Investigation of Bio-Air Contamination in Some Hospitals of Kermanshah, Iran

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Abstract

Background: Microorganism transmission is an important route for the outbreak of microbial pathogens in outdoor and indoor environments. Objectives: In this study, we performed air sampling and analysis of various bio-aerosol particles (bacteria and fungi) by a passive method in order to measure the level of contaminant particles. Materials and Methods: Air sampling was done in five hospitals in Iran, which included Imam Ali Hospital (IAH), Taleghani Hospital (TH), Imam Khomeini Hospital (IKH), Farabi Hospital (FH) and Imam Reza Hospital (IRH). In each hospital, units such as surgery, intensive care unit, angiography, emergency, oncology, nursing station, pathology laboratory, microbiological laboratory, operating room, isolation room (infectious section), delivery room and outdoor environment were investigated. Results: The total counts for viable bacteria and fungi in the sampled air from the hospitals were as follows: IAH (bacteria 0–100 colony-forming unit [CFU]/m³; fungi 0–14 CFU/m³), FH (bacteria 1–18 CFU/m³; fungi 0–7 CFU/m³), IRH (bacteria 0–14 CFU/m³; fungi 4–100 CFU/m³), TH (bacteria 4–250 CFU/m³; fungi 0–43 CFU/m³) and IKH (bacteria 11–1766 CFU/m³; fungi 0–25 CFU/m³). Conclusions: Results showed that microbial counts following the air sampling are strongly dependent on the environment. However, a low number of air microorganisms do not mean a clean and healthy environment.

Keywords: Air contaminant, bacteria, fungi, Iran hospitals, passive method

INTRODUCTION

Hospital environment consists of high levels of potentially hazardous agents. Poor ventilation, excess temperature, chemicals, dust and microorganisms are the main indoor air problems in hospitals.1 The microorganisms present in air rooms of the hospital may include pathogenic bacteria, virus, fungi, yeast and algae particles (bio-aerosol), which may be contributing factor for the overall health risk to the hospital personnel, patients and visitors.2 Sources of bio-aerosols from hospital environments include cool mists, vapourisers, humidifiers, flush toilets and air conditioners. If the microorganisms have survived the aerial transport, they can grow and reproduce in the new environment and may spread further. About 1.5 million people become infected during their hospitalisations each year in the United State.3 Contamination of hospital environment, particularly intensive care units (ICUs), operating theatres, etc., is considered among the most common life-threatening sources of nosocomial infections, especially to debilitated patients and patients undergoing surgical procedures requiring high level of environmental sterility (such as transplant surgery, open-heart surgery and cystoscopy).4 Therefore, there is a need to monitor and prevent the generation, introduction and spread of air particles in hospital environments.5,6

Despite various limitations of measuring bio-aerosol concentration, recently some efforts have been put to investigate bio-aerosol pollutions in hospital environments.7,8 Vonberg and Gastmeier;9 Ruiz-Camps et al.,10 and Armadans-Gil et al.11 suggested that microbiological air sampling may be
a useful method to detect increases in the concentrations of bio-aerosols in hospital environments. A direct relationship between bio-aerosols produced during hospital procedures and the respiratory system infections has been demonstrated.\(^{[11]}\)

The choice of method for air sampling and analysis depends on many parameters such as environment type, agent type and count of microorganisms (less or more than \(10^6 \text{ m}^{-3}\)). Microbiological content of the air can be usually detected by two methods.

**Active detection**

In which, the number of bio-aerosols present in the air is given in colony-forming units (CFUs)/m\(^3\) of air.\(^{[6,12,13]}\) The bio-aerosols in the air are detected by a microbiological air sampler that draws known volume of air physically through or over a particle collection device. This method is applicable when the amount of bio-aerosols is not very high.

**Passive detection**

In this method, the number of bio-aerosols present in air is given in CFU/plate/time (CFU/m\(^2\)/h).\(^{[14]}\) Standard Petri dishes containing culture media (settle plates) are exposed to the air for a given time to collect bio-aerosol particles; these ‘sediment’ are subsequently incubated. Passive detection has advantages such that the method is cheap, available everywhere and results obtained are reliable, reproducible and can be taken in different places at the same time.

