

# Types and Levels of Bioaerosols in Healthcare and Community Indoor Settings in Iran

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## Abstract

**Context:** Bioaerosols are associated with a wide spectrum of health effects, including infections and contagious diseases, acute toxicities, allergies, and even cancer.

**Evidence Acquisition:** Previous publications describing research conducted in healthcare and community settings during the years 2001-2016 were included in this analysis. The words bioaerosol, contamination, bacteria, fungi, viruses, and Iran were explored via the use of search engines such as PubMed, Google, Google Scholar, and Science Direct. A total of 28 studies were found.

**Results:** The levels of bacterial contamination were higher than those found in the fungal species. The most isolated of the bacterial species were *S. aureus* (38.24%) and *Micrococci* (31.6%), and the most isolated of the fungal species were *Penicillium* (32.28%) and *Aspergillus* spp (22.78%). The highest levels of contamination were detected in infectious disease (ID) settings (mean =  $91 \pm 86$  cfu/m<sup>3</sup> for bacteria and  $27 \pm 24$  for fungi). Moreover, levels of indoor air contamination were lower than the world health organization (WHO) standards, with the exception of *S. aureus* at 201 cfu/m<sup>3</sup> and 189 cfu/m<sup>3</sup> in infectious disease (ID) and intensive care unit (ICU) settings, respectively. In terms of geographic area and cultural differences, the numbers of bacterial and fungal agents were not significantly different (i.e., North versus South and East versus West). Moisture levels were significantly related to air contamination ( $p = 0.02$ ).

**Conclusions:** The levels of air contamination inside hospital and healthcare settings were lower than the WHO mean standard. Active air sampling methods are necessary for measuring bioaerosol contamination. There were no significant differences in the levels of contamination found in various indoor settings in Iran. Efficient ventilation systems and contamination prevention or minimization are necessary for these settings.

**Keywords:** Bacterial Bioaerosols, Fungal Bioaerosols, Hospital Indoors, Community Indoors

## 1. Context

Bioaerosols contribute to approximately 5% -34% of indoor air pollution, with a size range of 20 nm to > 100 m (1, 2). In terms of occupational frequency, respiratory infections comprise the problems most often caused by airborne pathogens or bioaerosols (3). All bacterial, fungal, and viral pathogens can contaminate the air in indoor hospital and community settings and thus promote infections (4). Proper diagnosis and checking the air in these settings, adequate ventilation and ensuring that infected air is not recirculated, the availability of isolation rooms, and the development of personal respiratory protective devices are some essential actions that help to reduce transmission of air contaminants. However, microorganisms can sometimes grow on air filters, be released into the filtered air, and consequently be transported into the ven-

tilated rooms (5, 6). Several disorders, such as infections and contagious diseases, acute toxicities, allergies (e.g., allergic rhinitis, asthma, or hypersensitivity pneumonitis), and even cancer are often associated with exposure to large concentrations of airborne microbes (7-9). Fungal or bacterial spores and vegetated forms and viruses can enter interior spaces from outdoor sources. Viral air contamination is rarely determined due to difficulties in obtaining cultures and a lack of molecular methods. In developed countries, a majority of people spend more than 90% of their time indoors and thus experience long-term exposure to common airborne pollutants. The quantitative and qualitative determination of bioaerosols therefore requires valid measurement techniques and strategies (10). According to the world health organization (WHO), the standard levels of contamination during meeting (morn-

ing) and visiting (afternoon) times are 50 cfu/m<sup>3</sup> and 100 cfu/m<sup>3</sup>, respectively. Furthermore, the European standard air contamination levels A, B, C, and D are designated as < 1 cfu/m<sup>3</sup>, 10 cfu/m<sup>3</sup>, 100 cfu/m<sup>3</sup>, and 200 cfu/m<sup>3</sup>, respectively (11). The compound of bioaerosols may vary among different areas to some extent. The survival of airborne microorganisms under these condition depends on several factors, such as temperature, ultraviolet radiation, humidity and pressure, type of microorganism, number of patient beds, and the presence of some pollutants in the atmosphere (12, 13). Among bioaerosols that have been isolates, pathogens such as *Staphylococcus aureus* (*S. aureus*), gram-negative bacilli, *Penicillium*, *Aspergillus* genera, and influenza respiratory pathogens are the most significant (14-16). A determination of the variety and number of air microorganisms would reveal the amount of indoor contamination. This review was performed to uncover the main biological contaminants and their levels in the air of indoor settings in various areas of Iran according to previously published data.

