Pharmacogn J. 2024; 16(5): 1170-1176
A Multifaceted Journal in the field of Natural Products and Pharmacognosy
www.phcogj.com

Research Article

Health Risk Assessment and Monte *Carlo* Simulation of Microorganism Aerosol Pollution at the Intensive Care Unit of Dr. Wahidin Sudirohusodo Hospital. Makassar

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History

- Submission Date: 10-04-2024;
- Review completed: 25-06-2024;
- Accepted Date: 08-10-2024.

DOI : 10.5530/pj.2024.16.191

Article Available online

http://www.phcogj.com/v16/i5

ABSTRACT

Microorganism pollutants can be bacteria, fungi and spores in the room. Microorganisms that are distributed in space are known as bioaerosols. The spread of bioaerosol in hospitals can result in danger to human health, especially for patients with weakened immune systems. Risk assessment is very important for an organization or institution to overcome current and future risks related to contamination. The QMRA approach has been applied to inform standards for the microbiological quality of food, water, air, and touched surfaces. The method uses descriptive analytics with a literature review design. Data was obtained through searches on the electronic databases Pubmed , Elsevier , and Google Scholar. Keyword terms such as: (Bioaerosol * and Airborne * and Infections * and Hospital *) , (Bioaerosol * and Microorganisms * and Inhalation) , (Airborne * and Microbial and * Hospital * or Intensive Room *) , (Bioaerosol * Quantitative Microbial Risk Assessment (QMRA)* and Hospital-Acquired Infection* and Intensive Care unit) . health risks AND sensitivity AND aerosol pollution AND microorganisms OR fungi OR bacteria AND montercarlo AND intensive care OR hospital rooms: (Bioaerosol * and Airborne * and Infections * and Hospital *) , (Bioaerosol * and Microorganisms * and Inhalation) , (Airborne * and Microbial and * Hospital * or Intensive Room *) , (Bioaerosol * Quantitative Microbial Risk Assessment (QMRA) * and Hospital-Acquired Infection * and Intensive Care unit) . health risks AND sensitivity AND aerosol pollution AND microorganisms OR fungi OR bacteria AND monter carlo AND intensive care OR hospital rooms are used. The search covered research conducted over the past ten years, from 2012 to 2022. Of the 27 articles found using the search terms, seventeen articles were selected for examination. The four categories of analysis are population, type of study, aims, and findings. According to research, one of the parameters for evaluating indoor environmental quality is bioaerosol. Microbial bioaerosol media in the air are ambient air and indoor air. The routes of exposure can be through ingestion/swallowing, direct contact and inhalation/inhalation. The cause of hospital infections is because hospital environmental conditions do not meet the requirements, causing high levels of room air germs. Poor hospital indoor air quality can cause HAIs. Therefore increasing levels of mechanical or natural ventilation as well as regular cleaning and maintenance activities can play an important role in improving indoor air quality.

Keywords: Bioaerosol, Health risk assessment, Microorganisms, Monte carlo, Pollution.

INTRODUCTION

Nosocomial infections or healthcare-associated infections occur in patients under medical care. Of every 100 patients admitted to hospital, seven in developed countries and ten in developing countries can contract nosocomial infections. Nosocomial infections are a major safety concern for healthcare providers and patients. With the increase in infections, there is an increase in the length of patient stay in hospital. This leads to a significant increase in medical costs for patients. Nosocomial infections or hospital-acquired infections (HAI) are a leading cause of morbidity and mortality in America. HAIs are infections in patients in hospitals or other health care settings that are not yet visible or are not in the incubation period when the patient is first admitted or that occur while the patient is hospitalized for more than 48 hours, which do not appear at the time of admission to the hospital. This also includes infections acquired by patients during treatment in hospitals or health facilities that only appear after the patient has been discharged, as well as infections among hospital staff [1].

