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Fungal indoor Air Quality and Associated Factors in Prison Inmate Cells of East Hararghe Zone and Harari Regional State, Eastern Ethiopia, 2020

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Abstract: The presence of fungi inside of buildings and structures is referred to as fungal indoor air quality. Infections, fragments of fungal cells, and metabolites of fungal organisms can all provide significant challenges in indoor structures, including prison inmate cells. In East Hararghe and Harari regional state, there is no evidence of a fungal load or associated factors in prisons. The purpose of this study was to evaluate the fungal indoor air quality and related factors in prison inmate cells. An Institution based cross-sectional study was conducted. The source and study population were all prisoner cells located in the East Hararghe zone and Harari regional state prisons. 62 prisoner cells were used in the investigation. The approach of non-random sampling was applied. Passively settle able plates were used to collect the samples (Koch sedimentation method). ANOVA, correlation, and chi-square statistical tests were used to examine the row data using SPSS statistical software and Microsoft Excel. The fungal concentrations were highest at 8:00 pm (537 CFU/m^3) and lowest at 2:00 pm (115 CFU/m^3), respectively. The number of people was poorly connected with the fungal load (r=0.192 and p=0.039), and there was a significant positive weak correlation between the fungal load and temperature (r= 0.275, P=0.031). In contrast, a significant positive correlation between the fungal load and relative humidity in prisoner cells was discovered (r = 0.983; p = 0.004). In conclusion, the fungal concentrations were in the intermediate region (<500CFU/m^3) except in one inmate cell of the investigated prisons. This study indicates that, it may pose threats to inmates. As a result, both the Harari region and the eastern Haragie zone prison offices should take action to address the issue. The prison facility needs to be restructured in accordance with current requirements.

Keywords: Fungi, Fungal Load, Indoor Air Quality, Settle Plate, Prison Inmate Cells

1. Introduction

Air, one of the five primary vital elements of life is usually available with a relatively high rate of impurities known as air pollutants. The presence of these unwanted particles and materials in the air can harm human health and other living things [1]. Indoor air quality is the quality of air within and around buildings and structures. It is also represented by temperature, humidity, ventilation and chemical or biological

contaminants of the air inside the building [2].

Dwellers spent 90% of time their time in door. Hence, this huge amount of exposure time and the air quality within it affects the health, comfort and wellbeing of building occupants. Poor indoor air quality causes sick building syndrome, reduced productivity and impaired learning in schools [3, 4]. Indoor air quality can be affected by gases, particulates, microbial contaminants and any stressors that can include adverse health conditions. Source control, filtration and the use of ventilation to dilute the contaminants are the primary methods to improve indoor air quality in most buildings [4]. Globally, 2.7% of burden of diseases was directly caused by indoor air pollutants [5].

Microbial pollution of indoor air involves specious of microbes such as bacteria and fungi that grow indoors when sufficient moisture is available; which are outsourced from outdoors and indoors. They also include a wide variety of microbes and allergens that spread from person to person. The presence of many fungal agents in the indoor environment is due to the presence of dampness, inadequate ventilation and excess moisture. Exposure to fungal contaminants thus clinically associated with respiratory symptoms and allergies asthma [6].

A prison is a facility in which inmates are forcibly confined and denied a variety of freedoms under the authority of the state. A prison cell is where prisoners spend the majority of their time when not engaged in activities such as programs, education or prison work. Prisoners will sometimes spend a lot of time in their cell due to limited access to association or work [7].

Most prisons built for public safety but not to maximize health in the world. They are built with lack of sanitation facilities like water, soap and laundry. Overcrowding, sharing toilets, showers, cells and food, poor personal hygiene, poor food handling practice inadequate ventilation, lack of knowledge and limited access for diagnosis and treatment of cases can be the major factors for the spread of diseases in prisons. These health problems in prisons can affect the health and safety and economic development of prisoners, prison workers and the general population [8]. Due to the crowded nature of the prison inmates, and increased human exposure to microbial indoor air pollutants or pathogens, the interest towards the emergency and dissemination of diseases has increased [9]. Even though less is done, some reports revealed that tuberculosis (TB) infection rates in prison may be up to hundred times more common than outside prison and up to a quarter of any country's TB cases may be found in prison [10]. A Meta-analysis made in Ethiopia in 2015 has showed that prevalence among prisoners was 8.33% [11]. Poor indoor air quality is implicated by many diseases and is recognized as a significant risk factor for respiratory health, especially in lower income countries and vulnerable population including prison inmates. Prisoners spend substantial proportion of their time indoors and may become exposed to elevated levels of air pollutants. The overcrowded prison cells create smaller indoor-air mixing volumes that allow infectious diseases to spread more easily from person to person [12]. In schools, office buildings, health institutions, and libraries, more study is being done on fungal burden and associated issues. However, according to the literature and to the best of the authors' knowledge, no study on fungal load and associated factors in prisons has been conducted in Ethiopia, particularly, in the study area of East Hararghe and Harari regional. The findings of this study will fill a gap in the shortage of baseline data on fungal indoor air quality in prisons and contributing factors, as well as provide guidance for future studies on prison inmate cell indoor air quality.

