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Microbiological indoor air quality and associated factors in private clinics of Harar Town, Eastern Ethiopia

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ABSTRACT

Background: Indoor air pollution, including airborne microorganisms, can cause allergies, respiratory diseases, and immune-toxic diseases. Sneezing generates millions of airborne microbial infections, and ventilation sources alter microbial communities. Few studies exist in developing countries, including Ethiopia, and Harar Town. The aim is to assess microbial indoor air quality and associated factors among private clinics, Harar town, Eastern Ethiopia.

Methodology: A cross-sectional study was conducted on 260 private clinic rooms in Harar town, using a systematic random sampling method and passive air sampling. Data was collected using the settle plate method and an observation checklist. Bivariate and multivariate analysis was performed using binary logistic regression, with a p-value of <0.05 considered statistically significant.

Result: The minimum and maximum bacterial loads were 3933 CFU/m^3 and 92 CFU/m^3, respectively. Based on the pollution degree of the European Commission, the mean bacterial load (904 CFU/m^3), was at higher bacterial load. The highest, lowest, and mean fungal loads were 1967 CFU/m^3, 9 CFU/m^3 and 401 CFU/m^3, respectively. Temperature of <25 °C (AOR = 1.58, p = 0.04, and 95% CI = 1.05, 1.91), >28 °C (AOR = 1.23, P = 0.03, and 95% CI = 1.51, 2.02) were significantly associated with bacterial indoor air quality. Relative humidity of treatment rooms (AOR = 1.87, p = 0.02, and 95% CI = 1.21, 3.09) had an association with bacterial loads. The clinic treatment rooms with a recorded temperature <25 °C (AOR = 6.32, p = 0.01, and 95% CI = 6.10, 8.25) had associated with fungal loads. Anyway, the rooms having a temperature of >28 °C (AOR = 0.41, p = 0.04, and 95% CI = 0.31, 0.78) were 59% less likely to comply with the fungal standards compared to rooms having a temperature of 25–28 °C. The clinic rooms with a relative humidity of <30% (AOR = 7.75, p = 0.02, 95% CI = 7.21, 8.39) were 7.75 times more likely to comply with those with a relative humidity of > 60% in the treatment rooms.

Conclusion: Private clinics in Harar had a moderate fungal load and a higher indoor air bacterial concentration when compared to different indoor air standards. Temperature, humidity, inadequate ventilation and the presence of unsanitary attached toilets are some variables associated with microbial loads.

Recommendation: When constructing private clinics in Harar town, it's crucial to integrate building maintenance practices from the outset for durable, easy to clean materials to prevent microbial growth. Ensure proper ventilation, and lighting, for optimal indoor air quality. Regular cleaning, pest control, and staff training are essential for maintaining a hygienic environment. A well-designed and well-maintained clinic contributes indoor air quality.

Key words: indoor air, indoor air quality, microbial load, bacteria load, fungi load, settle plate method

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Ethics approval and consent to participate: Ethics authorization for this study was obtained by the Institutional Health Research Ethics Review Committee (IHRERC) of the College of Health and Medical Sciences, Haramaya University. Informed consent was given by all the owners of the clinics and the regional health bureau.

Availability of data and material: This study has almost all of the data. Nevertheless, upon justifiable request, the corresponding author will provide more information.

Conflict of interest: The writers affirm that they have no competing interests.

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Introduction

The air inside a building that has been inhabited by individuals in different states for at least an hour is referred to as indoor air [1]. The term "indoor air quality" describes the state of the air inside and around buildings and other structures, with a focus on how it affects the comfort and health of those who live there [2]. People spend most of their time inside buildings [3]. Breathing an average of 14 m^3 of air per day is very important to determining a healthy life [4]. The indoor environment is a fundamental factor capable of impacting the health, well-being, and productivity of people [5].

Pollution of indoor air quality is a world problem, especially in developing countries. Everywhere they continue to become a significant cause of death and also outdoor contaminants that aggravate indoor air pollution, especially in many communities in developing countries, where death and illness from acute respiratory infections have been accepted as part of life, which has to be tolerated [5].

Globally, 3.8 million deaths were attributed to indoor air pollution in 2016. More than 90% of air pollution-related deaths occur in low- and middle-income countries, mainly in Asia and Africa, followed by low- and middle-income countries of the Eastern Mediterranean region, Europe, and the Americas [6]. Bio aerosols contribute about 5–34% of indoor air pollution [7].

Air in the indoor environment can be polluted by a number of pollutants, among which airborne microorganisms (bacteria and fungi) are one of the most important. It has been estimated that one-third of indoor air quality complaints may be due to microbial contamination [8]. Exposure to these may cause allergies, respiratory diseases, and immune-toxic diseases [9]. Clean, fresh air is the most important requirement for good indoor air quality in all buildings, but it is especially important with regard to the environments within hospitals and other healthcare facilities [10].