## 2. Evidence Acquisition

Reports of healthcare and community settings obtained from 2001 - 2016 were included. The words bioaerosol, contamination, bacteria, fungi, viruses, and Iran were explored via the use of search engines such as PubMed, Google, Google Scholar, and Science Direct.

Of the 14 studies found, both active and passive sampling methods, such as active, plate assay, and Anderson impactor/sampler, were included in our analysis. Studies featuring the assessment of clinical signs and infections (respiratory and other infections) in community and healthcare settings were excluded. Data were analyzed with Graph Pad Prism 6 software; ANOVA and Student's t-tests were used for comparisons. The confidence interval was calculated at 95%, and any difference ( $P < 0.05$ ) was considered to be significant.

## 3. Results

Among the approximately 8,000 air samples that were collected in the 28 examined studies, the levels of bacterial contamination were higher than those found in the fungal species. Hospital settings had higher levels of contamination than community settings ( $P = 0.122$ ; Figure 1). When considering Iran as a whole, the bacterial species most isolated were *S. aureus* (38.24%) and *Micrococci* (31.6%), while the fungi species most isolated were *Penicillium* (32.28%) and *Aspergillus* spp (22.78%). A majority of

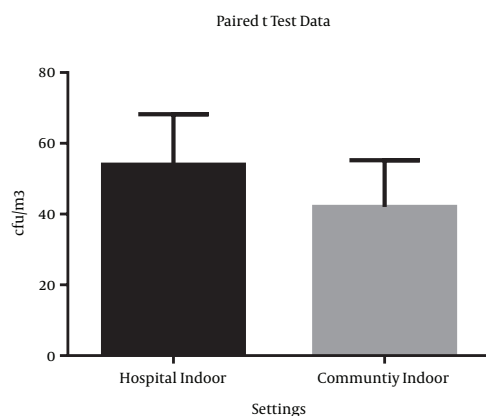
the other contaminations included *Micrococci*, coagulase-negative *Staphylococci*, gram-positive *Bacilli*, and *Cladosporium* and *Alternaria* spp (Figures 2 and 3) (14, 17-21).

Among the air samples obtained in various hospital settings, the highest level of bacterial contamination was determined in infectious disease (ID) ( $43.12 \pm 23$  cfu/m<sup>3</sup>) and intensive care unit (ICU) ( $41.61 \pm 12.6$  cfu/m<sup>3</sup>) settings, followed by urology (31.01cfu/m<sup>3</sup>), emergency (22.16 cfu/m<sup>3</sup>), oncology (11.09 cfu/m<sup>3</sup>), neurology (11.91cfu/m<sup>3</sup>), surgery (11.12 cfu/m<sup>3</sup>), burn (10.14 cfu/m<sup>3</sup>), dentistry (3.01 cfu/m<sup>3</sup>), and operation (2.01cfu/m<sup>3</sup>) settings. The highest level of fungal contamination was  $7.01 \pm 2.1$  cfu/m<sup>3</sup> in ID (Figure 4) settings. Active sampling could isolate the agents more exactly and with higher sensitivity ( $P = 0.02$ ). The colony counts varied among studies, and the means were calculated. A higher level of moisture was significantly related to air contamination ( $p = 0.02$ ). It was shown that ID, ICU, and urology wards were most significantly contaminated, while surgery and operation settings had the lowest levels of contamination.