HAIs are a major challenge for patient safety. It is estimated that in 2002, a total of 1.7 million HAIs included 33,269 HAIs among newborns in high-risk nurseries, 19,059 among newborns in healthy baby nurseries, 417,946 among adults and children in the ICU, and 1,266. 851 among adults and children outside the ICU[2] . One of the causes of hospital infections is that hospital environmental conditions do not meet the requirements, causing high levels of room air germs. Environmental conditions include air pollution, room density, humidity, indoor cleanliness, season, and temperature[3] . Poor hospital indoor air quality can cause HAIs because there are various microbial populations such as bacteria and fungi. One of the parameters for evaluating the quality of the indoor environment is bioaerosol[4,5] . Indoor bioaerosol levels were found to be at least tenfold higher than outdoors[6] . Microbial bioaerosol media in the air are ambient air and indoor air. The routes of exposure can be through ingestion/

Cite this article: Rochfika, Mallongi A, Syam A, Birawida AB, Arif SK, Sidin AI, Massi MN. Health Risk Assessment and Monte *Carlo* Simulation of Microorganism Aerosol Pollution at the Intensive Care Unit of Dr. Wahidin Sudirohusodo Hospital. Makassar. Pharmacogn J. 2024;16(5): 1170-1176.

swallowing, direct contact and inhalation/breathing[7]. Inhalation is the main exposure route of bioaerosol pollution[8].

Currently, the transmission of pathogenic viruses and bacteria is known to be an important pathway for various nosocomial infections. According to research, 10% of nosocomial infections are airborne infections and 16% of infections in intensive care units (ICUs) are caused by airborne transmission of pathogens[9]. The dynamics of HAIs in the ICU are estimated to originate from pathogenic sources, the patient's endogenous flora is 40-60%, cross infection through contaminated hands is 20-40%, changes in flora by antibiotics are 20-25%, contamination by the environment, food, air, personnel and other sources as much as 20%[10]. Quantitative microbial risk assessment (QMRA) is the application of mathematical models of exposure and dose to predict the likelihood of adverse outcomes resulting from exposure to pathogens[11]. QMRA is a modeling approach that integrates data related to microbial exposure and the relationship of human health effects with the aim of assessing the potential impact/health risks of exposure to harmful microorganisms[12]. Research conducted by Owildan, 2019, showed that the results of Bioaerosol risk analysis reported that the risk of HAIs in the ICU was higher than in the NICU, and the male population was more at risk than women[13].

The spread of bioaerosols in hospitals can cause harm to human health, especially for patients with weakened immune systems, potentially causing HAIs[14]. Hospital health complications are associated with HAIs in approximately 50%[15]. HAIs pose a significant and increasing threat to patients and healthcare workers[16]. HAIs can result in functional disability, emotional distress, reduce the patient's quality of life, one of the main causes of death, increase the duration of patient hospitalization thereby increasing the economic burden resulting in loss of work, increased use of medications, the need for isolation, and the use of additional laboratories and studies. Other diagnostics also contribute to the cost burden[15,17].

The results of interviews conducted by researchers with the PPI Hospital team, according to IPCN (Infection Prevention and Control Nurse), there are still infection incidence rates and some numbers that often exceed normal indicators are probably caused by staff negligence in implementing standard precautions, because as far as observations are concerned carried out by the IPCN every day, phenomena are always found that are at risk of causing HAIs. The results of observations carried out by researchers in the January-December 2023 period in the ICU showed that 7 out of 10 nurses who worked in the morning and afternoon shifts seemed to ignore standard precautions, such as not washing their hands according to procedures, and not doing it in five moments, as well as not using gloves. changing gloves after contact between patients, nurses were even found wearing gloves while writing nursing care, even though the nurses had not had contact with the patient's used fluids. The phenomenon mentioned above is an action that is very risky for increasing the incidence of HAIs in hospitals.

