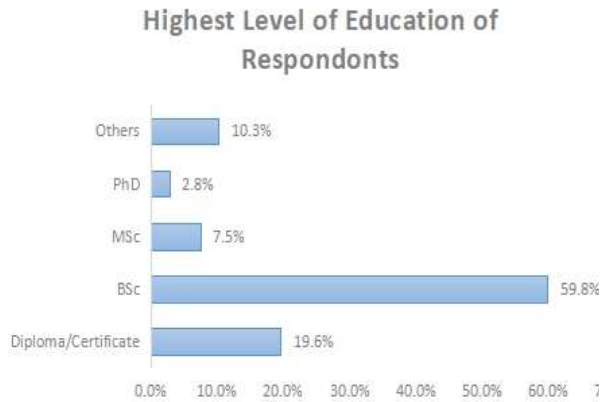

Figure 3: Bar Chart showing the highest level of education of respondents

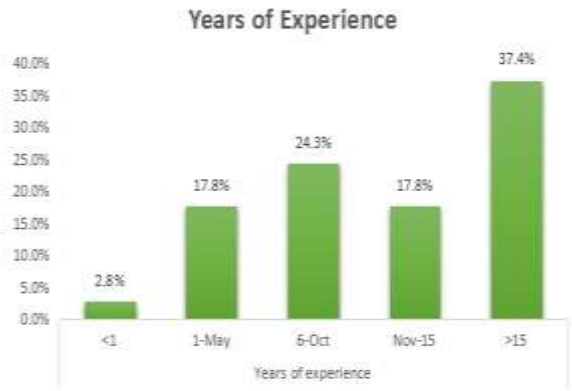

Figure 4: Bar Chart showing the years of experience of respondents

Table 2 presents data on the professional qualifications of the respondents. The respondents were predominantly nurses (56.1%), followed by doctors (23.4%), ICU technicians (10.3%), respiratory therapists (3.7%), and others (6.5%). In terms of ICU experience, 38.3% had 1–3 years, 27.1% had 4–6 years, 21.5% had more than 10 years, 5.6% had 7–10 years, and 7.5% had less than 1 year. Respondents were drawn from two tertiary facilities: 61.7% from OAUTHC and 38.3% from UTH. Key insights reveal that nurses, as frontline staff, are most exposed to IAQ issues yet often lack specialized training (Akinyemi et al., 2020; Mohammed et al., 2023). Healthcare workers with more than 10 years of ICU experience demonstrated significantly better awareness of IAQ challenges than those with fewer years (Kordzadeh et al., 2021; Seppänen & Fisk, 2004). However, even highly experienced staff faced limitations in managing specific pollutants and modern ventilation systems due to inadequate ongoing training (Dascalaki et al., 2019).

Larger facilities such as OAUTHC are expected to have superior resources, yet persistent IAQ gaps were observed across both institutions (Fonseca et al., 2022; Akinyemi et al., 2020). The findings underscore that professional role, years of experience, and facility size influence IAQ awareness, but none compensate for the critical absence of targeted training and real-time monitoring systems (Dascalaki et al., 2019; Mohammed et al., 2023).

Table 2: Professional qualifications of the respondents

		N	%
Professional role	**Nurse**	**60**	**56.1**
	Doctor	**25**	**23.4**
	Respiratory Therapist	**4**	**3.7**
	Intensive care unit technician	**11**	**10.3**
	Others	**7**	**6.5**
How long have you been working in the intensive care unit	**Less than 1 year**	**8**	**7.5**
	1-3	**41**	**38.3**
	4-6	**29**	**27.1**
	7-10	**6**	**5.6**
	More than 10	**23**	**21.5**
Specify your tertiary facility	**OAUTHC**	**66**	**61.7**
	UTH	**41**	**38.3**

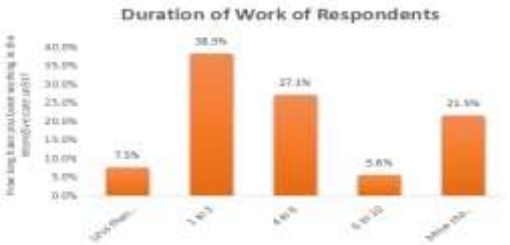

Figure 6: Bar chart showing the duration of work of respondents

Figure 5: Bar Chart showing the professional role of respondents

Personnel on Indoor Air Quality

The result in table 3 showed 107 ICU healthcare workers, predominantly young to middle-aged (49.5% aged 25–34 years, 26.2% aged 35–44 years), female (60.7%), and bachelor's degree holders (59.8%). Nurses constituted the majority (56.1%), followed by doctors (23.4%), ICU technicians (10.3%), and respiratory therapists (3.7%). Most respondents had 1–6 years of ICU experience (65.4% combined), while 21.5% had more than 10 years. Participants were drawn from two tertiary facilities: OAUTHC (61.7%) and UTH (38.3%). Healthcare personnel exhibited strong general awareness of IAQ importance: 92.5% recognized the critical role of ventilation systems, 91.6% acknowledged that poor IAQ contributes to infection spread, 86.9% agreed it negatively affects patient outcomes, and 84.1% understood the influence of humidity levels (Mohammed et al., 2023; Fonseca et al., 2022). However, significant gaps in specific knowledge and infrastructure persisted: 79.4% had never received formal IAQ training, 57.9% were unaware of any IAQ standards or guidelines, 77.6% reported complete absence of IAQ monitoring devices in their units, and 54.2% were unfamiliar with key physicochemical contaminants such as VOCs and PM2.5 (Vieira et al., 2020; Dascalaki et al., 2019; Abdel-Fattah et al., 2021; Mohammed et al., 2023; Kordzadeh et al., 2021).

