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Microbial Air Monitoring in the Pediatric Burn Ward: Experience at the University Hospital of Mashhad, Iran

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Abstract

Background
The aim of this study was to investigate the density and type of bacterial and fungal bioaerosols in the air of the pediatric burn ward.

Materials and Methods
In this cross-sectional study, two active and passive sampling methods were used simultaneously to evaluate the density and type of bacterial and fungal bioaerosols. In 2019, sampling was performed once every six days, according to the sampling guideline developed by the 2019 United States Environmental Protection Agency (EPA). Data were analyzed using SPSS software (version 22.0).

Results
According to the EU GMP standard, in the active method, bacterial and fungal contaminations in the indoor air of the burn ward were in grades C and D, respectively. According to this standard, in the active method, bacterial and fungal contaminations in the outdoor air of the burn ward were in grade C. According to the EU GMP standard, in the passive method, bacterial and fungal contaminations in the indoor air of the pediatric burn ward were in grade C. According to this standard, in the passive method, bacterial and fungal contaminations in the outdoor air of the burn ward were in grade C.

Conclusion
Given the importance of preventing infection in patients with burns and preventing deaths caused by infections in these patients, especially in children with burns, it is necessary to pay attention to the role of bioaerosols in developing nosocomial infections in burn patients.

Key Words: Bioaerosol, Bacterial, Burn, Fungal.

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1- INTRODUCTION

Annually, burns result in more than 7.1 million injuries and more than 250,000 deaths worldwide and the total loss of 18 million disability-adjusted life years (DALYs) (1). This is especially troubling for children as a vulnerable age group, as burns are the 11th leading cause of death (in children between 1 and 9 years of age) and the fifth most common cause of non-fatal injuries in children (2). High mortality and anomalies, long-term rehabilitation, dissatisfaction with beauty, pain and injury caused by dressings, hospitalization, and emotional problems are among the negative effects of burns in children (3). It is estimated that about 50% of deaths from burns are due to infection (4). Among the main causes of infection in patients with burns are the loss of mechanical barrier of the skin, damage to the respiratory tract, weakened immune system due to burning, long hospital stays, and invasive diagnostic and therapeutic procedures (5).

The source of microorganisms causing infections in patients with burns may be endogenous (the patient's own natural flora) or exogenous (environmental or from health care personnel). These microorganisms include bacteria (gram-positive and gram-negative), yeasts, and fungi (6). Bacteria that cause infection in burn patients include Staphylococcus aureus, Pseudomonas aeruginosa, Klebsiella pneumoniae, and Acinetobacter baumannii as well as the common fungi of Candida species and filamentous fungi including Aspergillus, Fusarium and Mucor (7, 8). One of the most important routes of transmission of infections is the air around the patient. It is estimated that air is responsible for 10% -20% of nosocomial infections. The presence of bioaerosols in hospital wards is one of the main causes of nosocomial infections (9, 10). Bioaerosols are very small particles in the air that are biologically derived from plants or animals and can include living organisms as well. Therefore, pathogenic or non-pathogenic living or dead microorganisms (e.g., viruses, bacteria, and fungi) may be present in bioaerosols. Due to their small size and light weight, bioaerosols are capable of transferring from one environment to another (11). Bioaroceles with a size of 1.0 to 5.0 micrometers generally remain in the air, while larger particles precipitate (12). Two important types of bioaerosols are bacterial and fungal bioaerosols (13). The concentration and distribution of bioaerosols vary according to biological factors such as microorganisms and non-biological factors such as environmental conditions, including relative humidity and temperature, and human activities (14).

Bioaerosols are generally sampled in both active and passive ways. Passive sampling is an accessible, easy and economical way of sampling that depends on gravitational force, in which particles on plates containing the culture medium precipitate. In the active sampling, the airflow passes through the plates containing the culture medium using the sampling pump (15). The presence of bioaerosols in hospital wards is one of the main causes of nosocomial infections. The aim of this study was to investigate the density and type of bacterial and fungal bioaerosols in the air of the pediatric burn ward.

2- MATERIALS AND METHODS

2-1. Study design and population

This descriptive cross-sectional study was performed to evaluate the density and type of bacterial and fungal bioaerosols of indoor and outdoor air of the pediatric burn ward of Imam Reza Hospital affiliated to the University of Medical Sciences in the 2019 winter. This university hospital with 1,228 active beds is one of the largest hospitals in the country (**Figure.1**).