2. Methods

2.1. Study Area and Period

An institutional-based cross-sectional study was carried out, from October 1to October 30, 2020, in prisons of, Adele town, Girawa town, Deder town, Harar city and Gursum town, in East Harage zone and Harar city in Harari regional state Eastern Ethiopia. There were six prisons in total in East Harage zone and Harari regional state. All the prisons were included in the study.

2.2. Source and Study Population

The study and source populations were all inmate cells of the prisons.

2.3. Inclusion and Exclusion Criteria

All inmate cells occupied by prisoners were selected and those inmate cells which were not occupied permanently were excluded.

2.4. Sample Size Determination

The sample was calculated based on the following formula

$$n = \frac{(Z\alpha/2)^2\pi(1-\pi)}{d^2}$$

Where n= sample size, $(Z\alpha/2) = 1.96$, $(1.96)^2 = 3.8416$ $\pi = 0.745$ and $d^2 = 0.05$

$\pi = 0.745$. This proportion was taken from [13].

$$n = \frac{3.8416\times0.755\times0.245}{(0.05)^2} = 284$$

The number of population was 62; then the reduction formula was used.

Thus $n = \frac{n_\circ}{1+\frac{n_\circ-1}{N}} \rightarrow \frac{284}{1+\frac{284-1}{62}} = 51$

However, all the inmate cells of the East Hararghe zone and the Harari regional state prisons were taken.

2.5. Sampling Procedure/Technique

Due to the possibility of incorporating all prison rooms in the East Hararghe zone and the Harari regional state, all inmate cells of the prisoners were taken as study units.

2.6. Data Collection Methods

The fungal samples were collected passively through use of

gravitational settle plate's (Koch sedimentation) method. Settle plates (also called settling plates or sedimentation plates) are culture plates containing potato dextrose agar that are opened and placed side up on 1 meter above the floor which is the human breathing zone, and 1 meter away from any walls and other obstacles; and collect settled particles on the plates for 1 hour exposure time so called 1/1/1 principle [14]. The samples were taken twice a day, in the morning and the afternoon, and finally transported to the medical laboratory department lab at the Haramaya University College of Health and Medical Science, where they were preserved in an icebox and incubated at 37°C for seven days along with the control media. Using checklists that had already been prepared, environmental elements were gathered through direct observation. To determine the home crowding index, metric measurements of the room and window areas were taken. Temperature, moisture content, and air velocity were all measured using air quality monitoring equipment.

2.7. Study Variable

Dependent variable: Fungal Indoor Air Quality while the Independent variable: temperature, humidity/moisture content, ventilation/velocity of air, growth of molds, Cleanness of the room and frequency of cleaning, number of occupants (crowding), time of data collection (morning and afternoon) and Behavior of the occupants (hygienic status, chat chewing and smoking behavior).

2.8. Data Quality Control

The nutrient media for fungal samples collection were first sterilized using autoclave at 121°C for 15 minutes to avoid fungal contamination before the data collection. Sample collection was done aseptically to prevent cross-contamination of the sample collection materials. Procedural controls were used for the data collection of fungal organisms to assure that the quality of data collection is maintained.

2.9. Methods of Data Processing and Analysis

For statistical analysis, SPSS software version 23 and Microsoft Excel 2013 were used. For the determination of the fungal load of inmate cells, descriptive statistics were employed, and the data was organized, processed, analyzed, and presented in words and tables. The mean comparison of fungal loads between sampling sites was done using one way analysis of variance (ANOVA), chi-square test for categorical variables, and correlation analysis for continuous data.