The quality of air in health care in relation to microbial contamination at a given time period is determined by the quality of air entering the building, the number of occupants in the building, their physical activities and resultant aerosol generation, human traffic, and the efficiency of ventilation [11]. In a healthcare environment with a high risk of being infected, sneezing has been described as the most vigorous mechanism of generating millions of airborne microbial infections in the healthcare environment [12]. Additionally, human occupancy inside buildings increases the number of bacteria in the air and leaves a distinct human microbial signal [13]. Ventilation source alters microbial communities, regardless of ventilation rates, in a hospital setting [14].

The study of airborne microorganisms in an indoor environment is important because it brings about an understanding of the population of airborne microbes in the healthcare environment. The healthcare facilities where patients are treated have an influence on the health of the patient who is recovering from or acquiring an infection that may complicate or increase the condition of the patient [15].

The problem of inadequate housing conditions has been a problem in developing countries like Ethiopia, and poorly ventilated rooms, which affect human health to a greater or lesser degree, are the problem of many institutions; and this, in turn, increases the transmission of airborne disease, resulting in an excessive number of deaths [5].

Studies conducted in Ethiopia revealed that the high microbial load in the hospital wards increased the risk of infection. According to studies conducted in hospitals in Hawassa, Gonder, Jimma, and Adama, the microbial air quality was typically higher than the sanitary requirements set by the European Commission for non-industrial premises (500–2000 CFU/m^3 as a high range) [16-19].

It is very crucial to assess the microbial loads and contributing factors to this high level of microbial load within healthcare facilities. However, the lack of studies on microbial load in private clinics is a significant gap in the literature, as private clinics are an essential component of the healthcare system in Ethiopia. Therefore, more research is needed to determine the microbial load in private clinics in Harar town, because, to author's knowledge, no such study has ever been conducted in Harar town. Therefore, the aim of this study was to assess microbial indoor air quality and factors affecting the microbial quality in private clinics.

Methods and Materials

Study area and period

An institutional based quantitative cross sectional study was conducted from September 13 to October 13, 2023 in Harar town. All the 50 private clinics in Harar town (inpatient rooms, outpatient rooms, maternal and child health rooms, offices and patient waiting rooms of the selected private clinics) were included in the study.

Source population and study populations

All the 50 private clinics in Harar town were the source population and all inpatient rooms, outpatient rooms, maternal and child health rooms, offices and patient waiting room of the selected private clinics were the study population.

Selection criteria

Inpatient rooms, outpatient rooms, offices and patient waiting rooms currently functional were included in the study, whereas rooms that are temporarily non-functional were excluded.

Sample size determination

The sample size was determined by using single population proportion formula with proportion of 50% which is the maximum sample size in the absence of study about the proportion of microbial loads below and above the WHO (1000 CFU/m^3) standards, 95% confidence interval and 5% margin of error.

$$n= ((Z\alpha_{/2})^2.P\ (1- p))/d^2$$

Where: n: is the minimum sample size required for the study. Z is the standard normal distribution ($Z\alpha/2=1.96$) with confidence interval of 95%. d: is the absolute precision or tolerable margin of error (5%). $n = (3.8416\times0.5\times0.5)/ (0.05)^2=384$.

Reduction formula was used since the total number of rooms was 607 which is less than 10,000. 10% contingency was added and finally the sample size was ***260.***

Sampling procedure and sampling technique

Stratified random sampling procedure was used to draw samples. From each level of the private clinic, sampling rooms was drawn proportionally (Figure 1). Each room was selected through systematic random sampling and all rooms (inpatient, outpatient, offices and patient waiting) have equal chance to be selected with (K= 4)

Data collection instruments and procedure

Blood agar and potato dextrose agar media were used for bacterial and fungal samples collections;

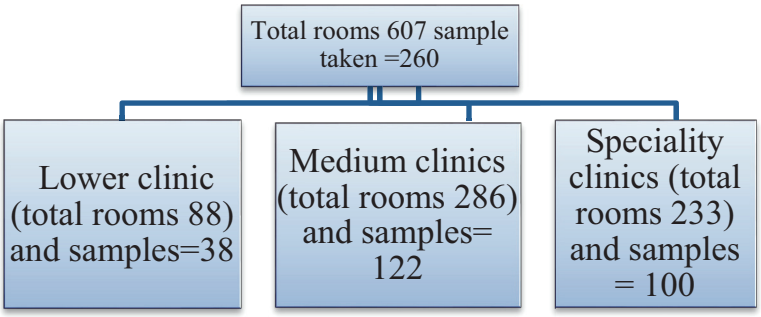

Figure 1. Stratified random sampling procedure based on level of clinic.