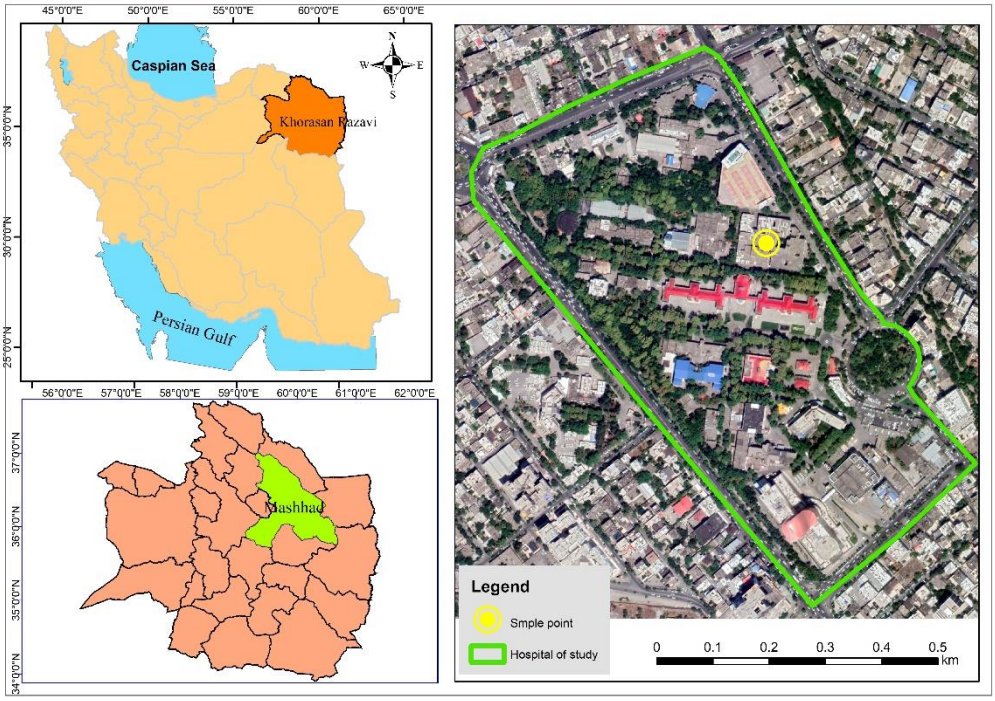

Fig.1: Imam Reza Hospital, Mashhad, Iran.

In order to evaluate the density and type of bacterial and fungal bioaerosols, we used two active and passive sampling methods simultaneously (16). The sampling was performed once every six days in accordance with the 2019 United States Environmental Protection Agency (EPA)'s sampling calendar from February 2019 to March 2019 (17). In order to prevent contamination load interference in visitors, the sampling was performed at 8-12 a.m. (local time). Indoor air sampling was carried out in one of the rooms of the ward with two beds, an area of about 15 square meters and equipped with high-efficiency particulate absorption (HEPA) filters. Outdoor air sampling was performed at a distance of 4 meters from the entrance of the ward (13). Simultaneously with bioaerosol sampling, environmental conditions such as temperature [°C], relative humidity [%] and pressure [mm Hg] were measured using a pen-type portable electronic device (Model: Lutron PHB-318).

2-2. Active method

Active sampling was performed at a flow rate of 25 liters per minute and a suction volume of 500 liters (18). We used the QuickTake 30 sampling pump equipped with the Bio Stage single-stage cascade impactor (SKC, USA[2]) with 400 holes (25 mm in diameter) (19). The sampler was placed at a distance of 1 m from the ground and 1 m from the walls and obstacles (18). At each sampling stage, the Bio Stage was sterilized with 70% alcohol to prevent cross-contamination (20). Since sampling was performed in non-standard temperature and pressure conditions, the volume of sampled air was standardized using the following equation:

$$\frac{P_1 V_1}{T_2} = \frac{P_2 V_2}{T_1}$$

In this equation, index 1 indicates standard conditions and index 2 indicates the studied conditions. Unit P is the atmospheric pressure, unit V is cubic meters, and T is Kelvin (21). The number of bioaerosols in the air obtained by the

[2] Bio Stage single-stage cascade impactor

active method is finally expressed as colony-forming units (CFUs)/m^3 (22).

2-3. Passive method

In this method, the standard Petri Dishes containing the culture medium (static plates) left open to the air according to the 1/1/1 standard (1 meter above the floor, 1 meter distance from walls and obstacles and for 1 hour) to collect bioaerosols in the air (10). But to improve the sensitivity of this method, according to the European Union's Guidelines to Good Manufacturing Practice, we increased the contact time from 1 hour to 4 hours (23). The number of bioaerosols in the air obtained by the passive method is expressed as cfu/m^2/h unit (22).

