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ORIGINAL RESEARCH

The measurement of microbial air contamination index in the pulmonary ward, intensive care unit and pediatric intensive care unit at dr. Zainoel Abidin hospital, Aceh, Indonesia

TRISTIA RINANDA[1*], SAKDIAH SAKDIAH[1], RIMA RISTIANTI[1], VONNA YUNIRA[1], FEBY VANIA[1] AND ANDIKA CITRA BUANA[1]

[1]Faculty of Medicine, Universitas Syiah Kuala, Banda Aceh, Indonesia

*Corresponding Author:
tristia.rinanda@usk.ac.id

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Abstract. Nosocomial infections are one of the major problems in hospitals. Air is one source of nosocomial infections. Hospitals are filled with many patients, their families, and health workers daily. This large number of people allows the spread of various microorganisms through the air in droplets dispersed through breathing, talking, coughing or sneezing. This study used passive air sampling or settle plate method to measure the air quality in the pulmonary ward, Intensive Care Unit (ICU) and Pediatric Intensive Care Unit (PICU) at dr. Zainoel Abidin Hospital (RSUDZA). The air microbial contamination index was determined by counting the microbial colonies grown on Nutrient Agar and converted to CFU/m^3 of air volume using the Polish Standard PN 89/Z-04008/08 Formula. The results showed that the air microbial contamination index in the pulmonary ward, ICU and PICU exceeded the maximum threshold mentioned in the decree of the Minister of Health of the Republic of Indonesia No.1204/SK/X/2004, which was 500 CFU/m^3 for the pulmonary ward and 200 CFU/m^3 for the Intensive Care Units. Although the findings of this study only represent the large microbial particles pulled by gravity, the high microbial contamination index of each unit trigger air quality alerts. Therefore, adequate air system management and periodic monitoring are needed to improve air quality in the wards and intensive care units at RSUDZA.

Keywords: Air quality, settle plate, hospital, CFU/m^3, droplets

INTRODUCTION

Nosocomial infection or Healthcare-associated infection (HAI), also known as hospital-acquired infection, is an infection a patient acquired while receiving care in a hospital or other healthcare facility. These infections are not experienced during admission and may be acquired after discharge. Nosocomial infections can occur in patients, healthcare workers, and hospital visitors [1]. The prevalence of HAI is estimated to be 5.7%-19.2% in low and middle-income countries and 7.5% in high-income countries. Variations in prevalence between countries are due to differences in infection prevention and control efforts that are implemented [2,3]. Nosocomial infections are a critical health issue. Besides prolonging the length of stay, it also leads to increased resistance of microorganisms to antimicrobials, increased financial burden for patients and healthcare centers, and increased morbidity and mortality [3,4].

A hospital is a dynamic environment where patients, doctors, visitors, trainee doctors, administrative and medical personnel and other professionals spend a significant fraction of their time. The number of patients and their health conditions, hygiene practices, and activities within the hospital contribute to indoor air quality. Indoor air quality is one of the important health determinants [5,6]. Indoor air contamination is one of the well-known sources of nosocomial infection, particularly for patients with immunocompromised conditions. The contaminants comprise biological and non-biological materials. Biological contaminants, or bioaerosol (well-known in clinical settings as droplets), are microbial airborne particles such as viruses, bacteria, mold spores, algae and other microorganisms. Non-biological materials are inorganic substances such as cigarette smoke and dust from building materials and furniture. Hospital indoor environments play an essential role in becoming a reservoir and spreading the pathogenic microorganisms through breathing, speaking,

sneezing, coughing and other activities conducted within [7]. The role of the hospital indoor air environment in spreading pathogens, especially viruses, was massively studied during the COVID-19 pandemic [8]. Previous studies reported the major airborne-transmitted pathogenic bacteria in hospitals, namely Staphylococcus aureus and Mycobacterium tuberculosis, and several fungi such as Aspergillus flavus, A. fumigates, Candida albicans and Trichoderma [7].

The pulmonary ward is very vulnerable to microbial air contamination because most patients have respiratory diseases. The pathogenic microbes are transmitted to the air and surrounding environment through small respiratory droplets. For healthy individuals, the airborne microbes are not harmful. On the other hand, pathogenic and opportunistic airborne microbes can be harmful to immunosuppressed patients such as those admitted to the Intensive Care Unit (ICU). Therefore, microbial air contamination becomes a critical risk factor for hospital-acquired infections [5].