The aim of bio-aerosol sampling is mainly to assess the contamination of a critical surface (wound, medicament and food) produced by the fallout of microorganisms coming from the air. Recently, for this purpose, the measurement of bio-aerosol air contamination by settling plates (passive sampling) appears in several official standards since it gives a direct indication of the microbial contamination of the surface. Both methods (passive and active sampling) are suitable for general monitoring of air contamination like routine surveillance programs. However, the choice must be made between one and the other to get specific information. If the air sampling performed during surgery is carried out to monitor the risk of microbial wound contamination, passive sampling is better than active sampling at predicting the likely contamination rate at the surgical room, as it allows a direct measure of the number of microorganisms settling on surfaces. On the other hand, if the sampling is performed to obtain information on the concentration of all inhalable viable particles, the active method should be done.\(^{[15]}\)

According to previous researches, both the amount and type of microorganisms that exist in the hospital environment are important and related to nosocomial activities.\(^{[16]}\) Therefore, we decided in this study to identify the types and estimate the amount of contamination particles (bacteria and fungi) by passive method in various units of five hospitals in Kermanshah city, Iran. The hospitals involved in the study were Imam Ali Hospital (IAH), Taleghani Hospital (TH), Imam Khomeini Hospital (IKH), Farabi Hospital (FH) and Imam Reza Hospital (IRH). Culture-able airborne bio-aerosols were recovered and quantified using six-stage Andersen samplers.

To the best of our knowledge, there is no report that determines the type and level of contamination in various units of these hospitals in Kermanshah, Iran.

**MATERIALS AND METHODS**

**The sampling site**

The study was performed in five hospitals in Kermanshah, Iran, between December 2016 and February 2017. Air samples were collected from several units in each hospital, including the surgery, ICU, angiography, emergency, oncology, nurses station, pathology laboratory, microbiological laboratory, operating room, isolation room (infectious section), delivery room and outdoors. Each area in the hospital was visited three times. Air sampling with 283 L value was performed at a height of 1.5 m above ground level during 10 min to simulate the breathing zone.

**Statistical analysis**

Results were expressed as mean values and percentages. The limit of statistical significance was \(P = 0.05\). All data analyses were performed using the Statistical Packages for the Social Sciences (SPSS) version 22 (IBM, Chicago, IL, USA). Furthermore, all the experiments were determined in triplicate and repeated three times to ensure reproducibility.

**RESULTS AND DISCUSSION**

The aim of bio-aerosol sampling is mainly to assess the contamination of a critical surface (wound, medicament and food) produced by the fallout of microorganisms coming from the air. Recently, for this purpose, the measurement of bio-aerosol air contamination by settling plates (passive sampling) appears in several official standards since it gives a direct indication of the microbial contamination of the surface. Both methods (passive and active sampling) are suitable for general monitoring of air contamination like routine surveillance programs. However, the choice must be made between one and the other to get specific information. Especially, if the air sampling performed during surgery is carried out to monitor the risk of microbial wound contamination, passive sampling is better than active sampling at predicting the likely contamination rate at the surgical room, as it allows a direct measure of the number of microorganism settling on surfaces. On the other hand, if the sampling is performed to obtain information on the concentration of all inhalable viable particles, the active method should be done.\(^{[15]}\) The current study investigated air contamination in the environment of five hospitals in Iran by passive method. The World Health Organization (WHO) has suggested relatively relaxed limits of 100 CFU/m\(^3\) for bacteria and 50 CFU/m\(^2\) for fungi in the air of hospitals.\(^{[17]}\) Therefore, quantitative and qualitative outcomes of this study...
demonstrate that contamination level and microbial variety in the studied hospitals are not far fetched from the WHO standards, especially with regard to fungal counts.

A few similar studies have been carried out in other hospitals in Iran. Eslami et al.\(^{19}\) found that the most prevalent bacteria identified were *Staphylococcus epidermidis* (75%) in the air of eye operating room and *Staphylococcus saprophyticus* (52%) in the internal ICU and isolation room. The most prevalent fungi identified in the air of selected wards were related to *Alternaria alternata* (43%), *Aspergillus flavus* (24%), *Penicillium* (36%) and *Curvularia* (21%). Mirzaei et al.\(^{19}\) collected 72 samples from three emergency rooms and three operating rooms that 17 types of bacteria were detected, including *Staphylococcus*, *Micrococcus*, *Viridans streptococci Pneumococcus*, *Escherichia coli*, *Streptococcus*, *Bacillus cereus*, *Bacillus subtilis*, *Klebsiella*, *Pseudomonas*, *Diptherther*, *Citrobacter* and *Enterobacter*. The most prevalent bacteria in this study were *Actinomyces* spp. (75.34%, from the outdoor air of IAH) and *S. epidermidis* (47.72%, from the air of nurses station of IKH). While the predominant fungal air contaminant was yeast (79%, from the outdoor air of IAH) and *Candida* spp. (56.12%, from the surgery room of IRH), Gizaw et al.\(^{20}\) reported that *Staphylococcus aureus* and *Streptococcus pyogenes* were found in most of the hospital wards.