Although more experienced respondents (especially >10 years) showed better awareness of IAQ issues (Kordzadeh et al., 2021; Seppänen & Fisk, 2004), experience alone did not bridge the critical deficits in technical knowledge, pollutant identification, or monitoring capabilities. Even in the larger, better-resourced OAUTHC, these gaps remained evident (Fonseca et al., 2022; Akinyemi et al., 2020). The study concludes that, despite high general awareness and recognition of IAQ's clinical significance, the persistent lack of formal training, unfamiliarity with specific pollutants, absence of real-time monitoring systems, and inconsistent infection control practices (e.g., only 59.8% mandated visitor facemasks) represent major barriers to effective IAQ management in intensive care units (Mousavi et al., 2020; Wang et al., 2020; Mohammed et al., 2023). Comprehensive, targeted continuing education and the urgent integration of IAQ monitoring technology are essential to close these gaps and protect both patients and healthcare workers in critical care settings.

Table 3: Knowledge level of IAQ in ICUs of Osun state Tertiary Institutions

	Yes	**No**
	N (%)	*N (%)*
Are you aware of what Indoor air quality (IAQ) refers to	84 (78.5)	23 (21.5)
Do you believe that poor IAQ in ICUs can negatively impact patient health outcome	93 (86.9)	14 (13.1)
Have you ever received formal training on the management of IAQ in health care settings	22 (20.6)	85 (79.4)
Do you know that ventilation systems are crucial for maintaining good IAQ in ICUs	99 (92.5)	8 (7.5)
Are you familiar with the specific physicochemical contaminants that can affect IAQ in ICUs	58 (54.2)	49 (45.8)
Do you think that poor IAQ can contribute to the spread of infections within ICUs	98 (91.6)	9 (8.4)
Are you aware of any standards or guidelines related to IAQ in healthcare facilities	45 (42.1)	62 (57.9)
Do you believe that the humidity levels in an ICU can affect IAQ	90 (84.1)	17 (15.9)
Have you ever encountered health issues among staff or patients that you believe were related to poor IAQ	59 (55.1)	48 (44.9)
Do you consider IAQ as a critical factor when making decisions about patients care in the ICU	86 (80.4)	21 (19.6)
Do you have IAQ monitoring device in the ICU	24 (22.4)	83 (77.6)
Do you have fan or air conditioner in the ICU	96 (89.7)	11 (10.3)

Is wearing of facemasks mandatory for ICU visitors	64 (59.8)	43 (40.2)
Is wearing of facemasks mandatory for all healthcare personnel in the ICU	81 (75.7)	26 (24.3)
Do you think that the ICU is still ventilated as it is	46 (43)	61 (57)

4.4 Perceived Causes and Effects of Poor Indoor Air Quality on Patients and Healthcare Personnel

The results from Table 4 reveal the perceived causes and effects of poor indoor IAQ among patients and healthcare personnel in ICUs. Respondents showed moderate-to-high awareness of major causes of poor IAQ: inadequate ventilation (46.7%), microbiological contaminants (49.5%), poor air filtration (55.1%), and high humidity (36.4%). Awareness was markedly low regarding chemical cleaning agents (only 15.9% moderately aware; 29.0% not aware at all) (Srikanth et al., 2021; Onmek et al., 2020; Gizaw et al., 2019; Gola et al., 2020; Abdel-Fattah et al., 2021). The most recognized effects were: increased airborne transmission and hospital-acquired infections (HAIs) in patients (68.2%), prolonged patient recovery time (58.9%), chronic health problems in healthcare personnel (56.1%), respiratory issues in patients (51.4%), and fatigue/headaches in staff (39.3%). These findings align strongly with the literature (Fonseca et al., 2022; Settimo et al., 2020; Nkosi et al., 2021; Kramer et al., 2019; Stockwell et al., 2019). Poor IAQ in ICUs significantly exacerbates respiratory diseases (asthma, COPD, SARS-CoV-2-related complications), cardiovascular complications (via PM2.5 systemic inflammation), prolonged hospital stays, higher mortality risk, neurological effects, fatigue, cognitive impairment, and psychological stress/burnout among both patients and healthcare workers (Groot et al., 2023; Ngoc et al., 2023; Fan et al., 2023; Baqer et al., 2023; Orellano et al., 2019; Alford et al., 2021; Maung et al., 2022; Mirhadyan et al., 2022; Zaman et al., 2021). Additional documented causes include patient visitation activities (Tang et al., 2019), poorly maintained HVAC systems, dirty attached toilets, inadequate waste disposal, and emissions from building materials/cleaning products (Maung et al., 2022; Stockwell et al., 2019; Shajahan et al., 2019).