This study aims to determine the Index of Microbial Air Contamination (IMA) in the pulmonary ward, ICU and Pediatric Intensive Care Unit (PICU) at dr Zainoel Abidin Hospital (RSUDZA), Banda Aceh, Indonesia. dr. Zainoel Abidin Hospital, is a provincial hospital known for its high occupancy rate and dynamic healthcare and academic activities. To our knowledge, the hospital has not yet implemented a monitoring system for indoor air quality. Although the Infection Prevention and Control (IPC) program has been established in RSUDZA, air quality monitoring and management still need to be part of the program that is prioritized to be periodically conducted and evaluated. The present study employed a passive air sampling method, which is recognized for its simplicity and cost-effectiveness. Additionally, the standardization of IMA calculations enhances the value of this approach in assessing the microbiological quality of indoor air within hospital settings.

METHODOLOGY

The Index of Microbial Air Contamination (IMA) was determined using a passive air sampling method or settle plates. The IMA measurement was conducted at pulmonary ward, PICU and ICU. The study protocol has been approved by The Research and Development Committee of RSUDZA. Nutrient agar (NA) was used as media to grow the microbes. Nutrient agar is one of the recommended growth media for microbial air monitoring because it is a medium with low selectivity. It can grow various microorganisms such as bacteria, yeasts and moulds [9]. There was no further identification or determination of specific microbes. Therefore, other differential media were not used in the present study.

The minimum number of plates or sampling locations was determined based on The International Standard Organization (ISO) 14644-1 formula.

$N_L = \sqrt{A}$…….(1)

N_L is the minimum number of plates or sampling locations

A is the area of the clean room

The area of pulmonary ward, ICU, and PICU were 363 m^2, 250 m^2, and 208 m^2, respectively. Therefore, based on the above formula, the number of plates or sampling locations for Pulmonary Ward, PICU and ICU were 19, 14 and 16. The 90 mm plates contained Nutrients Agar (NA) were distributed in several locations of each clean room using the 1/1/1 rule: 1-hour exposure, 1 m above the floor, and 1 m away from walls or any major obstacles [10, 11]. The plates were placed in the room corridors. The air sampling was carried out once in a parallel manner in each room at 10 AM. The exposed plates were transferred to the laboratory using a cooler box (at 4°C) and incubated for 24 hours at 37°C, and the growth colonies were counted using a colony counter. The number of colonies was converted to CFU/m^3 or air using the Polish Standard PN 89/Z-04008/08 formula [12].

$$\text{CFU/m}^3 = \frac{a \; x \; 10{,}000}{p \; x \; t \; 0.2} \text{ .....(2)}$$

a is the number of colonies on plates/Petri dish

p is the surface of the plates/Petri dish (πr^2)

t is the time of exposure (minute)

The Index of Microbial Air Contamination corresponds to the CFU/m^3. The results were later assessed based on the maximum threshold stated on the decree of the Minister of Health of the Republic of Indonesia No.1204/SK/X/2004 [13].

RESULTS AND DISCUSSION

The present study used the passive air sampling method or settled plates to determine the IMA. The index has been recognized as a standardized parameter to measure microbial contamination. Upon implementation, the threshold values vary and depend on the specific environment and geographic region. The IMA threshold values in Indonesia are based on the Decree of the Minister of Health of the Republic of Indonesia No.1204/SK/X/2004 [13].

The result showed that the IMA of the pulmonary ward (Figure 1), ICU (Figure 2) and PICU (Figure 3) at dr. Zainoel Abidin Hospital had exceeded the threshold values, which were 500 CFU/ m^3 for the medical ward and 200 CFU/m^3 for the intensive care units (ICU and PICU). Although some plates contained CFU/m^3 below the threshold, the general assessment showed the dominance of high IMA on other plates (94.7% in the pulmonary ward, 62.5% in the ICU, and 64.3% in the PICU). The number of colonies of each plate and the CFU/m^3 were provided in a supplementary file.