**Imam Ali and Taleghani Hospitals**

Table 1 presents the average bio-aerosol contaminant (bacteria and fungi) levels in the surgery units and the outdoor environments of IAH and TH during open-heart surgery and 3 h after open-heart surgery.

**Table 1: The average level of bio-aerosols (bacteria and fungi, colony-forming units/m\(^3\)) in different rooms of Imam Ali and Taleghani Hospitals**

| Hospital | Room       | Type          | Bacteria | Level (CFU/m\(^3\)) | Fungi | Type          | Level (CFU/m\(^3\)) |
|----------|------------|---------------|----------|---------------------|-------|---------------|---------------------|
| IAH      | Surgery    | ND            |          | -                   | ND    | -             |                     |
|          | ICU        | *S. aureus*   |          | 7 (4.79)            | ND    | Yeast         | 14 (56)             |
|          | Angiography| *S. epidermidis* |          | 7 (4.79)            | ND    | -             |                     |
|          | Outdoor    | *Actinomycetes* spp. |          | 11 (7.53)          | Yeast | 11 (44)       |                     |
|          | Outdoor    | *Bacillus* spp. |          | >100 (75.34)        |       |               |                     |
| TH       | Surgery (new)| *S. epidermidis* |          | >100 (250) (36.07) | ND    | -             |                     |
|          | Surgery (old)| ND            |          | -                   | ND    | -             |                     |
|          | ICU (new)  | *S. aureus*   |          | 4 (0.57)            | ND    | -             |                     |
|          | ICU (old)  | *S. epidermidis* |          | 18 (2.59)          | ND    | -             |                     |
|          | Emergency  | *Corynebacterium* spp. |          | >100 (250) (36.07) | Yeast | 7 (12.96)       |                     |
|          | Oncology   | *S. epidermidis* |          | 11 (1.58)          | ND    | -             |                     |
|          | Nursing station | *S. epidermidis* |          | 11 (1.58)          | ND    | -             |                     |
|          | Outdoor    | *S. aureus*   |          | 14 (2.02)          | Yeast | 4 (7.40)       |                     |
|          |            | *S. epidermidis* |          | >100 (15.87)       | Yeast | 43 (79.62)       |                     |
|          |            | *Lactobacillus* spp. |          | 11 (1.58)          |       |               |                     |

ND: Not detect, *S. aureus*: *Staphylococcus aureus*, *S. epidermidis*: *Staphylococcus epidermidis*, TH: Taleghani Hospital, IAH: Imam Ali Hospital, CFU: Colony-forming units, ICU: Intensive care unit

The Gram-positive bacteria (*Bacillus* spp. and *Actinomycete* spp.) and fungi (yeast) in outdoor air of IAH were 11 (<100) and 11 CFU/m\(^3\), respectively. Airborne bacteria and fungus particles were not detected from the surgery room environment of IAH. The absence of airborne bio-aerosols in the surgery room air compared to outdoor air indicated the presence of a sufficiently controlled system in IAH. The healthcare workers’ (HCWs') standard limit is <100 and <50 CFU/m\(^3\) for bacteria and fungi, respectively, in hospital rooms. According to HCWs' standard, IAH has the recommended environmental air condition.

In TH, air sampling of the old surgery room was done 3 h after an open-heart surgery. The bacteria and fungus particles were not detected in the air of old surgery and old ICU rooms. In the new surgery room, 250 CFU/m\(^3\) of *S. epidermidis* which is regarded as unsafe according to HCWs' standard. However, no fungus particles were isolated from this room. In the outdoor air, the major contaminant was *S. epidermidis* (>100 CFU/m\(^3\)) and yeast (43 CFU/m\(^3\)).