Table 4: Perceived causes and effects of poor indoor air quality on patients and healthcare personnel in ICUs

	Not aware *N (%)*	**Slightly aware** *N (%)*	**Moderately aware** N (%)	**Highly aware** N (%)
Poor ventilation in ICUs is a significant cause of poor IAQ	5 (4.7)	19 (17.8)	33 (30.8)	50 (46.7)
The use of chemical cleaning agent in ICUs contributes to poor IAQ	31 (29.0)	27 (25.2)	32 (29.9)	17 (15.9)
Micro biological contaminants (eg bacteria, viruses) in the air can deteriorate IAQ in ICUs	8 (7.5)	14 (13.1)	32 (29.9)	53 (49.5)
High humidity levels in ICUs can worsen IAQ	15 (14.0)	22 (20.6)	31 (29.0)	39 (36.4)
Poor IAQ can lead to respiratory issues in patients admitted to ICUs	5 (4.7)	12 (11.2)	35 (32.7)	55 (51.4)
Exposure to poor IAQ can cause fatigue and headaches in healthcare personnel working in ICUs	10 (9.3)	17 (15.9)	38 (35.5)	42 (39.3)
The presence of airborne pathogens in ICUs can increase infection rate among patients	7 (6.5)	3 (2.8)	24 (22.4)	73 (68.2)
Inadequate air filtration systems contribute to poor IAQ in ICUs	11 (10.3)	6 (5.6)	31 (29.0)	59 (55.1)
Poor IAQ can affect the recovery time of patients in ICUs	8 (7.5)	12 (11.2)	24 (22.4)	63 (58.9)
Prolonged exposure to poor IAQ can lead to chronic health issues for healthcare	9 (8.4)	9 (8.4)	29 (27.1)	60 (56.1)

4.5 The Physiochemical and Microbiological Contaminants of IAQ in ICUs of Tertiary Institutions

ICU healthcare workers in Osun State tertiary hospitals accurately identified major causes of poor IAQ as inadequate ventilation, overcrowding, toxic cleaning agents, high CO_2 levels (89.7% agreement), VOCs from disinfectants (82.3%), particulate matter (86.0%), and chemical emissions from building materials (Kordzadeh et al., 2021; Wang et al., 2022; Nkosi et al., 2021; Olawoyin et al., 2021). They also correctly recognized microbiological contaminants, particularly airborne bacteria/viruses (88.8%), fungal spores (81.6%), and bioaerosols (87.8%) as critical threats (Fonseca et al., 2022; Kern et al., 2022; Mousavi et al., 2020). Respondents demonstrated strong awareness of short-term health effects (respiratory irritation, asthma, chronic cough, fatigue, headaches, eye irritation) but significant knowledge gaps regarding long-term consequences, especially cardiovascular diseases, hypertension, and neurological impairments from chronic exposure to PM2.5, VOCs, and microbial agents (Seppänen & Fisk, 2004; Bako et al., 2021; Fisk et al., 2020; Olorunsola & Adebayo, 2021). This limited awareness of chronic risks contrasts with earlier studies that assumed deeper understanding among healthcare workers (Adegboye et al., 2018; Fisk et al., 2020). Perceived state of IAQ in the ICUs was rated poor to fair by the majority, primarily due to inadequate ventilation, absent or outdated air filtration systems, and overcrowding (Akinbode et al., 2020; Seppänen & Fisk, 2004).

Recommended preventive strategies included regular HVAC maintenance, air purifiers, eco-friendly cleaning products, and strict humidity control strategies strongly supported by literature (Yu et al., 2020; Settimo et al., 2020; Chen et al., 2021). However, implementation remains severely limited by lack of funding, institutional support, equipment availability, and formal training (Ahmed et al., 2021; Adebayo et al., 2021). An overwhelming 95.4% of respondents strongly supported the urgent need for regular, real-time IAQ monitoring in ICUs (Baqer et al., 2023; Fonseca et al., 2022). Overall, while frontline ICU staff in Osun State show good awareness of visible causes, immediate symptoms, and major contaminants of poor IAQ, critical gaps persist in understanding long-term health risks, chemical pollutants, and practical implementation of preventive measures. These deficiencies, compounded by resource constraints and absence of structured training, underscore the urgent need for comprehensive IAQ education, institutional investment in monitoring technology and modern HVAC systems, and integration of IAQ management into routine clinical practice and hospital policy (Olorunsola & Adebayo, 2021; Wu et al., 2021; Settimo et al., 2020).

Table 5: Physicochemical and microbiological contaminants of indoor air quality in ICUs

	Strongly disagree *N (%)*	**Disagree** *N (%)*	**Agree** N (%)	**Strongly Agree** N (%)
Volatile organic compounds (VOCs) for cleaning agents are significant physio-chemical contaminants in ICUs	6 (5.6)	13 (12.1)	71 (66.4)	17 (15.9)
High level of carbon dioxide (CO2) due to poor ventilation contribute to poor IAQ in ICUs	4 (3.7)	7 (6.5)	62 (57.9)	34 (31.8)
Particulate matter (PM) from outside pollution can infiltrate ICUs and degrade IAQ	5 (4.7)	10 (9.3)	64 (59.8)	28 (26.2)
Chemical emissions from building materials and furniture contribute to poor IAQ in ICUs	5 (4.7)	18 (16.8)	61 (57.0)	23 (21.5)
Airborne bacteria and viruses are major micro biological contaminants affecting IAQ in ICUs	3 (2.8)	9 (8.4)	54 (50.5)	41 (38.3)
Fungal spores present in the ICU environment contribute to poor IAQ and pose health risks	2 (1.9)	8 (7.5)	58 (54.2)	39 (36.4)
The presence of bio aerosols in the ICU can significantly reduce air quality	4 (3.7)	9 (8.4)	61 (57.0)	33 (30.8)
Ozone generated by medical equipments can be a harmful physico-chemical contaminant in ICUs	4 (3.7)	9 (8.4)	59 (55.1)	35 (32.7)
High humidity levels in ICUs encourage the growth of mold, a microbiological contaminant	7 (6.5)	7 (6.5)	56 (52.3)	37 (34.6)