3. Result

3.1. Microbial Indoor Air Quality in Inmate Cells

The study result showed that the highest fungal concentration was detected at 8:00 am in a Harari Regional state prison inmate cell, at 537 (CFU/m^3), while the lowest fungal concentration was detected at 2:00 pm in Deder prison, at 115 (CFU/m^3) (Table 1). The maximum and minimum mean fungal loads were recorded as 418 CFU/m^3 in Adele at 8:00 am and 199 CFU/m^3 in East Hararghe Harar zone branch at 2: pm respectively (Table 1 and Figure 1). The mean fungal loads in the morning and afternoon were 304 CFU/m^3 and 288 CFU/m^3, respectively (Table 2).

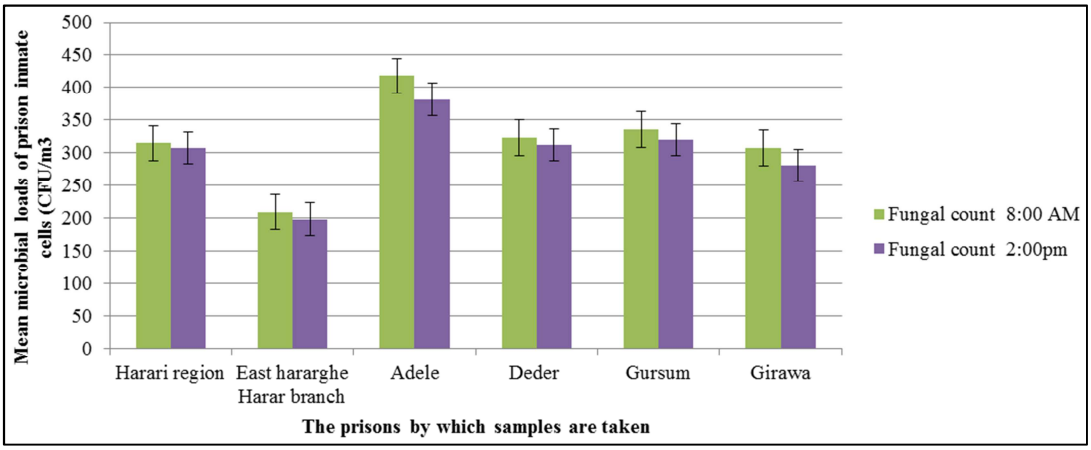

Figure 1. *Mean fungal loads of prison inmate cells in Harari Regional State and East Hararghe Zone, 2020 (n = 62).*

The fungal concentration was between 101 and 500 CFU/m^3, indicating an intermediate level of contamination. While one of the prisoner cells in the Harari district had a fungal load of more than 500CFU/m^3 (Table 3).

A one-way ANOVA was performed to assess the null hypothesis, according to which there is no mean difference in the fungal load between prison inmate cells; in accordance with the statistical analysis, (N = 62, DF = 61, p = 0,48, Fcalculated = 0.486, and Fcritical = 4.001) (Table 4) there was no a significant difference (p > 0.05) in fungal load between inmate cell.

Table 1. *Statistical summary of fungal counts in prison inmate cells of East Hararge Zone, Eastern Ethiopia, 2020 (n = 62).*

Statistics	Harari region		East Hararghe Harar branch		Adele		Deder		Gursum		Girawa	
	8:00am	2:00pm	8:00am	2:00pm	8:00am	2:00pm	8:00am	2:00pm	8:00am	2:00pm	8:00am	2:00pm
Mean	315	308	210	199	418	382	323	312	336	320	308	281
Median	308	314.5	196.5	197	419	384	315	284.5	315	341	301	294.5
Maximum	537	498	315	301	472	446	485	472	393	419	419	406
Minimum	131	157	144	131	380	328	183	115	288	170	223	157
Stdev.	113.4	86.8	55.8	51.7	37.9	42.6	105.3	119.9	44.	104.3	56.7	65.7
Variance.	12860.9	7536.2	3108.6	2675.1	1435.3	1811.2	11085.7	14370.4	1848.8	10875.3	3219.1	4318.5

Table 2. *Total mean fungal loads of prisons at the morning and afternoon, 2020 (n = 62).*

Variables	N	Minimum	Maximum	Mean	Std. Deviation
Fungal colony's in the morning	62	131	537	304	95.88117
Fungal colony's in the afternoon	62	115	498	288	94.96524
Valid N (list wise)	62				

Table 3. *An assessment of the indoor air quality in the inmate cells of the East Hararghe Zone, eastern Ethiopia, 2020 (n = 62).*

