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Airborne Microbial Risk Assessment in Indonesian Hospitals 2024: Control Strategies to Improve Environmental Quality

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ABSTRACT
Hospital is a place where healthy and sick people meet, therefore the air quality in the hospital needs to be considered because it can affect human health. One of the risks of exposure to indoor air bacteria is Mycobacterium tuberculosis in health workers who work in pulmonary services and have direct contact with Tuberculosis patients every day. The purpose of this study was to determine the magnitude of the risk of exposure to air germ numbers to the health of pulmonary clinic staff in the hospital. The results obtained will be analysed using the Microbial Risk Assessment method. Based on the measurement of the air germ count in the pulmonary clinic room, the total germ count is 32 CFU/m3, which means that the air germ count in the pulmonary clinic room meets the requirements and there is also no bacterial growth of Mycobacterium tuberculosis. The results of the risk characteristics in theMicrobial Risk Assessmentin this study are the risk level (HQ) in the hospital's pulmonary clinic staff of less than one which indicates that the risk agent does not cause adverse health effects on pulmonary clinic staff and there is also no growth of Mycobacterium tuberculosisbacteria. Suggestions that can be given to the hospital are disinfection, installation of exhaust fans in the hospital pulmonary clinic room to regulate air circulation.

Keywords: Lung Polyclinic Room, Airborne Germ Count, Microbial Risk Assessment

BACKGROUND
Health care facilities that serve as a means for the community to obtain services are hospitals. As a major health institution, hospitals serve a wide range of individual health needs, from the care of hospitalised patients to outpatients and the handling of emergency situations. (Ministry of Health, 2020). The implementation of health services in hospitals needs to implement several arrangements to maximise its services. By implementing good environmental health practices, hospitals can minimise health risks associated with the environment, such as infections, allergies and poisoning. Through the implementation of various measures and strategies, it is expected to minimise the negative impact of the environment on health and create a healthy, safe, and comfortable hospital environment for everyone. (Health 2019).

Maintaining the quality of water, air, soil, and the condition of building facilities in accordance with environmental health standards is an important step in preventing the spread of disease and maintaining public health. Poor air quality can be a breeding ground for harmful microorganisms, increasing the risk of infection and health problems. (Dewi et al.,

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2022). Hospitals should prioritise optimising indoor air quality, given its significant impact on the health of all those in the hospital environment. Inadequate air can increase the risk of infection and worsen the health conditions of patients, staff and visitors. Indoor air pollution has more detrimental effects on health than outdoor air pollution. (Sk Akhtar 2016). This suggests that the higher the level of indoor air pollution, the higher the risk to health. (A'yun, 2022).

Indoor air quality can be affected by several factors, including the physical condition of the air, such as temperature, humidity, and airflow, as well as the presence of chemical and biological contaminants, such as cigarette smoke, dust, and microorganisms. The spread of microbes in the air is influenced by environmental conditions, especially temperature and humidity, which are key factors for the growth of microorganisms. Indoors, microorganisms generally multiply more easily than outdoors. Airborne bacteria will adhere to ground, floor or indoor surfaces. The majority of airborne bacteria, especially those with the potential to cause hospital infections, include species such as *Bacillus sp., Staphylococcus sp., Streptococcus sp., Pneumococcus sp., Coliform, and Clostridium sp.* (Rizca Yunanda et al., 2020).. One of the risks of exposure to indoor air bacteria is health workers who carry out daily activities in hospital buildings or rooms.

The risk of exposure to bacteria in the room is because hospital health workers have direct contact with patients every day. Healthcare-associated infections (HAIs) are infections that occur in patients while they are hospitalised or in other healthcare facilities where the infection was not present at the time of admission and is not in the incubation period (e.g., an infection that was present when the patient was hospitalised but emerged when the patient was discharged), and infections caused by the work of hospital staff and healthcare workers responsible for the patient care process. (Ministry of Health, 2017).