2-4. Culture media used

To prevent fungal growth, blood agar (BA) with cycloheximide was used as a transfer culture medium to study bacterial bioaerosols, and to prevent the growth of any bacterium, sabouraud dextrose agar with chloramphenicol was used as a transfer culture medium for fungal bioaerosols. After preparation in the laboratory, the culture medium was transferred to the pediatric burn ward under sterile conditions. And after sampling, to prevent secondary contamination, the plates were sealed with adhesive and transferred to the laboratory with a cold box (24).

Determination of bacterial and fungal bioaerosols: The plates containing the culture medium of bacterial bioaerosols were placed in the incubator at a temperature of 35 ± 0.5 ℃ for 24-48 hours after transfer to the laboratory. Then, the number of colonies per plate was counted and according to Bergey's manual, biochemical tests were performed to determine their genus. While the plates containing the culture medium of fungal bioaerosols were placed at a temperature of 20-25 ℃ (room temperature) for 3-7 days after transfer to the laboratory. Then, the number of colonies per plate was counted and macroscopic and microscopic methods were used to identify them (25, 26). Microbiological air quality guidelines: There are many guidelines for indoor and outdoor air quality in the world so that researchers can make better judgments about their findings. However, in a study conducted to evaluate the microbiological quality of indoor and outdoor air of the pediatric burn ward, we used the European Union Good Manufacturing Practices (EU GMP) guidelines for the uniform coverage of all results due to the use of two active and passive methods (27). This guideline has 4 grades including A: very clean, B: clean, C: average contamination and D: contaminated (**Table.1**).

Table-1: Limits for Microbial Contamination of Environment as Recommended by European Commission Good Manufacturing Practices (28).

Grad	CFU/m^3	Settle Plate [a]
A	<1	<1 (157)
B	10	5 (786)
C	100	50 (7860)
D	200	100 (15719)

a: Colony-forming units (cfu) on settle plates 90mm diameter after 4 h of exposure.
Figures in parentheses are cfu/m2/h.

2-5. Ethical consideration

The project was approved by the Ethics Committee of Mashhad University of Medical Sciences with the code IR.MUMS.REC.1398.076. This research was part of MSc degree thesis in

environmental health engineering of Zohreh Rahnama Bargard.

2-6. Data Analyses

SPSS statistical software (version 22.0) (SPSS Inc. IL, Chicago, USA) was applied for analyzing data in this study. Data were presented using mean (SD), for the Numeric normal and non-normal variables respectively and frequency (percentage) for categorical variables.

3- RESULTS

Of the total sampling volume in the active method, 25% belonged to the sampling of the bacterial bioaerosols of indoor and outdoor air and 25% to the fungal bioaerosols of indoor and outdoor air and also in the passive method, 25% was for the sampling of the bacterial bioaerosols of indoor and outdoor air and 25% for the fungal bioaerosols of indoor and outdoor air. For every 25% of the total sampling volume, a control sample was taken to eliminate human intervention factors and errors (29). The environmental conditions of the pediatric burn ward are shown in **Table.2**. Based on the results of the sampling, it was found that the measured temperature in indoor and outdoor air was in the range of 12-26 °C and also the relative humidity was in the range of 25-42%.

Table- 2: Environmental conditions at Pediatric burn ward in Mashhad, Iran.

Location	Temperature [° C] mean ± SD	Relative Humidity [%] mean ± SD	Pressure [mm Hg] mean ± SD
Indoor	26.2±0.8	25.0±2.0	676.8±3.9
Outdoor	12.3±5.2	42.5±15.8	677.2±3.6

SD: Standard deviation.

3-1. Evaluation of the density of bacterial and fungal bioaerosols

The total concentration of bacterial and fungal bioaerosols obtained by the active method is shown in **Figure.2**. Based on the results, the mean concentration of bacterial bioaerosols obtained by the active method in the indoor air of the burn ward was 91.3 (±38.3) CFU/m^3 and the concentration of the outdoor air of the burn ward was 57.4 (±15.4) CFU/m^3. The mean concentration of fungal bioaerosols obtained by the active method in the indoor air of the burn ward was 115.2 (±8.5) CFU/m^3 and the concentration of the outdoor air of the burn ward was 81.1 (±15.9) CFU/m^3. The results showed that in the active method, the concentration of bacterial and fungal bioaerosols in the indoor air was higher than in the outdoor air. According to the EU GMP standard (28), in the active method, the bacterial contamination in the indoor air of the studied ward was in grade C and the fungal contamination was in grade D. According to this standard, bacterial and fungal contaminations in the outer air of the burn ward were in grade C. According to the EU GMP standard, 10 CFU/m^3 indicates a clean environment, so indoor and outdoor air contamination in the pediatric burn ward exceeded the permissible limit in terms of bacterial and fungal bioaerosols. The mean concentration of bacterial bioaerosols in indoor and outdoor air in the active method was significantly higher than the recommended value of EU GMP, < 1 cfu/m^3 ($P = 0.02$). The mean concentration of fungal bioaerosols in indoor and outdoor air in the active method was significantly higher than the recommended value of EU GMP, < 1 cfu/m^3 ($P = 0.00$). There was no significant difference between the mean concentration of bacterial bioaerosols in indoor and outdoor air in the active method ($P=0.229$); while there was a significant difference between