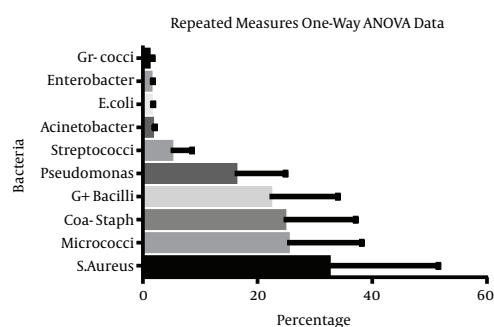
The mean densities of total bacteria and fungi observed during four seasons showed no significant differences, although one study from Southeast Iran demonstrated that in autumn, the total bacterial contamination was  $106.9 \pm 28.45$  cfu/m<sup>3</sup>, which was the significantly highest, and  $22.69$  cfu/m<sup>3</sup> in summer ( $P = 0.03$ ) (22). The levels of contamination in the different height of samplings were not determined in the studies. It was concluded that although the numbers of microorganisms in each hospital varied, the patterns and types were similar. The results showed no significant differences in the levels of contamination between Iran's geographical areas: North versus South ( $P = 0.21$ ) and East versus West ( $P = 0.43$ ). In some of the studies reviewed, the amount of morning bacterial and fungal contamination was observed to be lower than that found in the evening samplings.

The mean numbers of bacteria and fungi in all hospital settings were lower than the WHO standards of air contamination (Figure 4). However, the levels of contamination varied among different areas, from 300 cfu/m<sup>3</sup> to 20 cfu/m<sup>3</sup> for the bacteria and 130 cfu/m<sup>3</sup> to 15 cfu/m<sup>3</sup> for the fungi species.

In this study, hospital settings had higher levels of contamination compared to those observed in community settings. This result may be due to the hospital patient populations, particularly those in the infectious diseases wards. The levels of bacterial contamination were higher than those observed in the fungal species. Several previous studies found this same result (12, 23, 24). In terms of Iran as a whole, the bacterial species most isolated were *S. aureus* (38.24%) and *Micrococci* (31.6%), while the most isolated fungi species were *Penicillium* (32.28%) and *Aspergillus* spp



**Figure 1.** The Level of Contamination Between Hospital and Community Indoor Settings



**Figure 2.** Bacterial Species Isolated as Bioaerosols From Different Indoor Areas of Iran

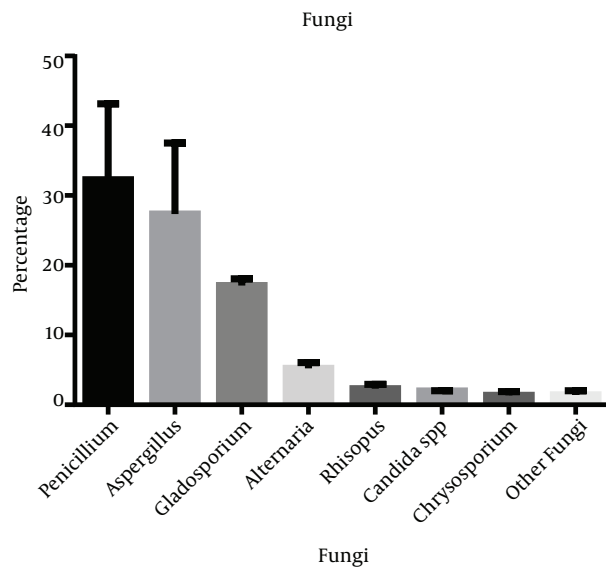
(22.78%). These findings are similar to those of Li in Thailand, Ekhaise in Benin city, Nigeria, Jo WK in Korea, Hussain in Malaysia, Mentese in Turkey, and Pastuszka in Poland and in other Eastern European countries, which indicated that *S. aureus*, *Micrococci*, *Penicillium*, and *Aspergillus* were the most common agents (23, 25-31); however, Hussain's study found *Pseudomonase*, rather than *Micrococci* (29), to be among the most isolated. In this study, other agents that were among the most distributed were coagulase-negative *Staphylococci*, gram-positive *Bacilli*, and *Cladosporium* and *Alternaria* spp.