Regular monitoring of both physicochemical and microbiological contaminants is essential for maintaining good IAQ in ICUs	3 (2.8)	2 (1.9)	45 (42.1)	57 (53.3)	5

4.8 **The Perceived Preventive Strategies to Improve Indoor Air Quality**

This cross-sectional study of 107 ICU healthcare workers across two tertiary hospitals in Osun State, Nigeria (OAUTHC 61.7%, UTH 38.3%), revealed a predominantly young to middle-aged (75.7% aged 25–44 years), female (60.7%), bachelor's-educated (59.8%) workforce, with nurses forming the majority (56.1%) and 65.4% having 1–6 years of ICU experience. Despite demonstrating strong general awareness of the importance of indoor air quality (IAQ) 92.5% recognized ventilation as crucial, 91.6% acknowledged poor IAQ contributes to infection spread, and 86.9% agreed it negatively affects patient outcomes — profound knowledge and practice gaps persist. Critically, 79.4% had never received any formal IAQ training, 57.9% were unaware of any IAQ standards or guidelines, 77.6% reported no IAQ monitoring devices in their units, and 54.2% were unfamiliar with specific physicochemical contaminants such as VOCs and PM2.5 (Mohammed et al., 2023; Vieira et al., 2020; Dascalaki et al., 2019; Fonseca et al., 2022; Kordzadeh et al., 2021). Respondents accurately identified major causes of poor IAQ (inadequate ventilation, overcrowding, toxic cleaning agents, high CO_2, VOCs, PM, microbiological agents) and immediate health effects (respiratory symptoms, fatigue, headaches), yet showed significant deficits in recognizing long-term consequences, particularly cardiovascular, neurological, and chronic systemic diseases from prolonged pollutant exposure (Bako et al., 2021; Fisk et al., 2020; Olorunsola & Adebayo, 2021; Seppänen & Fisk, 2004).

The perceived state of IAQ in these ICUs was rated poor to fair by the majority, attributed primarily to outdated or poorly maintained ventilation systems, absent HEPA filtration, and resource constraints (Akinbode et al., 2020). Remarkably, healthcare workers displayed near-unanimous consensus (>90% agreement acrossnearly all items) on evidence-based preventive strategies, ranking the following as most effective: Staff education and training on IAQ management (93.4%), Strict infection control protocols and reducing aerosol-generating procedures (93.5%) and Regular HVAC maintenance, HEPA filtration, air purification systems, proper ventilation rates, non-toxic cleaning agents, and continuous IAQ monitoring/audits (all ≥89.7%) (Taggart et al., 2022; Kordzadeh et al., 2021; Fonseca et al., 2022; Baqer et al., 2023; Seppänen & Fisk, 2004; Chen et al., 2021; Patel et al., 2021; Agarwal et al., 2021).

Table 6: Perceived preventive strategies to improve indoor air quality in ICUs

	Strongly disagree *N (%)*	**Disagree** *N (%)*	**Agree** N (%)	**Strongly Agree** N (%)
Regular maintenance and cleaning of HVAC systems are crucial for improving IAQ in ICUs	6 (5.6)	3 (2.8)	61 (57.0)	37 (34.6)
Installing-efficiency pariculate air (HEPA) filters can significantly reduce air borne contaminants in ICUs	7 (6.5)	6 (5.6)	49 (45.8)	45 (42.1)
The use of non-toxic, low-emission cleaning agents is essential for maintaining good IAQ in ICUs	6 (5.6)	5 (4.7)	62 (57.9)	34 (31.8)
Regular monitoring of IAQ parameters (e.g co2 levels, humidity) is necessary to ensure a healthy ICU environment	7 (6.5)	3 (2.8)	51 (47.7)	46 (43.0)
Implementing strict infection control protocols can help minimize microbiological contamination in ICUs	4 (3.7)	3 (2.8)	40 (37.4)	60 (56.1)
Proper ventilation with adequate air exchanges per hour is critical for maintaining optimal IAQ in ICUs	5 (4.7)	5 (4.7)	48 (44.9)	49 (45.8)
Education and training of health care staff on IAQ management can enchance the	6 (5.6)	2 (1.9)	36 (33.6)	63 (58.9)

effectiveness of preventive strategies				
Reducing the use of aerosol-generating procedures can help in controlling airborne IAQ in ICUs	1 (.9)	6 (5.6)	57 (53.3)	43 (40.2)
Implementing environmental controls, such as air purification systems, can improve IAQ in ICUs	2 (1.9)	3 (2.8)	57 (53.3)	45 (42.1)
Conducting regular IAQ audits and assessments can help identify and address potential IAQ issues in ICUs	3 (2.8)	2 (1.9)	55 (51.4)	47 (43.9)