Observational cheek list was used to assess the contributing factors such as ventilation system, crowdedness, room cleanness, and number of visitors, number of windows, room area, relative humidity, and temperature. The room temperature and relative humidity were measured by electrical aerator instrument.

Microbial air quality sampling was collected with settle plates (also called settling plates or sedimentation plates) method. The culture media was opened and placed side up on 1 meter above the floor which is the human breathing zone, and 1 meter from any walls and other obstacles, and collect settled particles onto the plates for 1 hour exposure time (1/1/1 principle) [20]. Sheep blood agar and potato dextrose agar was applied to grow bacterial and fungal colony, respectively. Prior to the data collection, the blood agar and the potato dextrose agar were prepared and sterilized with petri dish, forceps, and other materials at 121°C for 15 minutes. The sterilized media was poured to the 9 cm diameter petri dish aseptically and leveled immediately. Then, the media was transported to the data collection site with ice box. At the site of data collection, the media was opened and exposed for air to settle the aerosols to the media for one hour exposure time and the control group was kept closed. Then, the exposed petri dish were capped with control media aseptically and transported to the Haramaya university environmental health science laboratory for incubation. Finally, the bacterial and fungal samples with controls were incubated for 24 hours and 7 days at 37 °C respectively. The sample was collected two times a day in the morning and afternoon.

Study variables

Dependent variable: Bacterial load (CFU/m^3) and Fungal load (CFU/m^3).

Independent variable: Ventilation system, Waste management, Cleaning frequency, Temperature and Relative humidity.

Data quality control

Training was given to data collectors, supervisors and lab technicians before data collection. To keep the quality of the sample, the media were transported through use of an ice box. Control group was used to determine presence of contamination. Pretest was performed on 5% [13] private clinics of Dire Dawa city to maintain the quality of observational checklists.

Data analysis

After incubation the total number of colony forming units (CFU/plate/hr.) for bacterial and fungal air flora was enumerated and converted to organism's colony forming unit per cubic meter (CFU/m^3) through use of the following formula. $N=5a*104(bt)^{-1}$ [21]. Where N=bacterial CFU/m^3 of indoor air; a = number of colonies per petri dish; b = dish surface area (cm^2); and t = exposure time (minutes).

The data were entered to epi-data version 4.6 and exported to SPSS for further analysis logistic regression model was performed. The Chi-square test was used for categorical variables. A logistic regression model was used for both bivariate & multivariate

analysis in order to identify associated categorical independent variables with the indoor microbial load (grouped based on WHO standard <1000CFU/m^3 and >1000CFU/ m^3) [22]. Those categorical variables with a significant association (p<0.25) with the microbial load in the binary logistic regression analysis was entered in to multivariate logistic regression model. The findings were expressed in AOR with 95% CIs and significant level was considered at p<0.05 and the result were organized, summarized, and presented using graphs and tables.

Results

Indoor microbial load

The highest mean bacterial load (904 CFU/m^3) was recorded in the injection room. The highest bacterial load was 3933 CFU/m^3 recorded in the afternoon in the injection room of one of the specialty clinics. The lowest bacterial load (92 CFU/m^3) was recorded in the morning in the laboratory room of a specialty clinic (Figures 2, 3).

The mean fungal load (401 CFU/m^3) was recorded in the emergency room of a specialty clinic. The highest and lowest fungal loads (1967 CFU/m^3 and 9 CFU/m^3) were recorded in the afternoon in the administration office of the specialty clinic and in the morning in the patient waiting room of the specialty clinic, respectively (Figures 2, 3).

Based on the World Health Organization (WHO) standards [22] for indoor air microbial loads in public institutions, good bacterial indoor air quality (< 1000 CFU/m^3) and poor bacterial indoor air quality (> 1000 CFU/m^3) were assessed in the study. 120 (46.15%) treatment rooms had good bacterial quality, and 140 (53.85%) of them had poor bacterial quality. Similarly, World Health Organization sets fungal indoor air quality standards in public institutions, including health care facilities. The number of class rooms with good fungal indoor air loads (< 500 CFU/m^3) and poor fungal indoor air loads (> 500 CFU/m^3) was 150 (57.7%) and 110 (42.3%), respectively.