the mean concentration of fungal bioaerosols in indoor and outdoor air in the active method (P=0.031). According to Pearson's correlation analysis, in the indoor air, temperature and humidity, respectively, did not show a significant relationship with the concentration of bacterial bioaerosols (P=0.356 and P=0.217), and also did not show a significant relationship with the concentration of fungal bioaerosols (P=0.212 and P=0.351). According to Pearson's correlation analysis, in the outdoor air, temperature and humidity, respectively, did not show a significant relationship with the concentration of bacterial bioaerosols (P=0.324 and P=0.243), and also did not show a significant relationship with the concentration of fungal bioaerosols (P=0.680 and P= 0.760).

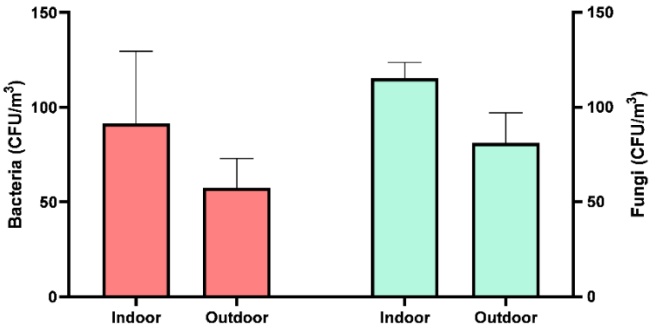

Fig-2: The mean of bacteria and fungi in indoor and outdoor air of Pediatric burn ward by active method.

The total concentration of bacterial and fungal bioaerosols obtained by the passive method is shown in **Figure.3**. Based on the results, the mean concentration of bacterial bioaerosols obtained by the passive method in the indoor air of the burn ward was 1703.7 (±472.5) CFU/m^2/h and the concentration of the outdoor air of the burn ward was 1092.1 (±529.6) CFU/m^2/h. The mean concentration of fungal bioaerosols obtained by the passive method in the indoor air of the burn ward was 873.7 (±920.5) CFU/m^2/h and the concentration of the outdoor air of the burn ward was 1048.4 (±693.4) CFU/m^2/h. The results showed that in the passive method, the concentration of bacterial bioaerosols in the indoor air was higher than in the outdoor air, but the concentration of fungal bioaerosols in the indoor air was lower than in the outdoor air. According to the EU GMP standard (28), in the passive method, the bacterial contamination of the indoor air of the pediatric burn ward was in grade C and the fungal contamination was in grade C. Also, according to this standard, in the passive method, bacterial and fungal contaminations in the outer air of the burn ward were in grade C. According to the EU GMP standard, 157 CFU/m^2/h indicates a clean environment, so the concentration of indoor and outdoor air of the pediatric burn ward exceeded the permissible limit in terms of bacterial and fungal bioaerosols. The mean concentration of bacterial bioaerosols in indoor and outdoor air in the passive method was significantly higher than the recommended value of EU GMP, 157 cfu/m^2/h (P=0.003). The mean concentration of fungal bioaerosols in indoor and outdoor air in the passive method was significantly higher than the recommended value of EU GMP, 157 cfu/m^2/h (P=0.044). There was no significant difference between the mean concentration of bacterial bioaerosols in indoor and outdoor air in the passive

method (P=0.210). Also, no significant difference was observed between the mean concentration of fungal bioaerosols in indoor and outdoor air in the passive method (P=0.806). According to Pearson's correlation analysis, in the indoor air, temperature and humidity, respectively, did not show a significant relationship with the concentration of bacterial bioaerosols, and also did not show a significant relationship with the concentration of fungal bioaerosols. According to Pearson's correlation analysis, in the outdoor air, temperature and humidity, respectively, did not show a significant relationship with the concentration of bacterial bioaerosols and also did not show a significant relationship with the concentration of fungal bioaerosols. Besides, no significant association was observed between active and passive methods for the measurement of bacterial bioaerosols and also there was no significant association between active and passive methods for the measurement of fungal bioaerosols.