According to previous research conducted by Dewi et al. (2022) at the Semarang Port Health Office resulted in a Hazard Quotient (HQ) value of >1, which means that exposure to airborne germ counts poses a risk of adverse health effects (Situmorang, 2020). Nosocomial infections that occur in hospitalised patients worldwide are almost 9% or <1.4 million patients (Sapardi et al., 2018). (Sapardi et al., 2018).

Healthcare workers are at risk of contracting *Mycobacterium tuberculosis (TB)* because they frequently interact with patients who may be infected with TB. Mycobacterium tuberculosis is transmitted when a person infected with pulmonary tuberculosis speaks, sneezes, or coughs, releasing droplet nuclei containing the *M. tuberculosis* microorganism. These droplets may fall to the floor, ground, or other surfaces. Sunlight or high air temperatures can cause evaporation of the droplet nuclei and, with the help of the movement of wind currents, the *M. tuberculosis* bacteria contained in the droplet nuclei can be dispersed and follow the air currents. A healthy person can be infected with tuberculosis if they breathe in air containing these bacteria. The risk of transmission of M. tuberculosis bacteria can occur especially in the healthcare environment where active TB patients are treated.

One of the hospitals in Surabaya City, Indonesia has a focus of services in pulmonary problems. Every day services are carried out to people infected with lung disease which allows for airborne disease transmission. An environmental health risk analysis approach is needed because it can determine the magnitude of exposure to germ numbers in pulmonary clinic staff. The approach that can be taken to measure the amount of health risk in hospital

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pulmonary clinic staff is the *Microbial Risk Assessment* (MRA) method.

Based on the above problems, a study will be conducted to analyse the risk of exposure to airborne germs on pulmonary clinic staff using the *Microbial Risk Assessment* (MRA) method and identification of *Mycobacterium tuberculosis* bacteria in the hospital pulmonary clinic room.

METHODS

This study is a type of descriptive research, exposure to airborne microbes will be calculated using the *Microbial Risk Assessment* (MRA) method to determine the risk of exposure that enters the body of pulmonary poly officers in the hospital. The sample used in this study was the entire population (Total Sampling), namely all nurses, doctors, pharmacists and administrative officers at the pulmonary poly service at the hospital studied, totalling 15 people consisting of 2 doctors, 4 nurses, 3 laboratory staff, 1 cleaning service, 1 radiographer, 2 pharmacists and 2 counter staff.

Sampling using the Grap Sampling method and using the MAS-100 Eco Air Sampler tool at 5 points of the room. According to the Decree of the Minister of Health of the Republic of Indonesia Number 1335/Menkes/SK/X/2002 concerning Operational Standards for Taking and Measuring Hospital Room Air Quality Samples, microbial sampling of room air in hospitals is carried out at a minimum of 10% of the number of each room. This study also conducted interviews with pulmonary clinic officers about individual respondent data including Exposure Frequency / EF(Years), Exposure duration through inhalation / EDinh (Years), Body Weight / BW (Kg).

This study applies Microbial Risk Assessment to estimate the risk quotient that may arise in humans due to exposure to microorganisms. The dose-response analysis step including the information collected will be evaluated to estimate the concentration of contaminants that can have an impact on individuals. The case that occurs if the exposure agent enters the body through the inhalation route can be used the Beta Poisson model, namely:

$$Pt\ (d) = 1 - \left(1 + \frac{d}{\eta}\right)^{-r}$$

Pt(d) : probability of infection (d)
d : dose (CFU/org)
η : model parameters (3.36)
r : model parameter (3.04)

The next stage is exposure analysis which is carried out to measure how much exposure occurs and to estimate the amount of agent that enters the human body. Average daily dose (ADD) through inhalation can be calculated using the following formula:

$$\text{ADDinh} = \frac{\text{C} \times \text{IR} \times \text{EF} \times \text{EDinhalation}}{\text{BW} \times \text{AT}}$$

ADDinh : Average daily dose by inhalation (CFU/kg.day)
C : Concentration of microorganisms in air ($^{CFU/m3}$)
IR : Inhalation rate (^{m3}/day)
EF : Frequency of exposure (days/year)
EDinhalation : Exposure time (years)
BW : Body weight (kg)
AT : Average time (days)