Group of microbes	Range	Pollution degree	Harari region		East Hararghe Harar branch		Adele		Deder		Gursum		Girawa	
			8:00 am	2:00 pm	8:00 am	2:00 pm	8:00 am	2:00 pm	8:00 am	2:00 pm	8:00 am	2:00 pm	8:00 am	2:00 pm
Fungal	<25	Very low												
	26-100	Low												
	101-500	Intermediate												
	501-2000	High												
	>2000	Very high												

Table 4. *One way ANOVA results for the mean fungal loads between prisons, 2020 (n = 62).*

Summary of Fungal Loads						
Groups	Inmate cells	Total loads	Average	Variance		
Harari region	14	4360	311.428571	9243.96		
East Hararghe zone	48	14014	291.958333	8223.45		
ANOVA						
Source of Variation	SS	Df	MS	F	P-value	F crit
Between Groups	4108.85	1	4108.85	0.486	0.488	4.001
Within Groups	506673.34	60	8444.56			
Total	510782.19	61				

3.2. Factors Associated with Indoor Air Quality in Inmate Cells

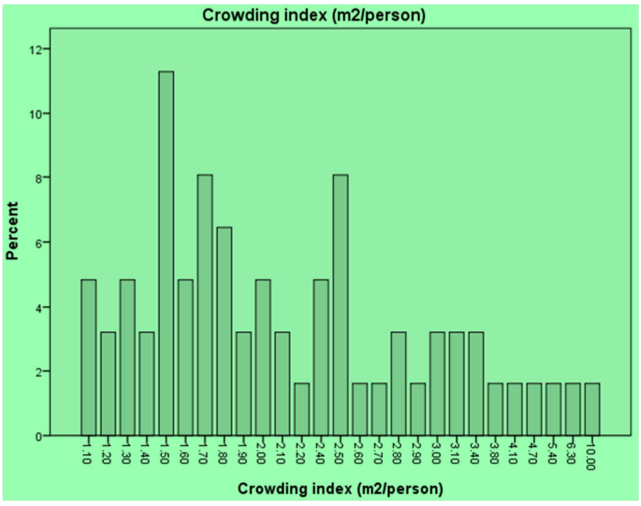

Figure 2. *Frequency percentage of crowding index of prison inmate cells, 2020 (n = 62).*

The fungal loads in prison inmate cells may be positively or negatively influenced by a variety of environmental conditions. According to this study finding, only 5 (8.1%) of the 57 inmate cells in the Harari regional state and East Hararghe Zone prisons had a crowding index of more over $4m^2$ per person (Figure 2).

The average air temperature in prison inmate cells was 69.90^0f. The minimum and maximum temperatures of all the prisons were 49.4^0f and 83.9^0f respectively. Inmate cells had a mean, minimum, and maximum relative humidity of 63.05%, 45.7%, and 82.1%, respectively. In the same way the min, minimum and maximum velocity of air were 5.0645, 2 and 9.0 m/s respectively (Table 5).

The paired sample t-test was used to approve that if the fungal loads of the prisons inmate cells are the same in the morning (8:00am) and afternoon (2:00 pm). However, there was no significant difference (t= 1.000, Df= 61 and p = 0.32) of fungal loads in the morning and afternoon (Table 6).

The association between the fungal load and the temperature, relative humidity, air velocity, number of people, chat chewers, smokers, inmates engaging in physical activity

in the prison inmate cell, and the crowding index of the inmate cells was investigated using a Pearson correlation test. The fungal load in the inmate cells shown a weak positive correlation (r= 0.275, P= 0.003) with temperature. The correlation between the fungal load and the number of inmates and relative humidity in the cells was shown to be weakly positive (r=0.192 and P=0.04) and strongly positive (r = 0.983 and P=0.004) correlated, respectively (Table 7).

The associations between various parameters and the levels of fungi in prisoner cells were examined using Fisher's exact test. This study found that the condition of the window during data collection time (openness) (Df =1, P = 0.04), the presence of artificial ventilation (Df=1, P = 0.04), the frequency of ventilation to work per time (Df =1, P=0.03), the presence of visible mold growth on the ceiling (Df =1, P = 0.04), the presence of accumulated waste on the floor (Df =1, P = 0.04), the frequency of cleaning (Df =1, P=0.03) and presence of unhygienic food and their products (Df =1, P = 0.01) were associated with the fungal counts of the prison inmate cells (table 8).