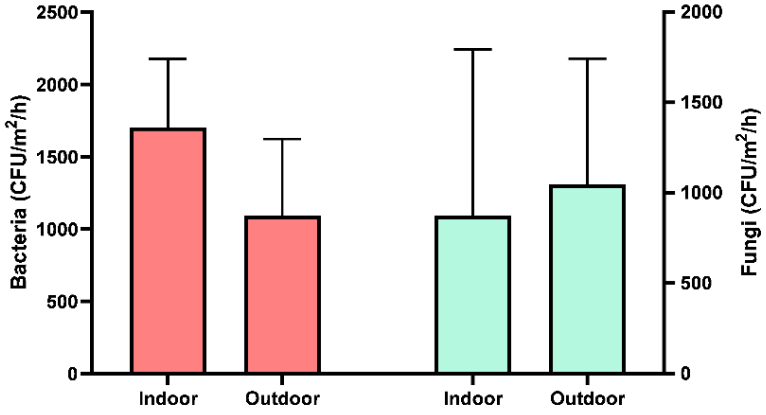

Fig-3: The mean of bacteria and fungi in indoor and outdoor air of Pediatrics burn ward by active method.

3-2. Evaluation of the genus and species of bacterial and fungal bioaerosols

The genus and species of bacterial bioaerosols obtained by active and passive sampling methods in indoor and outdoor air of the pediatric burn ward along with general information about their specifications are shown in **Table.3**.

Table-3: Genus and species of bacterial bioaerosols obtained by active and passive method together with general information about them (30).

Name	Genus	Gram	Type	Source
Staphylococcus aureus	Staphylococcus	Positive	Endogenous	Humans
Staphylococcus epidermidis	Staphylococcus	Positive	-	-
Non–Group A Beta Hemolytic Streptococcus	Streptococcus	Negative	-	-
Klebsiella pneumoniae	Klebsiella	Negative	Endogenous	Humans/ Environmental
Acinetobacter SPP	Acinetobacter	Negative	Endogenous	Humans
Pseudomonas aeroginosa	Pseudomonas	Negative	Noncommunicable	Environmental
Serratia marcescens	Serratia	Negative	Endogenous	Environmental

In the active sampling method, the bacterial species found in the indoor air of the pediatric burn ward included Staphylococcus aureus (55%), Staphylococcus epidermis (28%), Acinetobacter (7%), and beta-hemolytic Streptococcus except for the group A (10%). Also, the bacterial species found in the outdoor air of the burn ward included Klebsiella (42%), Staphylococcus aureus (25%) and Serratia marcescens (33%) (**Figure.4**). In the passive sampling method, the bacterial species found in the indoor air of the pediatric burn ward included Staphylococcus aureus (49%), Staphylococcus epidermis (31%), Klebsiella pneumoniae (10%), and Pseudomonas aeruginosa (10%). Also, the bacterial species found in the outdoor air of the burn ward included Staphylococcus aureus (80%), and Pseudomonas aeruginosa (10%) (**Figure.5**).

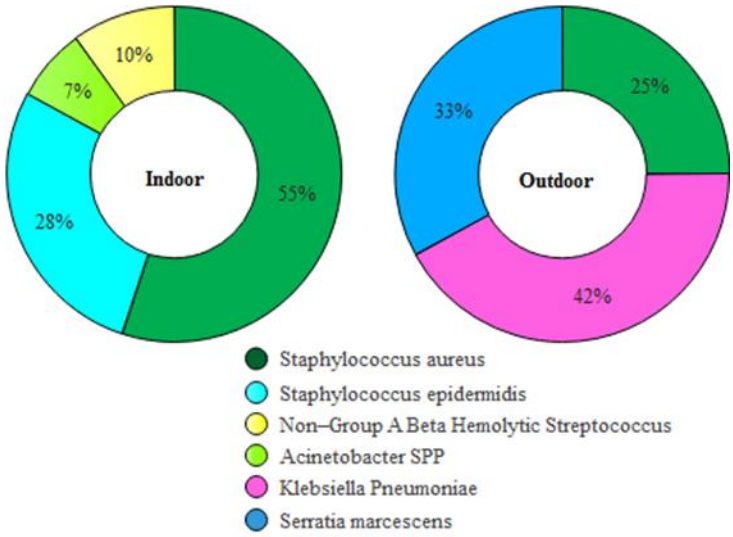

Fig-4: The percentage of bacteria bioaerosols by active method.