The last stage is the risk characteristics used to determine the level of risk or it can be said that the determination of risk factors at a certain amount calculated in ARKL is at risk of causing health problems in individuals. The probability of an agent causing illness in individuals can be calculated through the following formula:

$$Q = \frac{ADDinh}{RfD}$$

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HQ : Large risk of non-carcinogenic agents
ADD : Average daily dose by inhalation
RfC : Reference dose (CFU/(kg.day))

If the HQ value is less than equal to 1, the health risk is less likely to occur so it does not have to be controlled, but it is recommended to maintain every situation so that the HQ value is not more than 1. The HQ value also shows how the risk level of a population is.

RESULTS

1. Physical Environment Measurements

Lighting

Table 1. Lighting Measurement Results in the Pulmonary Poly Room

Location	Result (Lux)	Average	NAB (Lux)
Loc 1	47.6	106.7	100
Loc 2	131.3		
Loc 3	221.6		
Loc 4	102		
Loc 5	31		

Based on the results of the measurements that have been made, it is found that the room lighting has an average of 106.7 lux.

Temperature

Table 2. Temperature Measurement Results in the Pulmonary Poly Room

Location	Result (°C)	Average	NAB (°C)
Loc 1	29.2	29.8	22-23
Loc 2	29.6		
Loc 3	30.2		
Loc 4	30.5		
Loc 5	29.5		

Based on the results of the measurements that have been taken, the results show that the room temperature has an average of 29.8°C.

Humidity

Table 3. Humidity Measurement Results in the Pulmonary Poly Room

Location	Yield (RH%)	Average	NAB (RH%)
Loc 1	60.9	56.74	40-60
Loc 2	59.7		
Loc 3	48.6		
Loc 4	56.3		
Loc 5	58.2		

Based on the results of the measurements that have been made, it is found that the humidity of the room has an average of 56.74%.

Ventilation Rate

Table 4. Measurement Results of Ventilation Rate in Pulmonary Poly Room

Location	Result (m/s)	Average	NAB (m/s)
Loc 1	0,16	0.15	0.15-0.25
Loc 2	0,15		
Loc 3	0,12		
Loc 4	0,23		
Loc 5	0,10		

Based on the results of the measurements that have been made, it is found that the ventilation rate of the room has an average of 0.15 m / sec.

2. Concentration of Germ Numbers in the Air

Table 5. Measurement Results of Air Germ Numbers in the Lung Poly Room

Location	Results	NAB
Pulmonary Clinic Room	32 CFU	35 CFU

Based on the results of the measurements that have been carried out, the results show that the total germ count in the hospital's pulmonary clinic room is 32 CFU/m3, which means that the air germ count in the pulmonary clinic room still meets the requirements of the Regulation of the Minister of Health of the Republic of Indonesia Number 2 of 2023 concerning Regulations on the Implementation of Government

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Regulation Number 66 of 2014 concerning Environmental Health.

3. Identification of *Mycobacterium Tuberculosis* in the Air

Table 6. Identification Result of *Mycobacterium Tuberculosis* in Pulmonary Clinic Room

Location	Result	Normal Value
Pulmonary Clinic Room	0	-

Based on the results of laboratory tests that have been carried out, the results show that there is no growth of Mycobacterium tuberculosis in the pulmonary clinic room.

4. Microbial Risk Assessment

Microbial Risk Assessment (MRA) consists of 4 stages namely hazard identification, dose-response analysis, exposure analysis and risk characterisation.

Hazard Identification

Hazard identification is the first stage to determine the source of risk. The purpose of this stage is to find out specifically about the impact of exposure to a risk agent that causes health problems. The risk agent in this study is airborne microbes in the pulmonary clinic room. The presence of microbes in the air that exceed the threshold will cause infection. In particular, *Mycobacterium tuberculosis* bacteria come from TB patients who come to the pulmonary clinic every day. This bacterial contamination in the air can allow nosocomial infections to workers who have direct contact with patients every day.