Previous studies have revealed the use of the passive air sampling method in determining airborne microbial contamination. Several issues regarding the method standardization have been resolved by using the standardized plate size, length of exposure and position, well known as the 1/1/1 scheme [11]. Although some

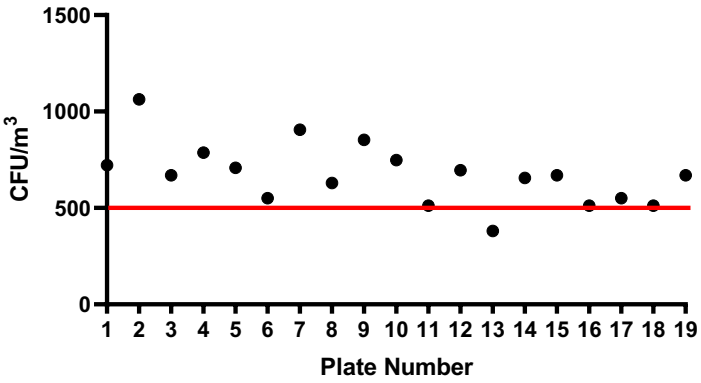

Figure 1. The IMA values at pulmonary ward. The black dots represented the CFU/m^3 on each plate. The red line denoted the threshold value based on the Decree of the Minister of Health of the Republic of Indonesia No.1204/SK/X/2004.

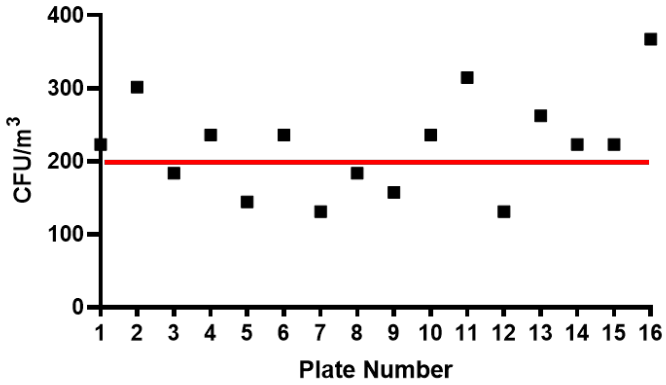

Figure 2. The IMA values at ICU. The black square represented the CFU/m^3 on each plate. The red line denoted the threshold value based on the Decree of the Minister of Health of the Republic of Indonesia No.1204/SK/X/2004.

studies reported the trends of higher CFU/m^3 calculated based on the conversion of CFU/plate, IMA measurements using the settle plates method are still reliable, especially with other advantages, namely economic and ease of use [14].

Hospitals are complex and dynamic environments, with a wide range of pathogenic microorganisms risk due to indoor pollution sources, such as contaminated surgical equipment and infected patients [15]. The infected patients originate more bioaerosol through coughing, sneezing and breathing than normal individuals. Thus, occupants and their activities, i.e. walking, talking, and breathing, are the primary sources of indoor microbial pollution. The airborne microbe concentration in the indoor air is also highly dependent on the nature and the performance of the building's ventilation system. Insufficient or inadequate ventilation may contribute to the buildup of higher indoor microbial load and other pollutants [16].

Based on the observation, three major factors contributed to the high IMA values in the pulmonary ward: inadequate ventilation, minimum indoor lighting and a high number of occupants. The pulmonary ward relies on a mechanical ventilation system (air conditioners), unaccompanied by an exhaust system. However, this setup results in inadequate indoor air circulation. Moreover, the lack of natural ventilation (openable windows) worsened indoor air quality. Without adequate ventilation, bioaerosol from patients, guests and hospital staff were entrapped and circulated in the room. This condition will further increase the risk of infection, especially respiratory infections. Although air is not a suitable medium for microbial multiplication and persistence, previous studies revealed evidence of microbial survival in the air with sufficient support from abiotic factors, such as temperature, relative humidity, insulation and the inadequate maintenance of the ventilation system [7]. The pulmonary ward used both lamps and windows as indoor light sources. However, the room still appeared dim. A previous study showed that light contributes to air quality by affecting humidity. The presence of ultraviolet influenced the bioaerosol concentration in indoor and outdoor environments since the light exposure was harmful to airborne microbes [7,15].

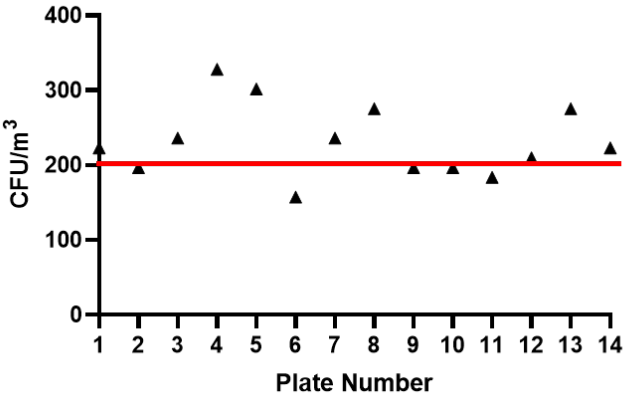

Figure 3. The IMA values at PICU. The black triangle represented the CFU/m^3 on each plate. The red line denoted the threshold value based on the Decree of the Minister of Health of the Republic of Indonesia No.1204/SK/X/2004