MATERIALS AND METHODS

Eligibility

The articles considered cover Airbone Bacteria and Airbone Fungi at one time, especially in Hospital *Intensive Care Units* using quantitative, qualitative experimental, research and development methods. The scope of this investigation extends beyond a focused geographic location. Research objectives were used to further screen the included studies. Despite containing several unrelated variables, many studies that excluded regions were excluded from the final separation process.

Information Source

The search included studies published over the past 10 years between 2012 and 2022. nine articles were selected for evaluation from the total 120 articles were identified using the search terms. Data were collected in Excel tables when the articles were obtained.

Search Strategy

Using keyword terms such as Bioaerosol * and Airborne * and Infections * and Hospital *) , (Bioaerosol * and Microorganisms * and Inhalation) , (Airborne * and Microbialand * Hospital * or Intensive Room *) , (Bioaerosol * Quantitative Microbial Risk Assessment (QMRA) * and Hospital-Acquired Infection* and Intensive Care units) . health risks AND sensitivity AND aerosol pollution AND microorganisms OR fungi OR bacteria AND monter carlo AND intensive care OR hospital rooms. Data was obtained through searches on electronic databases Pubmed, Elsevier, Google scholar. Other sources such as textbooks, national health reports, theses and dissertations are also used.

Selection Process

All studies were retrieved from the database, Mendeley was used as the search engine, and duplicates were removed through manual comparison of related instances and electronic configurations using Mendeley software. Articles not related to this study were removed at the screening stage, after the title and abstract of the study were checked. Full research texts were assessed independently by researchers using inclusion criteria. A third expert decided to exclude the study if there was any ambiguity or miscommunication between the two researchers. The listed references were checked to identify other relevant papers.

Data Collection

Data from included studies were extracted independently by members of the research team using data criteria divided into four categories: Title, Aim, Methods, and Results.

Data Synthesis

Because the data was obtained in quantitative, experimental, research and development form, the data was divided and discussed separately. The tabulation method is used to separate several key elements of research, such as population, type of research, objectives, and findings.

PRISMA The flow diagram of the article search process is shown in Figure 1.

RESULTS AND DISCUSSIONS

Microbiology is the study of Microorganisms consisting of large groups of microscopic organisms or agents that are too small to be seen with the naked eye and vary as single cells or groups of cells[18]. Microbiology has undergone rapid transformation over the past few decades. Most microorganisms cannot grow easily in pure culture[19]. However, Microorganisms can remain in the air for a long time[20].

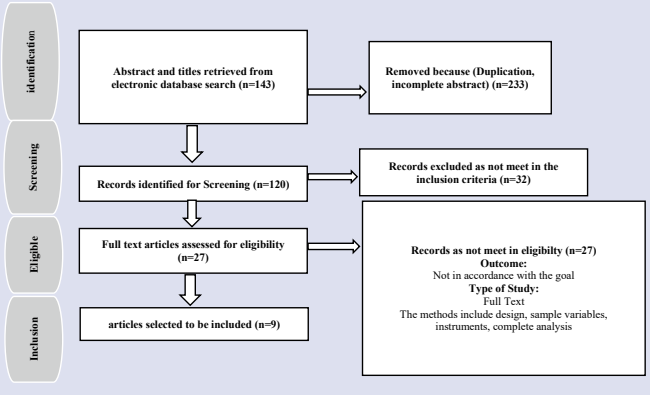

Figure 1. PRISMA Research Flow Chart.

Table 1. Child Growth Monitoring Strategy.