Dose-Response Analysis

Dose-response analysis aims to estimate the potential of risk agents to cause health problems in risk groups. According to the results of the above calculations, the probability of infection with airborne germs in the pulmonary clinic room is $9.9 \times {}^{10\text{-}1}$.

Exposure Analysis

The results of the exposure analysis describe the number of germs that enter the body (intake) in pulmonary clinic staff. The average intake dose was 0.38 CFU/kg/day. The minimum intake dose was 0.06 CFU/kg/day and the maximum was 0.85 CFU/kg/day.

Risk Characteristics

From the calculation of the HQ value, it is obtained if the HQ value of all lung poly officers at Husada Prima Hospital is <1. This can be interpreted if the exposure to airborne germ counts on lung poly officers at the hospital is said to be safe or not risky for officer health.

DISCUSSION

Lighting plays an important role in maintaining hygiene and health indoors. According to a previous scientific study conducted by Nugroho (2016) obtained results if there is a relationship between lighting and air germ numbers in the third class inpatient room of Dr Moewardi Surakarta Hospital. According to this study, the lighting was measured using a Lux meter at 5 points and resulted that the lighting in the pulmonary clinic room met the requirements with 106.7 lux. The hospital's pulmonary clinic room is an open space utilising natural lighting and artificial lighting. Natural lighting is obtained from glass windows that are opened and artificial lighting is added by installing several lamps at various points. The growth of microorganisms is greatly affected by lighting (Purnamasari et al., 2017)..

In this study, temperature measurements were taken using a thermometer at 5 points which resulted in a temperature of 29.8°C which means that the room temperature exceeds the predetermined threshold value. This can be caused because the hospital's pulmonary clinic room is an open room and uses natural air ventilation. In line with research

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Putra et al. (2018) which resulted in a relationship between room air temperature and the total number of airborne germs to health problems.

The growth of microorganisms, including bacteria, is influenced by air temperature. Each type of bacteria has an ideal temperature to reproduce optimally. At the optimal temperature, bacteria can grow and multiply well. Temperature will affect the cell breakdown process and inappropriate temperatures will cause damage to the cells (Nugroho et al., 2016). (Nugroho et al., 2016). The suggestion to overcome this is to install an exhaust fan in the pulmonary clinic room. According to Aulia et al. (2021)The exhaust fan can reduce heat so that the room air becomes comfortably cool.

In this study, humidity measurements were taken in the pulmonary clinic room using a Hygrometer tool which resulted in the humidity in the pulmonary clinic room being 56.7%, which means that the humidity meets the predetermined requirements. In line with research conducted by Dewi in 2022, building factors can affect the humidity level of a room. According to Dewi et al. (2022) in his research also explained that non-ideal building conditions, such as leaking roofs, impermeable floors and walls, and lack of natural and artificial light, can cause indoor humidity to increase.

The speed of air movement in the house, or ventilation rate, is crucial to prevent the growth of microorganisms. Inadequate ventilation can create an ideal environment for microorganisms to multiply rapidly, which can be harmful to human health. According to a scientific study conducted by Maulianti et al. (2021)Lack of ventilation can lead to a lack of oxygen in the house, which causes the indoor air humidity to increase. Air with high humidity is a good environment for the growth of pathogenic microbes.

The results of this study show that the ventilation rate in the pulmonary poly room is 0.15 m/second, which means that this figure meets the predetermined requirements. This is because the pulmonary clinic room is an open space with vents and doors that are always left open so that air exchange in the room can occur properly.

This study was conducted in the patient waiting room with the assumption that the room has a high risk because patients spend quite a long time waiting for the check queue. The results of this study by measuring the air germ count of the hospital right in the pulmonary clinic showed that the air germ count still met the applicable requirements. The total germ count in the pulmonary clinic room is 32 CFU/m3 which can be interpreted if the air germ count in the pulmonary clinic room meets the requirements of the Regulation of the Minister of Health of the Republic of Indonesia Number 2 of 2023 concerning Regulations for the Implementation of Government Regulation Number 66 of 2014 concerning Environmental Health.