Comparison of microbial load

A one-way ANOVA (Analysis of variance) was done to verify that there may be variability in

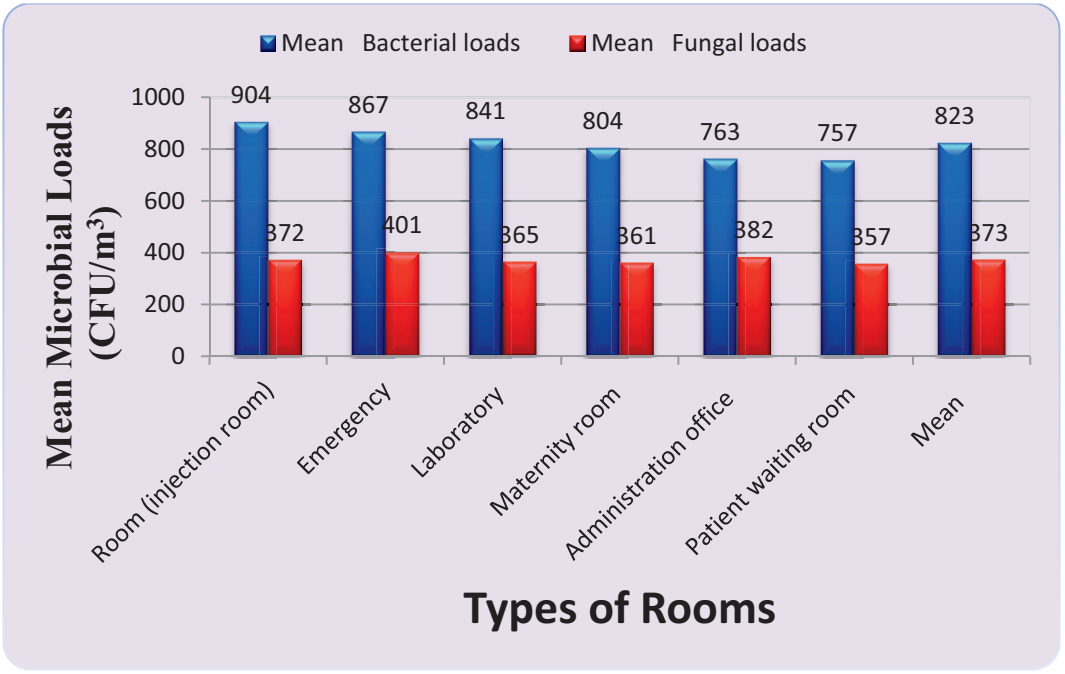

Figure 2. Mean microbial load of private clinics based on their rooms, Harar town, Eastern Ethiopia, 2022 (n = 260).

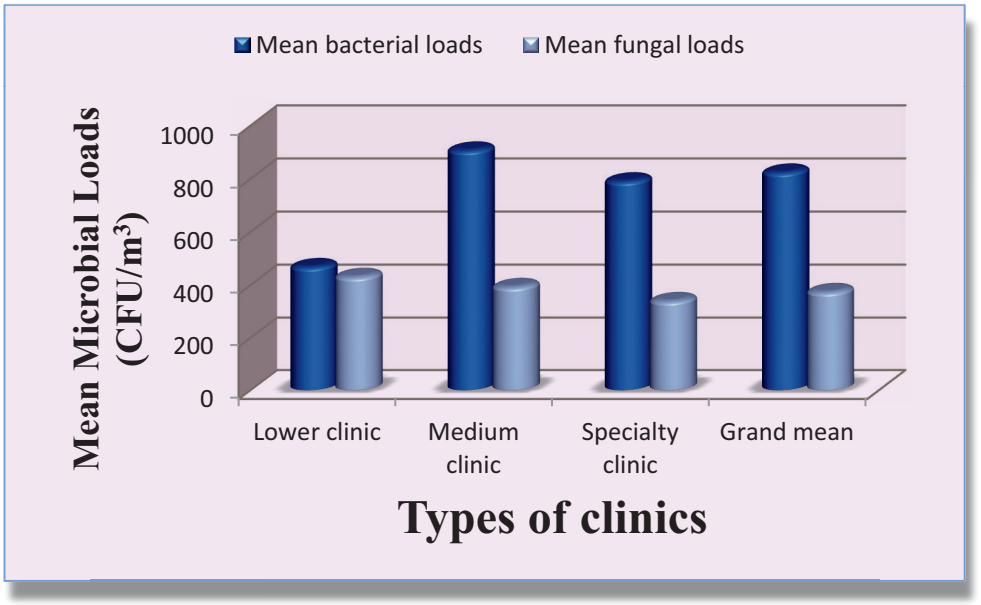

Figure 3. Mean microbial indoor air load of private clinics based on the type of clinics, Harar town, Eastern Ethiopia, 2022 (N = 260).

bacterial loads and fungal loads among the statuses of clinics (lower, medium, and specialty clinics). The ANOVA result shows there is variability in bacterial loads between the status of clinics (N = 18, df = 17, $F_{calculc.}$ = 4.04, $F_{critical}$ = 3.68, and P = 0.04) (Table 1).