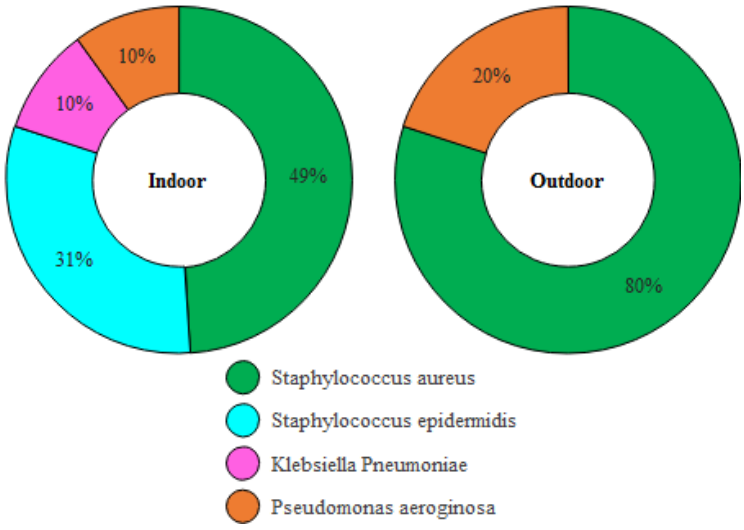

Fig-5: The percentage of bacteria bioaerosol by passive method.

As shown in **Figures 4 and 5**, in the active method, the most species found in the indoor air was gram-positive bacterium and in the outdoor air, gram-negative bacterium. However, in the passive method, the most species found in the indoor air and in the outdoor air was gram-positive bacterium. The genus of the fungal bioaerosols obtained by using active and passive sampling methods in indoor and outdoor air of the pediatric burn ward along with general information about their specifications is shown in the **Table.4**.

Table-4: Genus and species of bacterial bioaerosols obtained by active and passive method together with general information about them (30).

Name	Genus	Type	Source
Penicillium SPP.	Penicillium	No communicable	Environmental
Aspergillus SPP.	Aspergillus	-	-
Non-albicans Candida	Yeast	-	-

In the active method, the fungal species found in the indoor air of the pediatric burn ward included Aspergillus (70%), and Penicillium (30%). Also, the fungal species found in the outdoor air of the burn ward included Aspergillus (94%), and Penicillium (6%) (**Figure.6**). In the passive method, the fungal species found in the indoor air of the pediatric burn ward included Aspergillus (50%) Penicillium (30%), and Candida albicans (20%) and the fungal species found in the outdoor air of the burn ward included Aspergillus (96%) and Candida albicans (4%) (**Figure.7**).

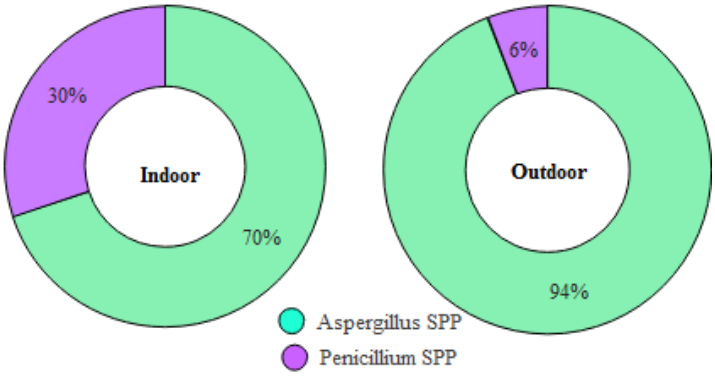

Fig-6: The percentage of fungi bioaerosol by active method.

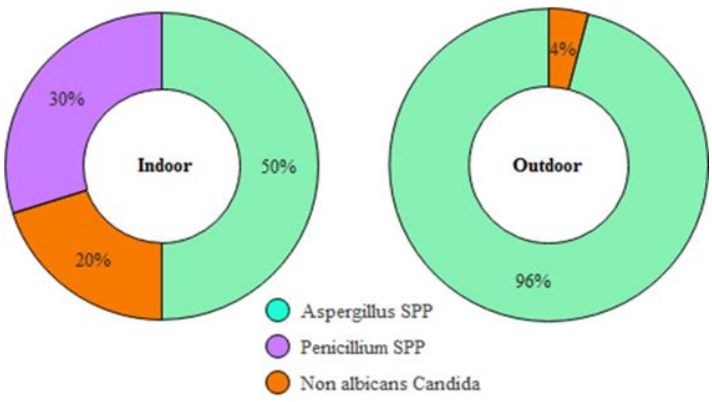

Fig-7: The percentage of fungi bioaerosol by passvie method.