According to research conducted by Hariyo (2020)The development and growth of microorganisms will be affected by physical environmental conditions that do not meet the requirements. In this study, the results of measuring the physical environment almost entirely met the requirements except for room temperature. The results of temperature measurements in the pulmonary poly room were found if the temperature was relatively high with an average of 29.8°C. High room temperature can affect the number of bacteria in the air. High temperatures can cause protein denaturation in bacterial cells. This process damages the structure of proteins and essential enzymes, which in turn can disrupt cellular functions and lead to cell death. (Astuti Dwi, 2022). These good physical environmental conditions and high room temperature can affect the number of germs in the air in the pulmonary clinic room which in fact meets the established requirements. The researcher measured the

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air germ count in only one room, namely the patient waiting room.

This study was conducted to identify the presence of *Mycobacterium tuberculosis* in the air of the pulmonary clinic room with the aim of knowing the size of the bacteria in the air. The results of this study showed that there was no growth of *Mycobacterium tuberculosis* in the pulmonary clinic room. Researchers only identified *Mycobacterium tuberculosis* bacteria in one room.

The physical environment of humidity, lighting, and temperature are environmental factors that support *Mycobacterium tuberculosis* bacteria to thrive. (Zulaikhah *et al.*, 2019).. In this study, the results of physical environment measurements almost entirely met the requirements except for room temperature. The physical environment of the room can affect the growth and spread of *Mycobacterium tuberculosis*. The bacteria can survive longer in low humidity environmental conditions. Dry conditions help bacteria stay alive longer in the air and on surfaces, as low humidity slows down the dehydration process of bacteria. (Andriana et al., 2023).. From the results of the measurements that have been made, the humidity level in the pulmonary poly room has fulfilled the requirements that have been set.

Natural sunlight has a significant destructive effect on *Mycobacterium tuberculosis*, mainly due to its *ultraviolet* (UV) light content. These UV rays can damage the bacteria's DNA and disrupt its reproduction process, thus killing or inactivating the bacteria. Therefore, rooms exposed to direct sunlight tend to have lower levels of bacteria. Regular exposure to sunlight helps to lower the concentration of *Mycobacterium tuberculosis* in the air and on surfaces, making the environment safer and healthier. (Sahadewa *et al.*, 2019).. This is an important reason to support that certain spaces, especially in health facilities, have access to adequate daylight to help control the spread of tuberculosis bacteria. The pulmonary clinic room is an open space so that sunlight can enter the room, in addition to artificial lighting from lamps. This can affect the growth of *Mycobacterium tuberculosis* in the air.

Hazard identification is the initial stage in conducting risk analysis. The purpose of this stage is to find out specifically about the impact of exposure to a risk agent that can cause adverse health effects. The risk agent in this study is the air germ count in the pulmonary clinic room. In line with research Dewi et al. (2022) The presence of germs in the air can be harmful to health, especially to pulmonary clinic staff who work for a certain period in a room.

Breathing air contaminated with germs can be harmful to health. In particular, Mycobacterium tuberculosis bacteria originating from 49 TB patients who come to the pulmonary clinic every day. This airborne bacterial contamination could allow nosocomial infection to workers who have direct contact with active TB patients every day. When a person with BTA-positive pulmonary tuberculosis speaks, sneezes, and coughs, they release droplet nuclei, which allow the spread of M. tuberculosis containing M. tuberculosis microorganisms, healthy people can be infected with tuberculosis if they inhale the bacteria. (Kenedyanti and Sulistyorini, 2017)..

The results of this study by measuring the hospital air germ count in the pulmonary clinic showed that the air germ count still met the established requirements. The total germ count in the pulmonary clinic room is 32 CFU/m3 which can be interpreted that the air germ count in the pulmonary clinic room meets the requirements of the Regulation of the Minister of Health of the Republic of Indonesia Number 2 of 2023 concerning Regulations for the Implementation of

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Government Regulation Number 66 of 2014 concerning Environmental Health.