No	Writer	Research Title	Topic/Objective	Method	Results
1.	**Writer:** Zahra Tolabia, Mahmood Alimohammadia, Mohammad Sadegh Hassanvanda, Ramin Nabizadeha, Hamed Soleimania Ahmad Zareib **Journal Name:** Published by Elsevier BV This is an open access article under the CC BY license (http://creativecommons.org/licenses/by/4.0/). **Year of Publication:** 2019 **Doi: https://doi.org/10.1016/j.mex.2019.03.016**	Investigation of types and concentrations of bio-aerosols in surgical room air: A case study at Shari'ati hospital, Karaj.	This study aims to determine the relationship between infections in hospitals and the size of the surgical incision in addition to determining the concentration and bioaerosol of bacteria and fungi found in the operating room.	This cross-sectional descriptive-analytic study was conducted in the operating room of Shariati Hospital in Karaj, Iran during 2016 and 2017. A total of 198 bacterial samples and 198 fungal samples were collected and analyzed using standard passive sampling methods (1/1/1) during 180 days. Soy Tryptic Media Agar (TSA) and Sabouraud Dextrose Agar (SDA) were used for bacterial and fungal samples, respectively. Relevant differential tests are used to determine the genus and species of bacteria and fungi such as DNase test, Bile-esculin test, urease test motility test	In general, this research presents: 1.Relationship between bioaerosol concentration and surgical incision size. 2.Intraoperative bacterial and fungal bioaerosol concentrations in the air in the orthopedic, internal and cesarean operation rooms were significantly higher than preoperative concentrations (p-value<0.05). 3.There is no significant difference between the concentrations of bacteria and fungi in various types of operating rooms) p value <0.05)
2.	**Writer:** Fatemeh Bolookata, Mohammad Sadegh Hassanvand, Sasan Faridi, Mostafa Hadei, Masoumeh Rahmatiniad,Mahmood Alimohammadi **Journal Name:** Published by Elsevier BV This is an open access article under the CC BY license (http://creativecommons.org/licenses/by/4.0/) **Year of Publication:** 2018 **Doi**:https://doi.org/10.1016/j.mex.2018.11.021	”Assessment of bioaerosol particle characteristics at different hospital wards and operations theaters: A case study in Tehran”	This research aims to determine the type and amount of bacterial and fungal bioaerosols in indoor air hospitals by ward type and operating room.	Bacterial and fungal samples were collected using passive sampling method 1/1/1 scheme over a six month period at Khatam-Al-Anbia hospital, Tehran, Iran. Simple linear regression was used to determine the relationship between bioaerosol concentration and the number of active beds.	1.Our results show that the number of beds has a significant effect on airborne fungal concentrations. 2.The results of this research can be used to set indoor air quality standards for hospital wards and operating rooms.
3.	**Writer:** Ki Joon Heo, Cheol Eon Lim, Hannah Bae Kim, Byung Uk Lee **Journal Name:** the Journal of Aerosol Science, Medical & Engineering Sciences **Year of Publication**: 2017 **Doi**: https://doi.org/10.1016/j.jaerosci.2016.11.008	“Effects of Human Activities on Concentrations of Culturable Bioaerosols in Indoor Air Environments ”	1.Studying the influence of human activities on the concentration of fungal and bacterial bioaerosols in the indoor air environment. 1.Carrying out experiments measuring the concentration of bioaerosols and aerosol particles in a test room with people carrying out various activities in it.	