Anyway, there is no difference in fungal loads based on the ANOVA result done to evaluate whether there is variability in fungal load between clinics (N = 18, df = 17, $F_{calculc.}$ = 2.46, $F_{critical}$ = 3.68, and P = 0.12) (Table 2).

According to the European Commission sanitary standards for non-industrial premises, the air quality in the sampling rooms was between intermediate and high for fungi and bacterial loads, respectively (Table 3).

Factors affecting indoor microbial load

The microbial loads in private clinics can be influenced by a variety of environmental conditions. Temperature, relative humidity, ventilation system, waste management, cleaning frequency, and other related variables were assessed and described. Based on the assessment result, the minimum and maximum temperatures recorded during data collection were 19°C and 31°C, respectively, and the mean temperature was 26.61°C. The mean, minimum, and maximum relative humidity was 64.63%, 59%, and 68%, respectively.

101 (38.8%) of the treatment rooms assessed had a temperature of less than 22°C, 123 (47.3%) rooms had a temperature of 22–26.1 °C, and the remaining 36 (13.8%) treatment rooms had a temperature of greater than 26.1°C. In the same way, there are treatment rooms below, above, and within the safer relative humidity for microbial growth. The number of treatment rooms below the standard (<30%), within the standards (30–60%), and above the standards (>60%) was 94 (36.15%), 123 (47.3%), and 43 (16.5%), respectively.

Chi-square test was used for environmental factors association with indoor microbial loads. The result of the chi-square revealed that cleanliness of toilets and showers (df = 4, p = 0.05), proper use of windows (df = 1, p = 0.02), frequency of cleaning (df = 4, p = 0.002), general cleanliness of the treatment rooms (df = 3, p = 0.04), and presence of mites and rodents (df = 1, p = 0.05) were associated with the bacterial loads. In the same way, proper use of windows (df = 1, p = 0.01) and cleanliness of the room (df = 3, p = 0.002) were

Table 1. One-way ANOVA result for mean bacterial loads between the status of clinics (lower clinics, medium clinics, and specialty clinics), Harar town, Eastern Ethiopia, 2022 (N = 18).

Summary						
Groups	*Count*	*Sum*	*Average*	*Variance*		
Lower clinics	6	2802	467	53287.6		
Medium clinics	6	5436	906	121226.8		
Specialty clinics	6	4740	790	56034.8		
ANOVA						
Source of Variation	*SS*	*df*	*MS*	*F*	*p-value*	*F crit*
Between Groups	621012	2	310506	4.04	0.04	3.68
Within Groups	1152746	15	76849.73			
Total	1773758	17				

SS, sum of squares; df, degree of freedom; MS, mean of squares; Fcrit., F critical; Fcalc., F calculated.

Table 2. One-way ANOVA result for the mean fungal loads between the status of clinics (lower clinics, medium clinics, and specialty clinics), Harar town, Eastern Ethiopia, 2022 (N = 18).

Summary						
Groups	*Count*	*Sum*	*Average*	*Variance*		
Lower clinics	6	2580	430	1358		
Medium clinics	6	2350	392	3134.27		
Specialty clinics	6	2034	339	10793.6		
ANOVA						
Source of Variation	*SS*	*df.*	*MS*	*F*	*p-value*	*F crit.*
Between Groups	25048.44	2	12524.22	2.46	0.12	3.68
Within Groups	76429.33	15	5095.29			
Total	101477.78	17				

Table 3. Assessment of air quality in the sampling rooms of private clinics in Harar town, Eastern Ethiopia, according to European Commission sanitary standards for non-industrial premises [23].

	Bacterial loads					**Fungal loads**				
	<50	**51-100**	**101-500**	**501- 2000**	**>2000**	**<25**	**26-100**	**101-500**	**501- 2000**	**>2000**
Rooms	**Very Low**	**Low**	**Intermediate**	**High**	**Very high**	**Very Low**	**Low**	**Intermediate**	**High**	**Very high**
Maternity room				✓				✓		
				✓				✓		
Laboratory room				✓				✓		
				✓				✓		
Emergency room				✓				✓		
				✓				✓		
Injection room				✓				✓		
				✓				✓		
Administration room				✓				✓		
				✓				✓		
Patient waiting room				✓				✓		
				✓				✓		

Table 4. Chi-square (X^2) result of microbial load with a cut point of 1000 CFU/m^3 and the associated factors in private clinics, Eastern Ethiopia, 2022.