At the emergency unit of TH various types of bacteria, *Corynebacterium* spp. (>100 CFU/m\(^3\)), *S. aureus* (11 CFU/m\(^3\)), *Actinomycetes* spp. (7 CFU/m\(^3\)) and fungi ([yeast] 7 CFU/m\(^3\)) were isolated.
were isolated. Therefore, this environment has not met the HCWs’ standard for the hospital personnel and the patients. According to the above results, the indoor environment of TH compared to the outdoor environment is more polluted.

According to the above results of IAH and TH, the environment of IAH (25 CFU/m³ total contamination of bacteria and 14 CFU/m³ total contamination of fungi) compared to TH (558 CFU/m³ total contamination of bacteria and 11 CFU/m³ total contamination of fungi) is very safe.[21]

Airborne indoor bacteria could be related to frequent movements of many individuals (patients, attendants, visitors and healthcare personnel).[22] Furthermore, airborne indoor fungi come from two sources: (1) the outdoor air and (2) the indoor fungal colonisation (colonisation originates mainly in every wet, dark and poorly ventilated area).[23]

All the isolated bacteria and fungi in IAH and TH are Gram positive and yeast, respectively, similar to what was observed in other hospital’s bio-aerosol studies. In our study, the total count for IAH was 25 CFU/m³ for bacteria and 14 CFU/m³ for fungi. This was slightly lower than levels reported from hospitals in Spain,[24] Sweden,[15] Palestine,[16] the United Arab Emirates[25] and India.[26] However, TH environment has higher levels of Gram-positive bacteria compared to some the above-mentioned hospitals.

**Imam Khomeini and Farabi Hospitals**

Table 2 presents the average level of bio-aerosol contaminants (bacteria and fungi) in some selected hospital rooms and outdoor environments of IKH and FH.

| Hospital | Room        | Bacteria Type | Level (CFU/m³) | Fungi Type | Level (CFU/m³) |
|----------|-------------|---------------|---------------|------------|---------------|
| IKH      | Surgery     | S. epidermidis | >100 (353) (9.45) | Yeast      | 25 (44.64)    |
|          | ICU         | S. epidermidis | >100 (353) (9.45) | Yeast      | 21 (37.50)    |
|          | Emergency   | S. aureus     | >100 (240) (6.42) | ND         | -             |
|          | Nursing station | S. aureus | 4 (0.10) | ND         | -             |
|          | Pathology laboratory | S. aureus | >100 (102) (2.73) | ND         | -             |
|          | Microbiological laboratory | S. epidermidis | 11 (0.29) | Aspergillus spp. | 10 (17.80) |
|          | Microbiological laboratory | S. saprophyticus | >100 (176) (4.71) | -         | -             |
|          | Microbiological laboratory | Bacillus subtilis | >100 (706) (18.9) | -         | -             |
|          | Microbiological laboratory | Bacillus subtilis | 28 (0.74) | -         | -             |
|          | Outdoor     | ND            | -             | ND         | -             |
| FH       | ICU         | Listeria spp. | 7 (9.45) | ND         | -             |
|          | Laboratory  | S. aureus     | 18 (24.32) | Yeast      | 7 (41.17)     |
|          | Laboratory  | S. epidermidis | 11 (14.86) | -         | -             |
|          | Outdoor     | S. aureus     | 5 (6.75) | Candida spp. | 2 (11.76)    |
|          | Outdoor     | S. epidermidis | 8 (10.81) | Penicillium | 1 (5.88)     |
|          | Outdoor     | Bacillus spp. | 13 (17.56) | Yeast      | 7 (41.17)     |
|          | Outdoor     | Actinobacteria spp. | 1 (1.35) | -         | -             |

ND: Not detect. S. aureus: Staphylococcus aureus, S. epidermidis: Staphylococcus epidermidis, IKH: Imam Khomeini Hospital, FH: Farabi Hospital, CFU: Colony-forming units, ICU: Intensive care unit.
0–28 CFU/m³ and India (10–150 and 45–120 CFU/m³) for bacteria and fungi, respectively. The high level of bio-aerosol contaminant recorded at IHK might be considered as possible reservoirs for opportunistic nosocomial infections in that hospital.

**Imam Reza Hospital**

The average level of bio-aerosol contaminants (bacterial and fungal) in various units of IRH is shown in Table 3.