In addition to ventilation and lighting, indoor air quality is also affected by the density of people in the room. A room occupied by many people with different health conditions will increase exposure to the risk of infections. When the sampling was taken, 23 patients occupied the pulmonary ward. The medical staff and the patient's family members were also present. Moreover, the pulmonary ward was very crowded in the evening since guests and family members fully occupied it. A room occupied by many people has a higher IMA than an empty or unoccupied room. The high number of occupants increases the release of carbon dioxide (CO2), and the gas will accelerate the breathing or respiration rate, resulting in a greater bioaerosol release. Therefore, the number of occupants is one of the factors causing the high IMA [17]. Airway infections can occur through droplet transmission caused by large droplets produced by expiratory events such as coughing and sneezing [18]. The pulmonary ward treated patients who predominantly suffer from lung diseases such as Chronic Obstructive Pulmonary Disease (COPD) and pneumonia. Both of these diseases cause patients to cough and sneeze frequently, causing the release of droplets into the air, which will cause air contamination by microorganisms.

Inadequate ventilation also contributed to IMA at the ICU and PICU. The rooms were provided with manual and centrally operated air conditioners and exhaust systems. However, the instruments showed inadequate maintenance of the ventilation system, particularly the area surrounding the ceiling cassette of central air conditioner units. The units appeared damp due to the water absorption. This type of damage increases the humidity of the indoor environment and supports fungal growth [16].

In accordance with the Decree of the Minister of Health of the Republic of Indonesia Number 1204/MENKES/SK/X/2004, the ventilation system in hospitals must meet several minimum standards, including sufficient and regular maintenance of the ventilation system, the presence of exhaust in each room placed at the end of the ventilation, the room ventilation system provides with two High-Efficiency Particulate Air (HEPA) filters, periodic monitoring of air quality at least once in 6 months and air cleaning using ultraviolet light, namely Ultraviolet germicidal irradiation (UVGI) once per month [13].

Heating, ventilation and air-conditioning (HVAC) have been known as the widely used ventilation system, especially in "high-risk" indoor environments such as hospitals, particularly ICUs. The main functions of this system are heating, cooling, humidifying and de-humidifying, filtering, ventilating and air distribution. However, previous studies showed that the improper function of HVAC caused the spread of airborne microbes such as *Aspergillus*, Methicillin-resistant *Staphylococcus aureus* (MRSA) and *Clostridium difficile* [5,19]. In order to ensure the optimal performance of HVAC, some critical aspects need to be maintained, including the temperature, relative humidity (below 60%), proper filtration and pressurization, air change (outside air/total) per hour and air distribution pattern. All of these aspects are adjustable and depend on the type of clean rooms. Proper handling and gradual maintenance of the HVAC system and indoor air quality monitoring are also essential in reducing IMA [20]. Previous studies revealed the use of air-decontamination technology, namely ZeBox. ZeBox is a non-ionizing electric field that captures naturally charged microbes from the air and exposes them to engineered microbicidal surfaces. The electric field, the unique three-dimensional structure of the surface and the microbicidal substances worked synergistically in inactivating a broad spectrum of microbes [21]. The efficacy of ZeBox in clinical settings has been reported as it was able to reduce 90% of airborne and 75% of surface bacterial load on ICUs [22]. The discovery of this promising air-decontamination technology offers expectancy in the control of nosocomial infections.

CONCLUSION

This study revealed the use of passive air sampling in determining IMA in the pulmonary ward, ICU and PICU at dr. Zainoel Abidin Hospital, Banda Aceh. These rooms represented the high-risk room for bioaerosol formation and the most vulnerable communities at the hospital. The IMA values exceeded the maximum threshold based on the national standards for medical wards and intensive care units. dr. Zainoel Abidin Hospital's existing air system must be comprehensively evaluated. Future improvements in the air ventilation system are necessary in order to prevent nosocomial infections. There are several limitations in this study as follows: 1) this study only exposed the number of colonies without the identification of the airborne microbes; 2) there were no measurements of temperature and relative humidity at the time the measurements occurred; 3) the settle plate method only captured the large particles. Large particles have a slow Brownian motion. Hence, they are easily pulled by gravitational forces, and 4) the measurement of IMA was only carried out once. Therefore, the results cannot fully describe the dynamics of IMA and its determinants.

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