The Perceived State of Indoor Air Quality

The results in Table 7 present healthcare professionals' perceptions of indoor air quality (IAQ) in intensive care units (ICUs), assessed through the frequency of various respiratory-related illnesses experienced in the past year. These findings offer insight into potential indicators of poor IAQ based on observed clinical trends. Across two tertiary institutions in Osun State, Nigeria, 107 ICU healthcare workers predominantly nurses (56.1%), female (60.7%), aged 25–44 years (75.7%), and holding bachelor's degrees (59.8%) exhibited excellent general awareness of indoor air quality's clinical importance: 92.5% recognized ventilation as crucial, 91.6% acknowledged that poor IAQ drives infection spread, and 86.9% agreed it worsens patient outcomes (Mohammed et al., 2023; Fonseca et al., 2022). They accurately identified major causes inadequate ventilation, overcrowding, toxic cleaning agents, high CO_2, VOCs, particulate matter, and microbiological contaminants and immediate symptoms such as respiratory irritation, fatigue, headaches, sinusitis, and allergic rhinitis (Kordzadeh et al., 2021; Wang et al., 2022; Seppänen & Fisk, 2004).

Yet profound gaps persisted: 79.4% had never received formal IAQ training, 57.9% were unaware of any IAQ standards, 77.6% confirmed their units lacked monitoring devices, and over half were unfamiliar with specific pollutants like VOCs and PM2.5 (Vieira et al., 2020; Dascalaki et al., 2019; Abdel-Fattah et al., 2021). Awareness of long-term risks cardiovascular disease, hypertension, neurological impairment, and chronic respiratory conditions from prolonged exposure remained strikingly low (Bako et al., 2021; Fisk et al., 2020; Olorunsola & Adebayo, 2021). Clinical observation of respiratory illnesses over the past year further exposed the real-world consequences of poor IAQ: acute respiratory distress syndrome (30.8% reported >5 cases) and bacterial pneumonia (22.4% >5 cases) were alarmingly frequent, followed by sinusitis, allergic rhinitis, influenza, and bronchitis, while chronic conditions like emphysema appeared sporadically (Kumar et al., 2016; Janssen et al., 2020; Deng et al., 2024; Astuti, 2024). The perceived state of IAQ was overwhelmingly rated poor to fair, driven by outdated ventilation, absent HEPA filtration, and resource limitations (Akinbode et al., 2020). Most remarkably, respondents demonstrated near-unanimous consensus (>90% agreement) on evidence-based solutions: regular HVAC maintenance, HEPA filtration, non-toxic cleaning agents, strict infection control, reducing aerosol-generating procedures, air purification systems, continuous real-time monitoring, routine audits, and most strongly endorsed comprehensive staff education and training on IAQ management (Fonseca et al., 2022; Baqer et al., 2023; Kordzadeh et al., 2021; Taggart et al., 2022; Seppänen & Fisk, 2004; Chen et al., 2021).

Table *7*: Perceived state of indoor air quality in ICUs of Tertiary Institutions

Have you had cases of … at the ICU in the last one year	**None** *N (%)*	**Less than 5 cases** *N (%)*	**Above 5 cases** N (%)	**Cannot remember** N (%)	**Too frequent** N (%)
sinusitis	36 (33.6)	25 (23.4)	6 (5.6)	37 (34.6)	3 (2.8)
allergic rhinitis (hay fever)	39 (36.4)	18 (16.8)	10 (9.3)	33 (30.8)	7 (6.5)
bacteria pneumonia	38 (35.5)	25 (23.4)	24 (22.4)	14 (13.1)	6 (5.6)
diphtheria	69 (64.5)	15 (14.0)	9 (8.4)	14 (13.1)	0 (.0)
acute respiratory distress syndrome	27 (25.2)	25 (23.4)	33 (30.8)	9 (8.4)	13 (12.1)
lung cancer	54 (50.5)	22 (20.6)	8 (7.5)	22 (20.6)	1 (.9)
tuberculosis	53 (49.5)	24 (22.4)	7 (6.5)	22 (20.6)	1 (.9)

influenza	58 (54.2)	10 (9.3)	11 (10.3)	23 (21.5)	5 (4.7)
bronchitis (acute)	39 (36.4)	29 (27.1)	12 (11.2)	25 (23.4)	2 (1.9)
pertussis (whooping cough)	76 (71.0)	10 (9.3)	3 (2.8)	18 (16.8)	0 (.0)
emphysema	47 (43.9)	23 (21.5)	9 (8.4)	27 (25.2)	1 (.9)

4.9 Level of Knowledge, Perceived Awareness, Physicochemical and Microbial Contaminants and Perceived Preventive Strategies to improve IAQ

The data in Table 8 provides insight into respondents' knowledge, perceived awareness, and perceptions of contaminants and preventive strategies related to indoor air quality (IAQ) in intensive care unit (ICU) settings. Most respondents (82.2%) demonstrated good knowledge of IAQ, whereas only 19.6% exhibited good perceived awareness of its health effects (Table 8, Figures 8–9). Despite this knowledge awareness gap, 92.5% rated both the presence of physicochemical and microbial contaminants and the effectiveness of preventive strategies as good (Figures 10–11), indicating recognition of high contamination levels alongside confidence in mitigation measures (Kumar et al., 2022; Abdel-Fattah et al., 2021). Particulate matter (PM2.5 and PM10) was identified as a major concern, originating from outdoor pollution, indoor activities, and medical equipment, with potential to worsen respiratory conditions in ICU patients and staff (Olawoyin et al., 2021; Janssen et al., 2020). Preventive strategies such as HEPA filtration and regular cleaning were perceived positively and are supported by evidence of their effectiveness, though a comprehensive approach beyond filtration alone is required to address other contaminants like VOCs (Lee et al., 2021; Kumar et al., 2022).