There were no bacteria or fungus particles detected in the outdoor air, the operation and the delivery rooms of IRH. However, we isolated *Lactobacillus* spp. (14 CFU/m³), *S. aureus* (25 CFU/m³), *E. epidermidis* (11 CFU/m³), *Bacillus* spp. (21 CFU/m³), *Listeria* spp. (14 CFU/m³), *E. coli* (7 CFU/m³) and *Mucor* (4 CFU/m³) in the surgery room, ICU, emergency room, angiography room, isolated room (infectious section), pathology laboratory and the microbiological laboratory of IRH, respectively. Various types of fungi (yeast: 64 CFU/m³, *Candida albicans*: 18 CFU/m³ and *A. flavus*: 4 CFU/m³) were detected. According to the above results and HCWs’ standard, IRH has a safe condition from the point of bacterial level and pollution from the point of the fungal level.

Our results were considerably lower than those previously reported by Curtis et al.,[31] by Doležal et al.[32] by Kelsen and McGuckin,[33] by Kotlarek-Haus et al.[34] and by Nunes et al.[35]

Based on the results, the following recommendations may be considered to mitigate bio-aerosol generation and transmission:

1. For hospital designers: Designing a better ventilation system or adding bed head removable return air inlets, which can be employed during nebulization therapy or when patients are coughing.
2. For managers and nurses: Using screens or individual rooms for separate patients.
3. For cleaners: Using low volatile organic compound emission detergents.
4. For nurses: Making bed gently and strictly using personal protective clothing (mask) during nebulization therapy or when patients are coughing.

**Conclusions**

In this study, bio-aerosol particle (bacteria and fungi) contamination in some hospitals of Iran (IAH, TH, IKH, FH and IRH) was investigated. Significant level of air contamination by bacteria (>100 CFU/m³) was detected at IAH, TH and IKH, and significant fungus particles (>100 CFU/m³) were detected at IRH. Very low level of bio-aerosol contamination was detected at FH. However, a low number of air microorganisms do not mean a clean and healthy environment. Therefore, comprehensive studies are necessary to determine health risk associated with the air environment of these hospitals.

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**Conflicts of interest**

There are no conflicts of interest.

**Table 3: The average level of bio-aerosol contamination (bacteria and fungi, colony-forming units/m³) in different rooms of Imam Reza Hospital**

| Hospital          | Room                      | Bacteria          | Level (CFU/m³) | Fungi          | Level (CFU/m³) |
|-------------------|---------------------------|-------------------|----------------|----------------|----------------|
| IRH               | Surgery                   | *Lactobacillus*   | 14 (14.58)     | *Candida*      | >100 (56.12)   |
|                   | Operating room station    | ND                | -              | ND             | -              |
|                   | ICU                       | *S. aureus*       | 4 (4.16)       | Yeast          | 4 (2.04)       |
|                   |                           | *E. epidermidis*  | 4 (4.16)       |                |                |
|                   | Emergency                 | *S. aureus*       | 7 (7.29)       | ND             | -              |
|                   | Angiography               | *Mucor*           | 4 (4.16)       | ND             | -              |
|                   | The isolated room         | *S. aureus*       | 7 (7.29)       | ND             | -              |
|                   | (infectious section)      | *Listeria*        | 14 (14.58)     |                |                |
|                   | Delivery room             | ND                | -              | ND             | -              |
|                   | Pathology laboratory      | *E. coli*         | 7 (7.29)       | Yeast          | 35 (17.85)     |
|                   |                           | *Bacillus*        | 7 (7.29)       | *C. albicans*  | 18 (9.18)      |
|                   | Microbiological laboratory| *Bacillus*        | 14 (14.58)     | Yeast          | 25 (12.75)     |
|                   |                           | *S. epidermidis*  | 7 (7.29)       | *Aspergillus*  | 4 (2.04)       |
|                   |                           | *S. aureus*       | 7 (7.29)       |                |                |
|                   | Outdoor                   | ND                | -              | ND             | -              |

ND: Not detect. *S. aureus*: *Staphylococcus aureus*, *E. epidermidis*: *Staphylococcus epidermidis*, IRH: Imam Reza Hospital, CFU: Colony-forming units, ICU: Intensive care unit, *E. coli*: *Escherichia coli*, *C. albicans*: *Candida albicans*
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