Among air samples obtained from various hospital settings, the highest level of bacterial contamination was determined in ID ( $43.12 \pm 23$  cfu/m<sup>3</sup>) and in ICU ( $41.61 \pm 12.6$  cfu/m<sup>3</sup>) settings, followed by urology (31.01 cfu/m<sup>3</sup>), emergency (22.16 cfu/m<sup>3</sup>), oncology (11.09 cfu/m<sup>3</sup>), neurology (11.91 cfu/m<sup>3</sup>), surgery (11.12 cfu/m<sup>3</sup>), burn (10.14 cfu/m<sup>3</sup>), dentistry (3.01 cfu/m<sup>3</sup>), and operation (2.01 cfu/m<sup>3</sup>) settings. The highest level of fungal contamination was  $7.01 \pm 2.1$  cfu/m<sup>3</sup> in ID (Figure 4) settings. Active sampling could isolate the agents more exactly and with higher sen-

sitivity. The colony counts varied among studies, and the means were calculated. A higher level of moisture was significantly related to air contamination ( $p = 0.02$ ). It was shown that the ID, ICU, and urology settings had the highest levels of contamination, while the surgery and operation settings had the lowest levels of contamination.

The mean densities of total bacteria and fungi showed no seasonal variations (Table 3), although one study from Southeast Iran demonstrated that in autumn, the total bacterial contamination was  $106.9 \pm 28.45$  cfu/m<sup>3</sup>, which was significantly highest, and 22.69 cfu/m<sup>3</sup> in summer ( $P = 0.03$ ) (22). In addition, Mentese's study demonstrated variations in the winter to summer (W/S) ratios for totals of both bacteria (0.24 - 19.59) and fungi (0.16 - 6.59) in Turkey (30).

In a study conducted in China, Li demonstrated that the concentrations of bacteria and fungi on hazy autumn days are higher than those occurring on non-hazy days (32). It has also been demonstrated that air concentration decreases during rainy days (33). In another study by Moon, bioaerosol concentrations were shown to be related



**Figure 3.** Fungal Species Isolated as Bioaerosols From Different Indoor Areas of Iran

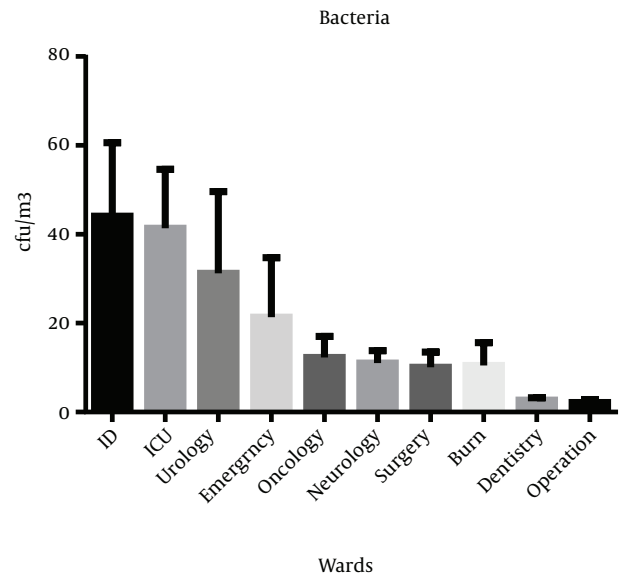
to temperature and to winter times (31). The levels of contamination in different height of samplings were not determined in the studies. It was concluded that although the numbers of microorganisms varied in each hospital, the patterns and types were similar. The results showed no significant differences in the levels of contamination between Iran's geographic areas: North versus South ( $P = 0.21$ ) and East versus West ( $P = 0.43$ ). The amount of bacterial and fungal contamination occurring in samplings obtained during morning hours were shown to be lower than those obtained during evening hours.

The mean numbers of bacteria and fungi in all hospital settings were lower than WHO standards ( $100 \text{ cfu/m}^3$  and  $50 \text{ cfu/m}^3$ , respectively) for air contamination. However, *S. aureus* exceeded this standard in ID ( $203 \text{ cfu/m}^3$ ) and in ICU ( $189 \text{ cfu/m}^3$ ) settings.

Active sampling methods, such as the Anderson sampler, were more efficient in isolating species compared to the plate assay ( $P = 0.46$ ). Fortunately, most of the studies used active air sampling.