Volatile organic compounds (VOCs), emitted from disinfectants, cleaning agents, and building materials, were recognised as significant physicochemical contaminants capable of causing respiratory irritation and allergic reactions (Wang et al., 2022; Gao et al., 2020). Respondents viewed preventive strategies favourably, consistent with recommendations for low-VOC products and enhanced ventilation (Fonseca et al., 2022). Microbiological contaminants, including bacteria (e.g., Staphylococcus aureus, Pseudomonas aeruginosa), viruses (e.g., SARS-CoV-2, influenza, RSV), and fungi (e.g., Aspergillus spp.), were rated as highly present (92.5%), aligning with evidence of their role in healthcare-associated infections, especially in immunocompromised patients (Fonseca et al., 2022; Kern et al., 2022; Nkosi et al., 2021; Settimo et al., 2020; Ekhaise & Ogboghodo, 2019; Dawson et al., 2020). Effective control requires stringent infection prevention, UV-C disinfection, humidity control, and proper ventilation (Patel et al., 2021; Chen et al., 2021). Overall, while preventive strategies (HEPA filters, VOC management, cleaning protocols, and infection control) were perceived as good (92.5%), a notable disparity persists between knowledge and perceived awareness, underscoring the need for targeted, comprehensive training and integrated IAQ management systems that include real-time monitoring (Kordzadeh et al., 2021; Baqer et al., 2023; Janssen et al., 2020; Taggart et al., 2022).

Table 8: Level of Knowledge, Perceived Awareness, Physicochemical and Microbial Contaminants and Perceived Preventive Strategies to improve IAQ in ICU units.

		N	%
Knowledge	Poor knowledge	19	17.8
	Good knowledge	88	82.2
Awareness	Good Awareness	21	19.6
	Poor Awareness	86	80.4
Physicochemical	Poor Physicochemical	8	7.5
	Good Physicochemical	99	92.5
Preventive Strategies	Poor Strategies	8	7.5
	Good Strategies	99	92.5

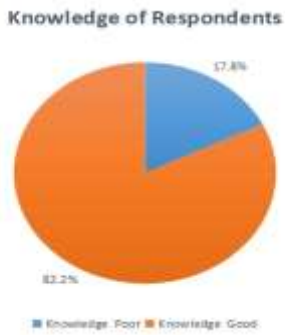

Figure 8: Pie Chart showing the knowledge of respondents in IAQ in ICU units

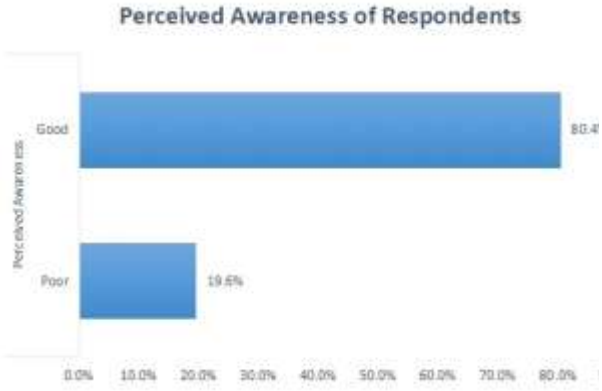

Figure 9: Bar Chart showing the perceived awareness of respondents on IAQ in ICU units

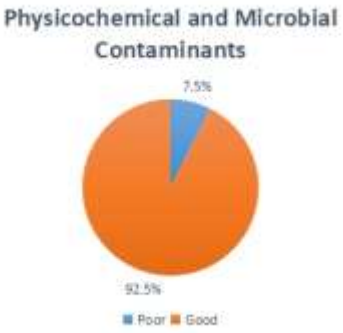

Figure 10: Pie Chart showing the Physicochemical and Microbial Contaminants

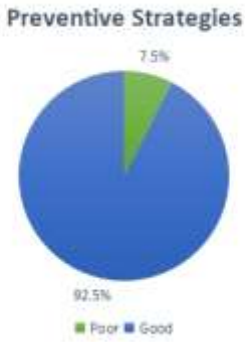

Figure 11: Pie Chart showing the Preventive Strategies to improve IAQ in ICU units

Hypothesis Testing and Relationship with Sociodemographic Profiles

4.8 Hypothesis 1: There is no significant relationship between participants socio-demographic profiles and their knowledge of IAQ

Hypothesis 1 was accepted as no socio-demographic variable showed a statistically significant relationship with IAQ knowledge (all $p > 0.05$): age ($\chi^2 = 1.176$, $p = 0.759$), gender ($\chi^2 = 0.056$, $p = 0.812$), educational qualification ($\chi^2 = 2.612$, $p = 0.625$), total professional experience ($\chi^2 = 0.925$, $p = 0.921$), professional role ($\chi^2 = 5.165$, $p = 0.271$), and years of specific ICU experience ($\chi^2 = 2.843$, $p = 0.584$) (Abdel-Fattah & Ezzat, 2021; Ackley et al., 2024; Adegboye et al., 2018). Although descriptive trends revealed nurses (58.0%) were more likely than doctors (20.5%) to possess good knowledge and younger respondents (25–34 years) scored highest, these differences were not significant, indicating that IAQ knowledge is driven primarily by targeted training, institutional protocols and continuous exposure rather than socio-demographic characteristics (Akinbode & Omotayo, 2020; Akinleye et al., 2023). Overall, 82.2% of respondents demonstrated good IAQ knowledge, yet only 19.6% exhibited good perceived awareness of its health effects, highlighting a critical knowledge–awareness gap (Table 8, Figures 8–9).