Table 5. *Statistical summary of the environmental factors among inmate cells of prisons, 2020 (n = 62).*

Environmental factors	N	Minimum	Maximum	Mean	Std. Deviation	Variance
Crowding index (m^2/person)	62	1.10	10.00	2.3613	1.41842	2.012
Temperature (of)	62	49.40	83.90	69.8855	7.70401	59.352
Relative humidity (%)	62	45.70	82.10	63.0500	6.73583	45.371
Velocity of air (m/s)	62	2.00	9.00	5.0645	1.48071	2.192
Individuals during data collection	62	3.00	30.00	13.3710	6.30699	39.778
Total prisoners during data collection	62	5.00	37.00	23.5323	6.49771	42.220
Smokers (in number)	62	.00	14.00	1.8548	2.71515	7.372
Chewers (in number)	62	.00	27.00	6.6290	6.49397	42.172
Valid N (listwise)	62					

Table 6. *Paired Sample T test of fungal loads between morning and afternoon, 2020.*

	Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the difference		t	Df	Stg.
				Lower	Upper			
Fungal count in the morning - fungal count at the afternoon	.01613	.12700	.01613	-.02676	.05901	1.000	61	.321

Table 7. *Pearson's correlation coefficient between fungal concentrations with environmental factors in Eastern Hararghe Zone, Eastern Ethiopia, 2020 (n = 62).*

		Temperature	Relative humidity	Velocity of air	Number of individuals	Chewing chat	Number of smokers	Physical activities	crowding index
Temperature	Pearson Correlation	1							
	Sig. (2-tailed)								
Relative humidity	Pearson Correlation	-.200	1						
	Sig. (2-tailed)	.118							
Velocity of air	Pearson Correlation	-.319*	.019	1					
	Sig. (2-tailed)	.011	.884						
Number of individuals	Pearson Correlation	-.322*	.117	.311*	1				
	Sig. (2-tailed)	.011	.366	.014					
chewing chat	Pearson Correlation	-.408**	-.052	.138	.554**	1			
	Sig. (2-tailed)	.005	.733	.368	.000				
Number of smokers	Pearson Correlation	-.396*	.069	.158	.432*	.542**	1		
	Sig. (2-tailed)	.041	.733	.432	.024	.004			
Physical activities	Pearson Correlation	-.327	-.529	.866	.961	-1.000**	.c	1	
	Sig. (2-tailed)	.788	.645	.333	.179	.	.		
crowding index	Pearson Correlation	.036	-.103	-.021	-.171	-.183	-.010	-.569	1
	Sig. (2-tailed)	.783	.428	.871	.184	.229	.959	.614	
Fungal load	Pearson Correlation	.275*	.983*	-.145*	.192*	.207	-.020	-.619	-.178
	Sig. (2-tailed)	.031	.004	.023	.039	.172	.921	.575	.166

Table 8. *Chi-square test of Environmental factors of fungal indoor air loads of the prison inmate cells Eastern Hararghe, Eastern Ethiopia, 2020 (n = 62).*

Factors	Fungal loads	
	Degree of freedom (Df)	p-value
Location of windows	1	0.41
Condition (openness) of window	1	0.04
Presence of artificial ventilation	1	0.04
Frequency of ventilation to work per time	1	0.03
Visible waste on the wall	10	0.07
The presence of visible growth of mold on the ceiling	1	0.04
Presence of accumulated waste on the floor	1	0.04
Frequency of cleaning	1	0.03

Factors	Fungal loads	
	Degree of freedom (Df)	p-value
Presence of un sanitized food and their products	1	0.01
Presence of pets and mice in the inmate cell	1	1.00
Type of insects	3	0.11

4. Discussion

The average fungal load (304 CFU/m^3) in the Harari Regional State and East Hararghe prisons was in the intermediate ranges. Different guidelines and requirements for fungal indoor air loads exist in different nations and institutions. According to the 2019 report from the government of Hong Kong Special Administrative Region Indoor Air Quality Management Group, the fungal load for public spaces may be excellent if it is less than 500 CFU/m^3 and good if it is less than 1000 CFU/m^3 [15]. This study revealed that the majority of prison inmate cells had excellent fungus loads. This might be as a result of the cells' greater air velocity (exchange rate) between indoor and outdoor air. Building condition and environmental elements, such as building age, room size, air temperature, relative humidity, window number, and frequency of cleaning, might influence fungal load [16].