Factors	Microbial load	Chi-square test value (χ^2)	(df)	p-value
Cleanliness of the toilet and shower during data collection	Bacterial	7.83	4	0.05
	Fungal	0.99	4	0.61
Proper use of window	Bacterial	8.34	1	0.02
	Fungal	12.03	1	0.01
Frequency of cleaning	Bacterial	34.95	4	0.002
	Fungal	3.70	4	0.59
Cleanliness of the room	Bacterial	8.24	3	0.04
	Fungal	10.69	3	0.002
Presence of mites and rodent	Bacterial	8.03	1	0.05
	Fungal	7.88	1	0.78

associated with the fungal loads in treatment rooms of private clinics (Table 4).

Based on the result obtained from the multivariate logistic regression analysis, treatment rooms recorded with a temperature of <25 °C (AOR = 1.58, 0.04, and 95% CI = 1.05, 1.91) were 1.58 times more likely to comply with the WHO standard of bacterial indoor air quality compared to those treatment rooms with a temperature of 25–28 °C. Similarly, clinic rooms with a temperature of >28 °C (AOR = 1.23, p = 0.03, and 95% CI = 1.51, 2.02) were 1.23 times more likely to comply with the standards compared to those with a room temperature of 25–28 °C. Furthermore, the relative humidity of treatment rooms during data collection was associated with bacterial quality, as the clinic rooms with a relative humidity of < 30% (AOR = 1.87, p = 0.02, and 95% CI = 1.21, 3.09) were 1.87 times more likely to comply with the bacterial quality standard when compared to the safe relative humidity of bacterial growth (30–60%). Likewise, clinic rooms with a relative humidity of >60% were 1.35 times more likely to comply with good indoor air bacterial quality compared with clinic rooms with a relative humidity of 30–60%. On the other hand, the absence of showers and toilets near the treatment rooms (AOR = 0.51, p = 0.04, and 95% CI = 0.30, 0.83) was 49.4% less likely to increase the bacterial loads to the safe level (Table 5).

According to the bivariate analysis, construction activity near the clinics, waste damping site near the room, presence of visible cracks in the room celling, presence of waste entering the room, temperature, and relative humidity showed p values less than 0.25 and thus became candidates for multivariate analysis. In multivariate logistic regression, the clinic treatment rooms with a recorded temperature <25°C (AOR = 6.32, p = 0.01, and 95% CI = 6.10, 8.25) were 6.32 times more likely to comply with the fungal quality standard of WHO compared to rooms having a temperature of 25–28°C. The rooms having a temperature of >28°C (AOR = 0.41, p = 0.04, and 95% CI = 0.31, 0.78) were 59% less likely to comply with the fungal standards compared to rooms having a temperature of >28°C. Similarly, the relative humidity of the clinic rooms had associations. The clinic rooms recorded with a relative humidity of <30% (AOR = 7.75, p = 0.02, 95% CI = 7.21, 8.39) were 7.75 times more likely to comply with those with a relative humidity of > 60% in the treatment rooms. Other environmental factors have associations with the fungal loads; the multiple regression result identifies that the absence of visible cracks on ceilings (AOR = 1.112, p = 0.04, and 95% CI = 1.02, 1.78) was 1.1 times more likely to comply with fungal standards compared to the presence of visible cracks on ceilings. The absence of waste entering the treatment rooms from the outside environment (AOR = 0.8, p = 0.02, and 95% CI = 0.01, 0.94) was 20% less likely to comply with the WHO fungal load standard compared to the presence of waste entering the treatment rooms (Table 6).

Table 5. Bivariate and multivariate logistic regression analysis results of bacterial indoor air quality and its associated factors in private clinics, Harar town, Eastern Ethiopia, 2022 (N = 260).