This response dose illustrates the chance that lung clinic staff in contact with airborne germs can potentially cause non-optimal health conditions. According to the calculation results show that the chance of infection with airborne germs in the pulmonary clinic room is 9.9 × 10-1, meaning that almost 10 cases in 10 people can be infected with airborne germs. According to research conducted by Pangestika and Wilti (2021) The high and low risk of exposure is also influenced by body weight.

In this study, interviews were also conducted with pulmonary clinic staff who found that none of the respondents complained of weight loss and night sweats. There was 1 pulmonary officer (7%) who complained of a cough with phlegm and had complaints of shortness of breath. There were 2 respondents with a history of respiratory distress (13%). Individuals with a history of respiratory problems have a greater risk of being exposed to TB bacteria due to their health conditions that weaken the immune system and increase potential exposure to TB bacteria (Dewi et al., 2024).

Respiratory disorders such as COPD can lead to decreased lung function, including low vital capacity and decreased airflow. This makes individuals vulnerable to bacterial infections that can result in lung disease. People with respiratory disorders, especially pulmonary clinic staff who have direct contact with active TB patients every day, can increase the risk of exposure to bacteria that cause tuberculosis (Zein et al., 2022). (Zein *et al.*, 2022) ..

In knowing how many microorganisms each person inhales in a population, exposure analysis is used to identify the exposure pathways of risk agents. The potential level of microbial contamination (toxin effect) determines the assessment of biological agents. The germ number concentration, inhalation rate and exposure time influence the evaluation of exposure via the inhalation route. The number of microorganisms entering through the inhalation route increases with the number of germs present.

In this study, exposure analysis was calculated for each pulmonary officer. The average *intake* dose was 0.38 CFU/kg/day. The minimum *intake* dose is 0.06 CFU/kg/day and the maximum is 0.85 CFU/kg/day. The results of these calculations can be assumed if the amount of air germ contamination in lung poly officers is 0.06 CFU/kg/day - 0.85 CFU/kg/day, meaning it is still in the minimum *intake* range.

Risk characteristics include hazard identification, hazard attributes, and exposure assessment methods used to make risk estimates and also provide estimates of effects on a particular group of people. Air contamination by bacteria does not directly cause cancer (non-carcinogenic). From the results of the study obtained the results of the risk level in the pulmonary clinic officers of Husada Prima Hospital HQ = <1 which means that the risk agent is not at risk of causing adverse health effects.

According to research Brągoszewska et al. (2018) stated that although airborne microorganisms in spaces, such as offices, schools, and home construction, do not harm health directly except in sensitive individuals. Actions that can be taken by the hospital to reduce the risk of exposure to airborne germ numbers to health workers in the pulmonary clinic room are to increase sanitation efforts to minimise airborne germ numbers. In addition to sanitation efforts, it is also necessary to conduct health promotion about the importance of wearing masks and nosocomial infections that can occur in hospitals as well as to all staff and patients.

In order to reduce the effects that may occur, risk management is necessary. Risk factors that cause health problems are also controlled in this risk management (Dehghani et al., 2018). Strategies that can be applied are to reduce the number of

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microorganisms to minimise the spread of disease and infection, kill microorganisms in the form of pathogenic bacteria, and prevent microorganisms from causing decay and destruction. Efforts that need to be made by the hospital are disinfection. Routine disinfection is carried out by using antiseptic liquids to clean patient beds, tables, and surrounding areas. Vapour or smoke spraying can be used to clean large spaces or air and is carried out 2-3 times a day. In the service room, UV lamps can be added to disinfect the air. (Ministry of Health, 2017).

CONCLUSION AND RECOMMENDATION

The risk characteristics in the study found that the level of risk (HQ) in the pulmonary clinic staff at Husada Prima Hospital is less than one, indicating that the agent is not at risk of causing adverse health effects. Prevention that can be done is to control the concentration of air germs. Efforts that need to be made by the hospital are the addition of UV lamps and routine disinfection of equipment and rooms and adding exhaust fans in the pulmonary clinic room for air circulation so that the room becomes cooler.

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