In this study, cultivable bioaerosols were targeted with a focus on bioaerosol infectivity, which is consistent with legal bioaerosol standards. established by the Korean Ministry of the Environment. The Bio-Culture device is a multi-jet impactor type sampler for collecting data on airborne microorganisms. The sampling flow rate was 100 L/min and the sampling time was approximately 1 min per sample to prevent colony crowding. The measurements were replicated at least three times under individual sampling conditions.	In this study, we examined the relationship between human activities and culturable bioaerosol concentrations. 1.Bacterial bioaerosol concentrations are closely related to human activities. Human presence and moving activities increase the concentration of bioaerosol bacteria. 2.Speech activities, including heavy inhalation and exhalation, decrease bacterial bioaerosol concentrations in confined indoor spaces. 3.The impact on humans of fungal bioaerosol concentrations is negligible. For ordinary aerosol particles, the concentration of large particles (optical particle diameter: dp>3 μm) in the test chamber increases with increasing human presence and moving activity but decreases with speaking activity. 4.Detailed mechanisms for the relationship between bacterial bioaerosol concentrations and human activities can be studied in future work.
4.	**Writer:** Anita Rae Modi **Journal Name:** CLEVELAND CLINIC JOURNAL OF MEDICINE VOLUME 87 • NUMBER 10 **Publication Year**: 2023 **Doi**: doi:10.3949/ccjm.87a.19117	“ Hospital-acquired and ventilator-associated pneumonia: Diagnosis, management, and prevention ”	Hospital-acquired pneumonia (HAP) and ventilator-associated pneumonia (VAP) account for significant numbers of hospitalized patients morbidity and mortality. This is particularly challenging to diagnose promptly in the intensive care unit because a large number of other causes can contribute to clinical deterioration in complex and critically ill patients. The authors describe diagnosis, management, and prevention of this disease based on current guidelines and current evidence.	**Design and Samples:** Non-invasive testing such as blood and sputum cultures and staphylococcal nasal swabs should be performed in patients with suspected HAP or VAP to isolate the causative organism and adjust antibiotic therapy. The procalcitonin test should not be used to decide whether to start antibiotics but can be used in conjunction with clinical assessment to determine the duration of treatment. Patients with suspected HAP or VAP who are immunocompromised, hemodynamically unstable, or unable to obtain timely lower respiratory tract samples for microbiological testing, deserve empiric antibiotic treatment with a regimen based on individual risk factors and local antibiotic resistance	1.In addition to addressing individual patient risk factors for HAP and VAP, physicians must address the potential for nosocomial transmission of pathogens that commonly cause pneumonia. 2.Timely vaccination of patients and healthcare providers reliably reduces transmission of influenza, Haemophilus influenzae, and Streptococcus pneumoniae pneumonia. 3.Although this pathogen is not generally associated with the disease in hospital settings, transmission from patients hospitalized for community-acquired pneumonia or from ill health care providers to others in the same unit has been reported and can trigger HAP and VAP. 4.Respiratory hygiene measures throughout the hospital such as hand hygiene and the use of masks or tissues for cough sufferers can reduce the spread of respiratory pathogens. 5.Observational studies suggest some benefit from routine stethoscope scope and procedural equipment cleaning, although single patient stethoscopes and universal gown-glove contact isolation are the primary options supported by theoretical benefits.