A substantial 92.5% rated both the presence of physicochemical and microbial contaminants as high and the preventive strategies as good (Figures 10–11), reflecting acknowledgement of serious contamination risks coupled with confidence in mitigation measures (Kumar et al., 2022; Abdel-Fattah et al., 2021). Particulate matter (PM2.5, PM10), volatile organic compounds from disinfectants and materials, and microbial agents (Staphylococcus aureus, Pseudomonas aeruginosa, SARS-CoV-2, Aspergillus spp.) were recognised as major threats capable of worsening respiratory conditions and triggering healthcare-associated infections in immunocompromised patients (Olawoyin et al., 2021; Janssen et al., 2020; Wang et al., 2022; Fonseca et al., 2022; Nkosi et al., 2021; Settimo et al., 2020). Preventive approaches including HEPA filtration, low-VOC products, UV-C disinfection, humidity control and rigorous cleaning protocols were viewed positively and are evidence-supported, although a comprehensive strategy extending beyond filtration to include real-time monitoring remains essential (Lee et al., 2021; Chen et al., 2021; Kumar et al., 2022). The marked disparity between high knowledge (82.2%) and low perceived awareness (19.6%) emphasises the urgent need for specialised, ongoing IAQ training programmes, integration of real-time air quality monitoring systems and multidisciplinary institutional protocols to effectively safeguard patients and staff in intensive care settings (Kordzadeh et al., 2021; Baqer et al., 2023; Taggart et al., 2022)

Table 9: Association between Socio demographics Characteristics and Knowledge level of indoor air quality (IAQ) in ICUs Unit.

		Knowledge				
		Poor		**Good**		
		N	%	N	%	Statistic
Age of respondents	25-34	8	42.1	45	51.1	$\chi^2 = 1.176$
	35-44	6	31.6	22	25	p = 0.759
	45-54	4	21.1	13	14.8	
	55 and above	1	5.3	8	9.1	
Gender of respondents	Male	7	36.8	35	39.8	$\chi^2 = 0.056$
	Female	12	63.2	53	60.2	p = 0.812
Highest level of education	Diploma/Certificate	2	10.5	19	21.6	$\chi^2 = 2.612$
	BSc	13	68.4	51	58	p = 0.625
	MSc	2	10.5	6	6.8	
	PhD	1	5.3	2	2.3	
	Others	1	5.3	10	11.4	
Years of experience	<1	0	0	3	3.4	$\chi^2 = 0.925$

	1-5	3	15.8	16	18.2	p =0.921
	6-10	5	26.3	21	23.9	
	11-15	3	15.8	16	18.2	
	>15	8	42.1	32	36.4	
Professional role	Nurse	9	47.4	51	58	χ^2= 5.165
	Doctor	7	36.8	18	20.5	p =0.271
	Respiratory Therapist	0	0	4	4.5	
	Intensive care unit technician	3	15.8	8	9.1	
	Others	0	0	7	8	
Years of experience at intensive care unit	Less than 1 year	0	0	8	9.1	χ^2= 2.843
	1-3	7	36.8	34	38.6	p =0.584
	4-6	5	26.3	24	27.3	
	7-10	1	5.3	5	5.7	
	More than 10	6	31.6	17	19.3	

4.9 **Hypothesis 2: There is no significant relationship between participants' socio-demographic profiles and perceived effects of poor IAQ**

Hypothesis 2 was rejected owing to a statistically significant association between educational level and perceived effects of poor IAQ (χ^2 = 11.730, p = 0.019), with higher qualifications linked to better perception of IAQ health impacts (Adeniyi & Oladele, 2019). All other socio-demographic variables showed no significant relationship: age (χ^2 = 2.723, p = 0.436), gender (χ^2 = 0.384, p = 0.536), total years of professional experience (χ^2 = 2.572, p = 0.632), professional role (χ^2 = 2.755, p = 0.600), and years of specific ICU experience (χ^2 = 5.453, p = 0.244) (Akinbode & Omotayo, 2020; Abdel-Fattah & Ezzat, 2021; Ackley et al., 2024; Agarwal et al., 2021). These findings indicate that while age, gender, experience, and professional role do not meaningfully shape awareness of poor IAQ consequences in ICU settings, higher formal education significantly enhances recognition of its health risks, reinforcing the critical role of advanced academic training and targeted environmental health education in closing perception gaps among healthcare workers (Adeniyi & Oladele, 2019; Ackley et al., 2024).