		Compliance with WHO bacterial quality standard (CFU/m^3)				
Variables	**Category**	**Good (< 1000)**	**Poor (> 1000)**	**p-value**	**COR (95% CI)**	**AOR (95% CI)**
Presence of shower and toilet near the clinics	Yes	52 (20%)	82 (31.5%)		1	1
	No	68 (26.2%)	58 (22.3%)	0.04	0.54 (0.34-0.79)	0.51 (0.30,0.83)
Presence of play ground near the clinics	Yes	62 (23.9%)	62 (23.8%)	0.74	1.34 (0.86, 1.45)	1.906 (0.64,1.80)
	No	58 (22.3%)	78 (30%)		1	1
Presence of waste damping near the clinic	Yes	76 (29.1%)	82 (31.5%)		1	1
	No	38 (24.7%)	58 (22.3%)	0.04	1.41 (0.90, 2.06)	0.95 (0.28, 0.98)
Presence of artificial ventilation	Yes	22 (8.5%)	24 (9.2%)	0.81	0.90 (0.47, 1.08)	1.06 (0.66,1.68)
	No	118 (45.3%)	116 (44.6%)		1	1
Temperature [24]	<25 ˚C	74 (28.5%)	27 (10.4%)	0.04	1.41 (1.21, 1.78)	1.58 (1.05, 1.91)
	25 – 28˚C	32 (12.3%)	91 (35%)		1	1
	>28˚C	14 (5.4%)	22 (8.4%)	0.03	1.02 (1.09, 1.15)	1.23 (1.51, 2.02)
Relative humidity [25]	<30%	65 (25%)	29 (11.2%)	0.02	2.02 (1.09, 2.25)	1.87 (1.21, 3.09)
	30 – 60 %	36 (13.9%)	87 (33.5%)		1	1
	>60%	19 (7.3%)	24 (9.1%)	0.04	1.69 (1.01, 2.07)	1.35 (1.01, 1.91)

COR, crude odds ratio; AOR, adjusted odds ratio; CI, confidence interval.

Table 6. Bivariate and multivariate logistic regression analysis results of fungal indoor air quality and its associated factors in private clinics, Harar town, Eastern Ethiopia, 2022 (N = 260).

		Compliance with WHO fungal quality standard (CFU/m^3)				
Variables	**Category**	**Good (<500)**	**Poor (>500)**	**p– value**	**COR (95% CI)**	**AOR (95% CI)**
Construction activity near the clinics	Yes	87 (33.5%)	45 (17.3%)		1	1
	No	66 (25.4%)	62 (23.8%)	0.14	1.84 (0.86,1.96)	3.24 (0.69,15.11)
Waste damping site near the room	Yes	51 (19.6%)	34 (13.1%)		1	1
	No	102 (39.2%)	73 (28.1%)	0.61	1.07 (0.96,2.06)	1.455 (0.34,6.21)
Presence of visible crack in the room celling	Yes	25 (9.6%)	28 (10.8%)		1	1
	No	128 (49.2%)	79 (30.4%)	0.04	0.55 (0.22, 1.44)	1.112 (1.02, 1.78)
Presence of waste enter to the room	Yes	32 (12.3%)	32 (12.3%)		1	1
	No	121 (46.6%)	75 (28.8%)	0.02	0.62 (0.19, 1.08)	0.8 (0.01,0.94)
Temperature	<25 ˚C	74 (28.5%)	27 (10.4%)	0.01	6.97 (5.94, 7.35)	6.32 (6.10, 8.25)
	25 – 28 ˚C	32 (12.3%)	91 (35%)		1	1
	>28 ˚C	14 (5.4%)	22 (8.4%)	0.04	0.25 (0.12, 0.93)	0.41 (0.31, 0.78)
Relative humidity	<30%	65 (25%)	29 (11.2%)	0.02	8.3 (7.52, 8.90)	7.75 (7.21, 8.39)
	30 – 60 %	36 (13.9%)	87 (33.5%)		1	1
	>60%	19 (7.3%)	24 (9.1%)	0.04	0.21 (0.20, 0.09)	0.23 (0.15, 0.97)

Discussion

The microbial indoor air quality in clinics is the reflection of the hygiene quality and construction standards of private clinics. In this study, the highest mean bacterial load was 906 CFU/m^3 which was recorded in medium clinics. The grand total mean recorded in all types of the clinics was 823 CFU/m^3. This finding is lower as compared with the study done in Jimma University specialized hospital (3356.5 CFU/m^3) [26], Hawassa (1943.85 CFU/m^3) [27] and Arba Minch (1914 CFU/m^3) [24]. This deviation might be due to low patient loads in private clinics, relatively good ventilation, and high quality standard of construction in private clinics than government hospitals, unsafe temperature and relative humidity for bacterial growth in the treatment rooms of the clinics.

The highest bacterial load in this study was 3933 CFU/m^3, and the lowest bacterial load was 92 CFU/m^3. This result was higher than the study conducted in a tertiary hospital in India, with the highest bacterial loads of 1179 CFU/m^3 and the lowest bacterial loads of 65.52 CFU/m^3 at 60 min exposure. This discrepancy may be due to the standards of private clinics and tertiary hospitals [22].

The highest mean bacterial load (904 CFU/m^3) was recorded in the injection room, and the lowest mean bacterial load (757 CFU/m^3) was recorded in the patient waiting room. Our study showed higher mean bacterial loads compared to an assessment conducted in a public hospital in the city of Agadir, Morocco, which had the highest average concentration of bacterial colony counts (393 CFU/m^3) and the lowest average of the total bacterial colony counts recorded (109 CFU/m^3). This variation might be because the quality and standards of treatment rooms in hospitals and private clinics were different in the two study areas [29].