4- DISCUSSION

This study was performed in a university hospital affiliated to the University of Medical Sciences in Mashhad in order to investigate the density and type of bacterial and fungal bioaerosols in the air of the pediatric burn ward. The proposed values for the density of bioaerosols have a wide range. Perhaps the most important reason for this wide range is the diversity of bioaerosols and their pathogenicity (31). For example, the maximum limit recommended for the total number of bioaerosol particles by the National Institute of Occupational Safety and Health (NIOSH) is 1000 cfu/m^3 and the value recommended by the American Conference of Governmental Industrial Hygienists (ACGIH) is 500 cfu/m^3. Also, the World Health Organization (WHO) has recommended that the microbial load in work environments should be less than 300 cfu/m^3 and for people with a suppressed immune system should be less than 100 cfu /m^3 (24, 32). However, in this study, because both active and passive sampling methods have been used, it seems that the EU GMP guideline is more comprehensive than other guidelines. In the present study, this EU GMP guideline was used to evaluate the microbiological quality of the air (28). According to the EU GMP standard, in the active method, the bacterial contamination in the indoor air of the pediatric burn ward with 91.3 cfu/m^3 and the fungal contamination with 115.2 cfu/m^3 were at the average contamination and contaminated levels, respectively. According to this standard, in the outdoor air of the burn ward, the bacterial contamination with 57.4 cfu/m^3 and the fungal contamination with 81.1 cfu/m^3 were at the level of average contamination. According to the EU GMP standard, in the passive method, the bacterial contamination in the outdoor air of the pediatric burn ward with 1703.7 cfu/m^2/h and the fungal contamination with 873.7 cfu/m^2/h were at the level of average contamination. Also, according to this standard, in the outdoor air of the pediatric burn ward, the bacterial contamination with 1092.1 cfu/m^2/h and the fungal contamination with 1048.4 cfu/m^2/h were at the level of average contamination. In a study conducted in Ahvaz, the mean concentration of bacterial and fungal bioaerosols on normal days (without dust) in the indoor air was 329 cfu/m3 and 386 cfu/m3, respectively, and in the outdoor air was 423 cfu/m3 and 596 cfu/m3, respectively, which is in line with our results (13). However, in a study conducted in a French hospital, the mean concentration of fungal bioaerosols in the indoor environment of the adult and pediatric hematology wards was 4.1 cfu/m^3 and 3. 9 cfu/m^3, respectively, and in the outdoor environment, it was122.1 cfu/m^3 (33). In a study conducted in Parama on 29 operating rooms, in the working operating room, the mean concentration of bacterial and fungal bioaerosols obtained by the active method was 140.14 cfu/m^3 and 5.09 cfu/m^3, respectively, and the mean concentration of bacterial and fungal bioaerosols in the passive method was 9.45 cfu/m^2/ h and 0.27 cfu/m^2/h, respectively (23). In a study conducted on 60 orthopedic operating rooms using both active and passive methods, the mean bacterial load was 123.2 cfu/m^3 in the active method and 2232.9 cfu/m^2/h in the passive method, which is in line with the results of the present study (18). The results of this study, compared to the EU GMP guidelines, showed that the concentration of bacterial and fungal bioaerosols in the pediatric burn ward was not acceptable. A study by Masoudi Nejad et al., in which the EU GMP standard was used to compare the results, found that 75% of bioaerosol sites measured by the active method were at the clean level and 80% of bioaerosol sites measured by the passive method ware at the contaminated level (34). The results of the present study

are also consistent with the results of a study conducted at a hospital in Qazvin (35). The reason for the high concentration of bacterial and fungal bioaerosols can be the failure to replace the filter in time, which can lead to the return of bacterial and fungal bioaerosols removed from the air to the indoor environment. It can also be due to the presence of patients or large and often infectious wounds and treatment processes in these patients such as changing burn dressings. Factors such as the presence of companions and the opening of windows did not affect the concentration of bioaerosols because sampling was performed during non-visiting hours and due to special conditions of patients, there was a restriction on accompanying the patient and also according to hospital regulations, windows were not allowed to open (36). As studies have shown, actions such as changing the patient's bed and changing the dressing have significantly changed the increased concentration of bioaerosols (37, 38).

Since the burn ward is located near one of the streets with heavy traffic in the city center, the microbiological (bacterial and fungal) quality of the outdoor air obtained by both active and inactive methods is at the level of average contamination, which in turn can lead to the reduction of microbiological indoor air quality, as some guides have suggested comparing the density of bioaerosols in indoor and outdoor air as a criterion for performing control measures (39). In the present study, according to both active and passive sampling methods, the most abundant bacterial bioaerosol in the indoor air was Staphylococcus aureus (Gram-positive cocci). According to the active sampling method, the most abundant bacterial bioaerosol in the outdoor air was Klebsiella pneumoniae (gram-negative bacilli) and based on the passive sampling method, the most abundant bacterial bioaerosol in the outdoor air was Staphylococcus aureus (gram-positive cocci). The results of the present study were consistent with the results of a study conducted in Karaj Hospital using the passive sampling method and with the findings of a study conducted in an educational hospital at the University of Benin in Nigeria using the active sampling method (10, 40). The presence of gram-positive bacteria in all environments is due to the natural flora of the skin, mucous membranes, and human and animal hairs (10). Staphylococcus aureus (Gram-positive cocci) is the leading cause of infection in burn patients, and 64% of children with burns have Staphylococcus aureus infection. Perhaps this is why the most abundant bacterial bioaerosol in this study was Staphylococcus aureus (41).