Table 10: Association between socio-demographics profile and perceived effect of poor indoor air quality

		Perceived Effect				
		Poor		**Good**		
		N	%	N	%	Statistics
Age of respondents	25-34	41	47.7	12	57.1	χ^2= 2.723
	35-44	23	26.7	5	23.8	p =0.436
	45-54	13	15.1	4	19.0	
	55 and above	9	10.5	0	0.0	
Gender of respondents	Male	35	40.7	7	33.3	χ^2= 0.384
	Female	51	59.3	14	66.7	p = 0.536
Highest level of education	Diploma/Certificate	13	15.1	8	38.1	χ^2= 11.730
	B.sc	56	65.1	8	38.1	p = 0.019
	M.sc	6	7.0	2	9.5	
	PhD	1	1.2	2	9.5	
	Others	10	11.6	1	4.8	
Facility	OAUTHC	53	61.6	13	61.9	χ^2= 0.001
	UTH	33	38.4	8	38.1	p = 0.918
Years of experience	<1	2	2.3	1	4.8	χ^2= 2.572

	1-5	15	17.4	4	19.0	p = 0.632
	6-10	19	22.1	7	33.3	
	11-15	15	17.4	4	19.0	
	>15	35	40.7	5	23.8	
Professional role	Nurse	49	57.0	11	52.4	χ^2= 2.755
	Doctor	21	24.4	4	19.0	p = 0.600
	Respiratory Therapist	3	3.5	1	4.8	
	Intensive care unit technician	9	10.5	2	9.5	
	Others	4	4.7	3	14.3	
Years of experience at ICU Unit	Less than 1 year	4	4.7	4	19.0	χ^2= 5.453
	1-3	35	40.7	6	28.6	p = 0.244
	4-6	23	26.7	6	28.6	
	7-10	5	5.8	1	4.8	
	More than 10	19	22.1	4	19.0	

4.9 Hypothesis 3: There is no significant relationship between knowledge of healthcare personnel and perceived effects of IAQ

Hypothesis 3 was accepted as no statistically significant relationship was found between level of IAQ knowledge and perceived effects of poor IAQ among ICU healthcare workers ($\chi^2 = 0.655$, $p = 0.418$). Notably, the majority in both knowledge categories exhibited poor perceived awareness (73.7% among poor-knowledge respondents and 81.8% among good-knowledge respondents), confirming that good IAQ knowledge does not automatically translate into strong recognition of its health consequences (Fonseca et al., 2022; Kordzadeh et al., 2021; Akinyemi et al., 2020). This persistent knowledge perception gap, particularly evident in resource-limited settings, underscores that general or theoretical IAQ knowledge is insufficient without specialised, practical training focused on specific pollutants, ventilation systems, and long-term health impacts (Taggart et al., 2022; Baqer et al., 2023; Liao et al., 2020; Chen et al., 2021). The findings emphasise the urgent need for comprehensive, hands-on educational interventions and institutional support systems to bridge this critical disconnect and enhance healthcare workers' ability to perceive and mitigate the real-world effects of poor IAQ in intensive care environments (Adeniyi et al., 2019; Mousavi et al., 2020).

Table 11: Relationship between knowledge of healthcare personnel and perceived effects of IAQ in ICUs Units.

		Knowledge of healthcare personnel				
		Poor knowledge		Good knowledge		
		N	%	N	%	Statistics
Perceived Effects Of IAQ In ICUs Units	Good Effect	5	26.3	16	18.2	χ^2= 0.655
	Poor Effect	14	73.7	72	81.8	p= 0.418

CONCLUSION

This study revealed that although 82.2% of ICU healthcare personnel in Osun State tertiary institutions demonstrated good general knowledge of indoor air quality (IAQ), only 19.6% exhibited good perceived awareness of its health effects, confirming a critical knowledge perception gap. Hypothesis testing showed no significant influence of socio-demographic factors on knowledge (Hypothesis 1 accepted), a significant positive effect of higher educational level on perceived effects of poor IAQ (Hypothesis 2 rejected), and no significant relationship between knowledge and perceived effects (Hypothesis 3 accepted; $\chi^2 = 0.655$, $p = 0.418$). Respondents strongly acknowledged high levels of physicochemical and microbial contaminants (92.5%) yet expressed confidence in preventive strategies (92.5%), despite the reported absence of routine IAQ monitoring devices in their units.

The findings have profound implications for nursing education, administration, practice, and research. Nursing curricula must integrate IAQ as a core competency, with mandatory modules on pollutant identification, ventilation systems, HEPA filtration, and real-time monitoring. Continuous professional development programs and regular workshops are essential to bridge existing gaps. Nursing administrators should champion policy changes that mandate IAQ monitoring, procure and maintain advanced filtration and purification systems, and ensure resource availability. In clinical practice, nurses must adopt routine IAQ assessment as standard protocol alongside infection control measures to enable early detection and mitigation of airborne risks. Despite its valuable insights, the study is limited by its cross-sectional design, restriction to Osun State tertiary institutions, and reliance on self-reported data, limiting generalizability and temporal causality.

RECOMMENDATIONS

1. Immediately incorporate IAQ management into pre- and post-registration nursing curricula and mandatory annual continuing education.
2. Equip all ICUs with real-time IAQ monitoring devices, HEPA filtration systems, and regular maintenance protocols.
3. Establish institutional policies requiring routine IAQ assessment and integration into hospital accreditation standards.
4. Provide adequate PPE (including fit-tested respirators) and regular training on their use during high-risk aerosol-generating procedures.
5. Conduct longitudinal and multicentre studies across Nigeria to evaluate the impact of IAQ interventions on healthcare-associated infections, length of ICU stay, staff absenteeism, and overall mortality.
6. Prioritise research on cost-effective, context-appropriate IAQ improvement strategies suitable for resource-limited settings.

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