This result showed that the grand mean fungal load in all clinics and treatment rooms was 373 CFU/m^3. This finding is higher when compared with the study conducted in India (262 CFU/m^3) [22], Nigeria (160 CFU/m^3) [28]. This might be due to the high environmental quality of Indian and Nigerian health institutions, but, particularly lower than the study conducted in Jimma [19] and Arba Minch [24], The highest fungal load in this study may be due to the unhygienic condition of the room, not opening the door or window.

The highest and lowest mean fungal loads were recorded (401 CFU/m^3 and 351 CFU/m^3) in different treatment rooms, respectively, which was higher than a similar study done in a public hospital in the city of Agadir, Morocco, which stated that the highest and lowest average fungal colony counts were 176 CFU/m^3 and 29 CFU/m^3, respectively. This difference might be due to the standard difference between clinics and hospitals and the environmental hygiene difference [29].

Comparing the sanitary standards of the European Commission for non-industrial premises [16] in this study, the indoor microbial load of rooms in private clinics in Harar was not in hygienic conditions. This might be due to an insufficient ventilation system and favorable temperature and relative humidity for the growth of microorganisms.

Regarding the associated factors, presence of unsanitary toilets and showers near the rooms, presence of damped waste, temperature and relative humidity were associated with bacterial quality of the clinic rooms. In the same way, entrance of waste from the external environment, presence of visible cracks in the room ceiling, temperature and relative humidity were significantly associated with fungal loads in private clinics. A previous study done in Arbaminch General Hospital [24] shows cleanness of the room had association with microbial loads, but temperature was not associated with microbial loads. This difference might be due to differences in ventilation status and having different standards in hospitals and private clinics.

This study shows that presence of unhygienic showers and toilets near the treatment rooms have implications on the bacterial loads as it raises the bacterial load by 49%. The construction of showers and toilets should be at reasonable distance and the hygienic status should be maintained in its quality [16].

Conclusion

Private clinics in Harar had a moderate fungal load and a higher indoor air bacterial concentration when compared to different indoor air biological standards. There are a number of environmental factors that could be contributing to this microbial load,

including temperature, humidity, inadequate ventilation, the presence of unsanitary attached toilets and a subpar waste management system, the presence of showers and toilets close to the clinics, and the presence of waste damping sites.

Recommendation

The Harar Health Bureau and private clinic management are required to conduct routine site inspections to see whether any conditions exist that could encourage the growth of bacteria and fungi, such as leaks and other sanitation issues or the presence of waste entering treatment rooms. The clinics must be constructed based on the health standards set by the Ethiopian Food, Medical, and Health Care Authority. When constructing private clinics in Harar town, it's crucial to integrate building maintenance practices from the outset for durable, easy-to-clean materials to prevent microbial growth. Ensure proper ventilation, and lighting, for optimal indoor air quality. Regular cleaning, pest control, and staff training are essential for maintaining a hygienic environment. A well-designed and well-maintained clinic contributes indoor air quality.

Limitation of the study

The study's use of passive sampling was one of its shortcomings. Due to the nature of passive air sampling techniques, environmental conditions may affect the quality of passive sample collection, and reverse diffusion may inadvertently overestimate or underestimate the microbial load. The second constraint is the cross-sectional study methodology, which has limitations of its own because it does not demonstrate patterns over time. The seasonal variation was not considered. Bacterial isolation was not done because of time and media constraints. This study didn't include chemical indoor air pollutants like CO_2, particulate matter, oxygen concentration and carbon monoxide samples because of the absence of sampling instruments. Antimicrobial susceptibility tests were not done because of shortages of time and trained manpower. This study did not investigate the disease caused by high bacterial and fungal loads.

Abbreviations

AOR: Adjusted odd ratio
ANOVA: Analysis of Variance
am: Antemeridian
CDC: Centers for Disease Control and Prevention
cm: Centimeter
X^2: Chi-square
CFU/m^3: Colony forming unit per Cubic meter
CI: Confidence interval
COR: Crude odds ratio
°c: Degree Celsius
Df: Degree of freedom
EPA: Environmental Protection Agency
G: Gram
g/l: Gram per liter
Hrs: Hours
IAQ: Indoor Air Quality
MS: Mean of Squares
Ml: Milliliter
pm: Post meridian
SPSS: Statistical Package for Social Science
$F_{calculc}$: Student F-test calculated
$F_{critical}$: Students F- test critical
SS: Sum of squares
WHO: World health organization.

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