5.	**Writer:** Vincenzo Russotto, Andrea Cortegiani, Santi Maurizio Raineri and Antonino Giarratano **Journal Name:** Russotto et al. Journal of Intensive Care (2015) 3:54 **Year of Publication**: 2015 **Doi:** 10.1186/s40560-015-0120-5	"Bacterial contamination of inanimate surfaces and equipment in the intensive care unit "	The purpose of this review is to provide Current evidence on surface contamination of inanimate objects and equipment in the ICU is based on the concept patient zone and the possible implications of cross-transmission of bacterial pathogens to critically ill patients	**Design and Samples:** Intensive care unit (ICU)-acquired infections are a challenging health problem worldwide, especially when caused by multidrug-resistant (MDR) pathogens. In the ICU, inanimate surfaces and equipment (e.g., bed rails, stethoscopes, medical charts, ultrasound machines) may be contaminated by bacteria, including MDR isolates. Cross-transmission of microorganisms from inanimate surfaces may have an important role in colonization and infections acquired in the ICU. Contamination can occur through the hands of health workers or through direct release of bacteria from patients which can survive for several months on dry surfaces. Higher environmental contamination has been reported around infected patients than around colonized-only patients and, in this latter group, a correlation has been observed between the frequency of environmental contamination and the location of culture-positive bodies.	1.Surfaces of inanimate objects and equipment in the ICU are heavily contaminated by bacteria, including MDR species. 2.Bacterial contamination can cause infections in the ICU 3.colonization or infection, however further research is needed to evaluate this correlation. 4.Clinicians and researchers must be aware of the risk of cross-transmission of pathogens from inanimate surfaces for appropriate infection control measures to be adopted
6.	**Writer:** Smith J, Adams CA,,King MF, Noakes CJ, Robertson C, Dancer SJ. **Journal Name:** Journal Of Hospital Infection **Year of Publication**: 2018 **Doi**: https://doi.org/10.1016/j.jhin.2018.04.003	"Is there a relationship between airborne and surface microbes in the critical care environment?"	1.Correlating environmental pollution to air and surfaces in the ICU; 1.To examine the association between environmental contamination and ICU-acquired staphylococcal infections.	1.Patients, air, and surfaces were screened on 10 sampling days in a mechanically ventilated 10-bed ICU over a 10-month period. 1.Hand touch locations near the patient (N = 500) and air (N = 80) were screened to determine the total number of colonies and Staphylococcus aureus. 1.The amount of air is compared with the amount of surface based on proposed standards for air and surface bioburden. 1.The patient was monitored for staphylococcal infections acquired in the ICU during this time .	1.Overall, 235 of 500 (47%) surfaces did not meet aerobic count standards (≤2.5 cfu/cm2). Half of the passive air samples (20/40: 50%) failed the 'microbial air contamination index' (2 cfu/9 cm plate/hour), and 15/40 (37.5%) of the active air samples failed to meet clean air standards (<10 cfu/m3). 2.The settling plate data approximates the pass/fail proportion of the surface and provides the best agreement between air and surface parameters when evaluating surface benchmark values of 0–20 cfu/cm2. 3.The surface standard most likely to reflect a pass/fail cleanliness result compared to air is 5 cfu/cm2. 4.The rate of ICU-acquired staphylococcal infections was associated with the number of surfaces per bed over 72 hours during the day of sampling (P = 0.012). Conclusion Passive air sampling provides quantitative data similar to that obtained from the surface. Settling plates can serve as a proxy for routine environmental examination to determine the risk of infection in the ICU
7.	**Writer:** Dipender Kaur Najotra, Aneeta Singh Malhotra,1 Poonam Slathia, Shivani Raina, and Ashok Dhar. **Journal Name:** Microbiological surveillance of operating theatres: Five-year retrospective analysis from a Tertiary Care Hospital in North India. Int J App Basic Med Res 2017;7:165-8 **Year of Publication**: 2017 **Doi**: 10.4103/ijabmr.IJABMR_281_16	"Microbiological Surveillance of Operating Rooms: A Five-Year Retrospective Analysis of a Tertiary Care Hospital in North India"	The aim was to identify bacterial colonization of surfaces and equipment and to determine microbial contamination of the air in work spaces in a tertiary care hospital.	Materials and methods: Five years (January 2010–December 2014) a retrospective analysis was carried out on data obtained from routine microbiological surveillance in five inpatient rooms at the hospital. Surface samples were taken by wet swabbing from various locations and equipment. Bacterial species were isolated and identified by conventional methods. OT air quality surveillance is carried out using the settlement plate method.	Results: A total of 4387 samples were collected from surfaces and items from various PLs. Of this number, only 195 (4.4%) samples showed bacterial growth and produced 210 isolates. The dominant species isolated was Bacillus with 184 (87.6%) isolates followed by coagulase-negative Staphylococcus 17 (8.1%), Staphylococcus aureus 6 (2.9%), and Enteroccoccus spp. 3 (1.4%). Analysis of air samples in the operating room showed the lowest air colony forming unit (cfu) rate (27 cfu/m3) in the ophthalmology operating room and the highest rate of 133 cfu/m3 in the general surgery operating room. Conclusion: Studies show that operating rooms in our hospitals show very low levels of bacterial contamination in surface swabs and the number of cfu per m3 of air is within permissible limits.