#### 4. Conclusions

The levels of air contamination in hospitals and other indoor healthcare settings were lower than WHO's mean standard. Active air sampling methods are necessary for use in the measurement of bioaerosol contamination. The levels of contamination are not significantly different in various indoor settings of Iran. Efficient ventilation systems and contamination prevention or reduction is neces-



**Figure 4.** Mean Amounts of Bacterial and Fungal Contamination ( $\text{CFU/m}^3$ ) in Various Hospital Settings

sary in these settings. There were no significant seasonal variations in bioaerosol concentrations.

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This manuscript was written by the authors.

#### Footnote

**Authors' Contribution:** Abdolmajid Ghasemian, Sepideh Khodaparast, and Farshad Nojoomi and Hassan Rajabi Vardanjani designed the study and wrote the manuscript

**Table 1.** The Amount of Bacterial Contamination in Various Hospitals Settings

Isolate/setting, CFU/m <sup>3</sup>	ICU	ID	Surgery	Oncology	Urology	Neurology	Burn	Operation	Emergency	Dentistry
<i>S. aureus</i>	189	203	23.12	43.56	89.12	32.12	21.18	12.12	84.21	6.12
Micrococci	75.2	136	11.36	23.79	77.32	1.00	2.10	9.02	73.33	5.39
Coa- <i>Staphylococci</i>	74.6	101	21.12	32.61	67.77	28.12	23.45	12.41	64.39	4.03
Gr- Bacilli	43.8	83	11.31	11.21	34.58	11.32	20.11	-	53.31	2.02
<i>Pseudomonas</i>	6.34	6.59	2.34	1.26	7.12	4.03	12.14	3.31	9.3	3.89
Streptococci	1.47	1.62	1.66	-	-	12.51	24.12	-	1.22	-
<i>Acinetobacter</i>	3.72	7.43	3.48	1.02	3.32	6.21	6.43	-	2.11	-
<i>E. coli</i>	5.21	6.38	2.39	2.01	4.21	6.42	4.22	-	2.51	-
Enterobacter	1.34	2.11	0.21	-	1.01	3.04	1.03	-	0.51	-
Gr- cocci	-	0.26	-	-	-	-	0.01	-	-	-

**Table 2.** Levels of Contamination in Various Hospital Settings (WHO Mean Standard = 50 cfu/m<sup>3</sup>)

Isolate/setting, CFU/m <sup>3</sup>	ICU	ID	Surgery	Oncology	Urology	Neurology	Burn	Operation	Emergency	Dentistry
<i>Penicillium</i>	21.11	25.12	4.22	-	3.12	3.12	1.18	1.01	2.05	1.01
<i>Aspergillus</i>	11.21	11.34	3.32	0.79	4.01	3.00	2.30	2.00	3.33	2.31
<i>Cladosporium</i>	1.61	2.46	2.12	-	-	-	0.03	0.01	0.32	-
<i>Alternaria</i>	4.82	3.13	3.41	0.21	1.01	-	0.11	0.22	0.32	-
<i>Rhizopus</i>	1.24	0.59	0.34	0.06	-	-	1.00	-	0.01	-
<i>Candida spp</i>	1.57	0.64	1.26	-	-	0.51	0.14	0.21	0.02	0.15
<i>Chrysosporium</i>	2.72	0.41	0.48	-	-	-	-	-	-	-

**Table 3.** Mean Concentrations (cfu/m<sup>3</sup>) of Main Aerosol Bacteria and Fungi Genera During Each Season<sup>a</sup>

Genera/Season	Spring	Summer	Autumn	Winter	Rainy Times	Pr > F
Staphylococci	17.67	19.43	21.98	23.37	ND	> 0.001
Micrococci	14.77	12.18	21.23	19.18	ND	> 0.001
Gr+ bacilli	9.94	11	10.33	11.12	ND	> 0.001
Gr- bacilli	8.53	7.11	9.28	9.01	ND	> 0.001
<i>Penicillium</i>	10.72	8.90	11	9.21	ND	> 0.001
<i>Aspergillus</i>	7.9	8.33	9.11	8.61	ND	> 0.001
<i>Cladosporium</i>	3.25	4.44	3.93	3.82	ND	> 0.001

Abbreviation: ND: not determined.

<sup>a</sup>Pr > F: ANOVA analysis showing no significant difference.

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