Aspergillus was also the most abundant fungal bioaerosol in indoor and outdoor air of the pediatric burn ward in both active and passive sampling methods. In a study conducted at three Greek hospitals on fungal bioaerosols, 70.5% of filamentous fungi were related to Aspergillus species (42). According to the literature, common species isolated from burn wounds are Candida, Aspergillus, Mucor, and Fusarium, and the prevalence of Aspergillus has recently increased compared to other filamentous fungi. It is probably the main reason for the abundance of Aspergillus species in the pediatric burn ward in both active and passive sampling methods (8).

Based on the results of the present study, the average temperature and relative humidity in the indoor air of the pediatric burn ward were 26.2 °C and 25.0%, respectively. In a similar study conducted in France, in winter, the range of temperature varied from 19.2 °C to 25.9 °C with an average of 22.8 °C and the range of humidity varied from 15.7% to 47.9 % with an average of 33.4%, which is consistent with the results of our study (43). The American Society of Heating,

Refrigerating and Air-Conditioning Engineers (ASHRAE) has recommended a temperature range of 20-24 ℃ and a relative humidity of 30-60% as an acceptable temperature range and relative humidity percentage for comfort in winter, while in summer, a temperature range of 23-27 ℃ with the same percentage of relative humidity has been recommended (44). Given that our study was conducted in winter, according to the above-mentioned standard, the indoor air temperature of the pediatric burn ward was higher than the standard recommended and the relative humidity was lower than the standard, which indicates the poor performance of the hospital's ventilation system. In the present study, there was no significant relationship between the two variables of temperature and humidity on the concentration of bacterial and fungal bioaerosols in indoor and outdoor air. Due to the small range of temperature and relative humidity changes given in Table.2, temperature and relative humidity did not significantly affect the concentration of bacterial and fungal bioaerosols (45).

But a study in China found that temperature and relative humidity had a positive effect on microbial communities (46). Statistical analysis did not show a significant relationship between the mean concentration of bioaerosols in indoor and outdoor environments of the pediatric burn ward in both the active and passive methods. These results are consistent with the results of Godini et al.'s study and Nourmoradi et al.'s study (47, 48). While no significant association was found between the concentration of indoor and outdoor bacterial bioaerosols in Obbard's study (49). Moreover, there was no significant relationship between the measurement of bacterial and fungal bioaerosols by active and passive methods, while Sautour et al. found a significant relationship between active and passive methods in terms of the number and type of bioaerosols collected by these two methods (50). In case of improper management of microbiological quality in the wards with burn patients, especially pediatric burn ward, in addition to disrupting the healing process of patients, it can cause various infections which in turn gives rise to disease development, prolonged hospital stay, and medical costs. Since the pediatric burn ward was equipped with high-efficiency particulate absorption (HEPA) filters, in order to reduce the number of bioaerosols and improve the air quality of the ward, it is recommended that some measures be taken to maintain the filters and provide regular services for them so that these patients who are susceptible to infection do not suffer from nosocomial infections.

Given that the temperature and humidity in the pediatric burn ward were not within the standard range recommended, it is suggested to repair the ventilation system so that it may bring some thermal comfort to the patients and hospital staff. Since in the present study, both the active and passive methods showed almost the same level of contamination of microbiological air quality status of the pediatric burn ward, in order to reduce costs and reduce the number of tools and equipment, it is recommended to use the passive method.

5- CONCLUSION

In the present study, in order to evaluate the microbiological quality of the air of the pediatric burn ward, the concentration and type of bacterial and fungal bioaerosols of indoor and outdoor air of the burn ward were investigated in two active and passive methods. According to the proposed EU GMP standard, the microbiological quality of the air was not optimal in terms of bacterial and fungal bioaerosols. Considering the importance of preventing infection in burn patients and ultimately preventing deaths

caused by infection in these patients, especially in children with burns, and given that children's health is one of the most important health status indicators in a society, it is very important to take into account the current issue studied. Finally, the role of bioaerosols in developing nosocomial infections in burn patients should not be overlooked. It is also suggested that, in collaboration with the University of Medical Sciences, efforts be made to improve the microbiological quality of the air of the burn ward and to achieve valid global standards to prevent infection in children admitted to the pediatric burn ward.

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7- CONFLICT OF INTEREST: None.

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