8.	**Writer:** Ameneh Yousefzadeh, Afshin Maleki, Saeed Dehestani Athar, Ebrahim Darvishi, Manochehr Ahmadi, Ebrahim Mohammadi, Van Tai Tang, Rasoul Nassiri Kalmarzi, Hajar Kashefi. **Journal Name:** Environmental Science and Pollution Research (2022) 29:14143–14157 **Publication Year**: 2021 **Doi**: https://doi.org/10.1007/s11356-021-16733-x	"Evaluation of bio-aerosol type, density, and distribution modeling inside and outside different wards in a teaching hospital"	The aim is to determine the type and concentration of bacterial and fungal bioaerosols, as well as their distribution in the indoor and outdoor air of teaching hospitals to serve as a reference for future research or action.	Materials and methods: Air samples were collected with a single-stage Anderson sampler and particle mass counter over a four-month period in the fall and winter of 2019. In total, 262 bacterial and fungal samples were collected from the ward air of Tohid Hospital, Sanandaj, Iran. Antibiotic resistance testing, bacterial identification using the PCR method, and modeling of the distribution of bio-aerosol concentrations were also carried out. To identify bacteria and fungi, several biochemical and molecular tests as well as microscopic and macroscopic characteristic methods are applied.	The results showed that the highest and lowest bioaerosol densities were observed in the lungs and operating room (336.67 and 15.25 CFU/m3). Additionally, the highest and lowest particle concentrations were seen in the emergency ward and operating room, respectively. The most common fungi isolated from hospital air were Penicillium (24.7%), Cladosporium (23.4%), Aspergillus niger (13.3%), and Aspergillus Flavus (11.4%). Furthermore, the highest concentration of isolated bacteria was Staphylococcus hemolyticus (31.84%). Most bacteria showed the highest resistance to gentamicin. The overall average of hospital air pollution from bioaerosols is slightly higher than the standards proposed by international organizations. Due to the high concentration of bioaerosols and particles in the hospitals studied, providing appropriate conditions such as temperature, humidity, good ventilation, and intelligent air conditioning systems using efficient ventilation systems, and limiting ward entrances can reduce air particles in the hospital environment.
9	**Writer:** Ki-Hyun KiM, EhsanulKabir, Shamin AraJahan. **Journal Name:** 1001-0742/© 2017 Environmental Science Research Center, Chinese Academy of Sciences. Published by Elsevier BV **Year of Publication**: 2017 **Doi**: https://doi.org/10.1016/j.jes.2017.08.027	"Bioaerosols in the air and their impact on human health"	The goal is to expand knowledge regarding their identification, quantification, distribution, and health impacts (e.g., infectious and respiratory diseases, allergies, and cancer). related to bioaerosol risk assessment based on bacterial and fungal culture methods.	Materials and methods: Airborne particles are collected into a liquid collection medium using the impinger and/or cyclone method. The shredder is operated by channeling a stream of air through a nozzle into a liquid-filled collection chamber. The bioaerosol samples are ultimately collected into a specific sample medium, most commonly a filter through which they can be transferred to a plate or dissolved into a liquid solution for further microscopic examination or culture experiments.	Research results The presence of bioaerosol is thought to be the cause of various diseases in humans which not only include infectious/respiratory symptoms but also cancer. Bioaerosols are also found in most closed environments due to their presence in nature. Higher bioaerosol concentrations can be observed indoors (compared to outdoors) due to various internal sources generally associated with human activities. Therefore, increasing mechanical or natural ventilation levels as well as regular cleaning and maintenance activities can play an important role in improving indoor air quality. However, even under ideal conditions for preventive maintenance, the possibility of bioaerosol exposure remains. Given the fact that there is still much uncertainty in exposure assessment (i.e., underdeveloped tools for measuring risk), efforts to resolve the issue must be advanced in many ways. There are various types and non-ideal microbiological techniques available for sampling and analyzing bioaerosols (and their exposure levels) which have left much confusion and misunderstanding. Until new and reliable techniques are introduced, common protocols for quantitation based on currently available methods should be used to offer a nearly uniform basis to allow cross-comparison between different experimental data sets. Therefore, more research is needed to establish better assessment tools regarding bioaerosol exposure and their validation.