The temperature of the inmate cells was 21.02°C (69.9°F). For excellent indoor air quality, the temperature range is 20.0-25.5°C (68-77.9°F), according to the Hong Kong Environmental Protection Department. In comparison, the temperature of the inmate cells is excellent. When compared to Malaysia, which suggests a temperature range of 23–26°C (73.4–78.8°F), this range was lower [17]. This discrepancy may be caused by the status of the buildings in these areas and the number of inmates occupying the prison cells.

According to this study, the inmate cells had a crowding index that ranged from 1.1 to 10.0 m^2/person (2.36 m^2/person). A crowding index below the recommended level (4m^2/person) could be interpreted as being too crowded [18, 19]. This shows that a large number of prisoners reside in overcrowded prison cells and may increase the risk of infection as the number of potential transmitters is increased [20]. The relative humidity ranged from 45.0 to 82.1% with a mean of (63.05%). According to the Canadian government, the recommended relative humidity levels are 30 to 80% in the summer and 30 to 55% in the winter. This study was in the range of the Canadian standard. According to the American Society of Heating, Refrigerating, and Air Conditioning Engineers (ASHRAE), the recommended relative humidity values for summer and winter were 40 to 60% and 30 to 60%, respectively [17]. In comparison to the ASHRAE air quality standard, the relative humidity of air in this investigation was greater. This could be as a result of mold growth and poor building conditions. The air velocity in this investigation ranged from 2.0 to 9.0 m/s, with a mean of 5.06 m/s. According to WHO guidelines, the air should move at a speed of 0.25 m/s. This result is 20 times higher than the WHO limit for indoor air quality, which could make people feel uncomfortable in the temperature and create a draught in the prisoner's cell [21].

According to this study, there is no difference between fungal loads in the morning and afternoon. This shows that the time of data collection is not a determinant in the fungal loads of the inmate cells. According to a Polish study, the timing of data collection affected the variation in fungal burdens [22]. This discrepancy might be caused by the inmate cells' morning and afternoon air velocities, population density, and structural issues.

5. Conclusion

Except for one inmate cell in the Harari Regional State Prison Commission, the fungal loading in the East Hararghe Zone and Harari regional State Prisons was in the intermediate range (below 500 CFU/m^3). The correlation between fungal load and temperature was found to be weakly positive, whereas the correlation between fungal load with relative humidity and the number of prisoners in each cell was strongly positive. According to this study, inmates may be at risk from fungal burdens. The prison administrations in the Eastern Haragie zone and the Harari region should thus take action to resolve the problem. A significant reconstruction of the prison facility is necessary based on present requirements.

6. Recommendation

Based on the result, both the Harari region and the eastern Haragie zone prison offices should take action to address the issue. The prison facility needs to be restructured in accordance with current requirements. Researchers should also conduct assessments on the fungal indoor air quality of prisons which have no recorded findings and monitor air quality in public places.

Abbreviations and Acronyms

ASHRAE:	American Society of Heating, Refrigerating and Air conditioning Engineers
ANOVA:	Analysis of Variance
CFU/m^3:	Colony Forming Unit per meter cub
°C:	Degree centigrade
DF:	Degree of Freedom
°F:	Degree Fahrenheit
SPSS:	Statistical Package for Social Science
WHO:	World Health Organization
MS:	Mean of Squares
SS:	Sum of Squares
am:	Antemeridian
pm:	Prime meridian
m^2/person:	Square
Stg.	Statistical significance

Authors Contributions

TS conceived the idea and collected, analyzed and interpreted the data and played a major role. The authors (TS, SM, BA, NB, DA, DM, and AG) contributed to data analysis, writing, and editing the document. All authors (TS, SM, BA, NB, AG, DM, DA, LM, GA and YA) gave valuable ideas for the manuscript. Finally, the authors read and approved the final version to be published and agreed on all aspects of this work.

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Data Availability

Almost all data are included in this study. However, additional data will be available from the corresponding author upon reasonable request.

Ethics Approval and Consent to Participate

The Institutional Health Research Ethics Review Committee (IHRERC) of the College of Health and Medical Sciences, Haramaya University, granted ethical permission for this study. All subjects and interested parties involved in this investigation provided their informed consent.

Competing Interests

The authors declare that they have no conflict of interest.

Limitation of Study

One of the limitations of the study was the use of passive sampling. Due to the nature of passive air sampling techniques; the efficient collection of passive samples may be influenced by environmental parameters and reverse diffusion can underestimate or overestimate fungal load.

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