Bacteria in the air come from various external sources such as soil, vegetation, animals and water bodies, while the atmosphere itself is not a habitat for airborne bacteria. However, bacteria released from various sources enter the atmosphere by the process of aerosolization. Variations in meteorological factors significantly influence the initial aerosolization and dispersion processes[21]. The primary sources of airborne bacteria, viruses, and fungi to the environment include humans, pets, plants, plumbing systems, heating, ventilation, and air conditioning systems, mold, dust resuspension, and the outdoor environment[22].

The role of the environment regarding the medium of transmission of pathogenic microorganisms has a big influence. Environmental surfaces in patient rooms are often contaminated with pathogenic microorganisms. Pathogenic microorganisms can survive on indoor surfaces, patient beds, and medical equipment for long periods of time. Contact with environmental surfaces in treatment rooms or contaminated medical equipment by health workers or patients themselves often causes hand or glove contamination and has a significant correlation[23]. Related research results can be seen from several research literature results in table 1.

Risk assessment is the qualitative or quantitative characterization and estimation of the potential adverse health effects associated with exposure of individuals or populations to hazards (materials or situations, physical, chemical, and microbial agents). Risk assessment is not used in isolation but as part of a broader context as risk analysis[24]. Quantitative microbial risk assessment (QMRA) is the application of mathematical models of exposure and dose to predict the likelihood of adverse outcomes resulting from exposure to pathogens[11]. QMRA has treated a wide range of pathogens, including viruses, bacteria, protozoa, and prions, and produced estimates of likelihood of harm. The role of the environment regarding the medium of transmission of pathogenic microorganisms has a big influence. Environmental surfaces in patient rooms are often contaminated with pathogenic microorganisms. Pathogenic microorganisms can survive on indoor surfaces, patient beds, and medical equipment for long periods of time. Contact with environmental surfaces in treatment rooms or contaminated medical equipment by health workers or patients themselves often causes hand or glove contamination and has a significant correlation[23].

This literature review explains that the concentration of bioaerosol bacteria is closely related to human activities. The presence of potentially pathogenic bioaerosols in indoor and outdoor environments can increase the incidence of hospital-acquired infections. Air is a medium for transmitting infection by microorganisms. Bioaerosol is dust that can contain microorganisms, including endotoxins, fungi and bacteria, which can affect health when inhaled. Bioaerosols can cause infectious diseases, allergies, asthma and neurological diseases. Indoor air quality in hospitals is statistically and measured by microorganisms in the air that have the potential to cause HAIs

Identification and quantification of different airborne Microorganisms in various indoor environments is necessary to identify associated risks and to establish exposure thresholds. Control methods have also been briefly reviewed. However, some level of individual effort such as regular cleaning operations, maintenance activities, and proper ventilation systems also work best to improve indoor air quality. Respiratory hygiene measures throughout the hospital such as hand hygiene and the use of masks or tissues for cough sufferers can reduce the spread of respiratory pathogens.

CONCLUSIONS

One of the parameters to evaluate the quality of the indoor environment is bioaerosol. Microbial bioaerosol media in the air are ambient air and indoor air. The routes of exposure can be through ingestion/swallowing, direct contact and inhalation/inhalation. The cause of hospital infections is because hospital environmental conditions do not meet the requirements, causing high levels of room air germs. Poor hospital indoor air quality can cause HAIs. Therefore increasing levels of mechanical or natural ventilation as well as regular cleaning and maintenance activities can play an important role in improving indoor air quality.

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Cite this article: Rochfika, Mallongi A, Syam A, Birawida AB, Arif SK, Sidin AI, Massi MN. Health Risk Assessment and Monte Carlo Simulation of Microorganism Aerosol Pollution at the Intensive Care Unit of Dr. Wahidin Sudirohusodo Hospital. Makassar. Pharmacogn J. 2024;16(5): 1170-1176.