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Effect of Cleaning Process on Physical and Microbiological Air Quality in Hospital Environment: Case Study of Bhakti Dharma Husada Hospital

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ABSTRACT
Examination of air quality at Bhakti Dharma Husada Surabaya Hospital showed a non-conformity of standards in the LAF Room (Laminair air flow). The study aimed to analyse the physical and microbiological air quality factors in the cleaning process in the LAF (Laminair Air Flow) room. The study used an observational descriptive design with a cross-sectional approach. The study population was room air in the LAF room. The research variables included temperature, humidity, lighting, air germ count, Staphylococcus, and room cleaning process. Data collection techniques were observation, measurement, and laboratory examination. Data were analysed and presented descriptively. The study's results showed the value of the air germ number before the cleaning process was 16 CFU/m^3, exceeding the required quality standard of 10 CFU/m^3. Measurements after the cleaning process have met the requirements of 9 CFU/m^3. Room temperature and humidity measurements before and after the cleaning process have met the quality standards of 16-25°C and 35-50%. The lighting measurement of 110.6 lux does not meet the minimum requirement of 500 lux. Environmental health officers should monitor room cleaners for compliance with the use of personal protective equipment. It is necessary to increase the intensity or modify the lighting.

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INTRODUCTION

Healthcare in hospitals encompasses a wide range of activities that aim to provide care, treatment, and support to patients. As a healthcare institution, hospitals play an important role in providing quality medical services. However, the quality of health services is not only determined by the competence of medical personnel, but also greatly influenced by the surrounding environmental conditions. An unhealthy environment can negatively affect the health and well-being of patients, visitors, as well as medical staff.

Hospital environmental pollution is a serious issue that requires special attention. Hospital environmental health efforts include various aspects, such as clean water supply, air pollution control, food processing, linen management, room and equipment sanitation, and pest control such as insects and rats (Amiroh *et. al,* 2019). Environmental health services in hospitals are an important part of preventing infections, especially nosocomial infections, through good hygiene management and sterilisation.

One important aspect of environmental health care is indoor air quality. About 80-90% of

activities in hospitals take place indoors, so it is important to ensure clean and contaminant-free air. Contaminants such as dust, gas, smoke and vapour can carry harmful viruses and bacteria. Data shows that deaths due to air pollution in urban areas of developing countries reach 9%, while in rural areas it is around 1%. (Dewi, 2021). Therefore, indoor air quality management needs to be a major concern in an effort to improve the quality of health services.

Some areas of the hospital have a high risk of airborne infection transmission, such as operating theatres and laboratories. These rooms require special management, especially since medical activities in them involve the use of sterile preparations that must be free from pathogenic microorganisms. Therefore, handling air hygiene, periodic air quality monitoring, as well as the implementation of strict hygiene protocols are very important (Noya, 2020).

Based on data from periodic inspection of air quality at Bhakti Dharma Husada Regional General Hospital Surabaya in 2023, *Staphylococcus* microorganisms were found in the LAF *(Laminar Air Flow*) room. Although this bacterium is a normal flora of the skin, it can be an opportunistic pathogen that causes serious infections in individuals with low immunity. (Anggraini, 2020). This emphasises the importance of air pollution control through regular air quality monitoring and periodic cleaning to prevent nosocomial infections.

Air contamination in hospital rooms is influenced by various complex factors, such as building conditions, ventilation and air conditioning (AC) systems, humidity, temperature, lighting, as well as human behaviour in the room. Poorly maintained buildings can allow contaminants from outside to enter. In addition, carpets, air conditioners, and other materials that are not cleaned regularly can be a breeding ground for microorganisms (Ginting, 2022). Humidity and temperature factors also play a role in creating conditions that favour the growth of microorganisms that cause infection.

Research by Noya et. al, (2020) in the operating theatre of Ambon's Sumber Hidup Hospital showed that the level of air contamination exceeded the established threshold of 100 CFU/m³. This is thought to be related to the frequency of surface cleaning and the condition of the room floor. Meanwhile, research by Pala'langan et al. (2023) in Bhayangkara Mamuju Hospital showed that the number of germs in the class II treatment room reached 955 CFU/m³, with 56.5% humidity, 28°C temperature, and 147 lux lighting. These results indicate that the microbiological quality of the air does not meet the standards. Another study by Susilawati et al. (2021) also stated that physical environmental factors such as temperature, humidity, lighting, and dust affect the number of microorganisms in the air.

Based on the description above, the author is interested in further research on the relationship between physical and microbiological air quality factors on the effectiveness of the cleaning process in the LAF*(Laminar Air Flow*) room of Bhakti Dharma Husada Surabaya Regional General Hospital.

RESEARCH METHOD

This study is a descriptive observational study with a cross-sectional approach, which aims to evaluate the effect of the cleaning process on physical and microbiological air quality in the Laminar Air Flow (LAF) room of Bhakti Dharma Husada Surabaya Regional General Hospital. The LAF room was chosen because it is a sterile area used for pharmaceutical activities that require environmental conditions free of microbiological contamination.

The population in this study was the air in the LAF room. The samples used were air conditions taken at three time points, namely before the cleaning process, after cleaning using the conventional disinfection method, and after cleaning using the dry mist method. These three conditions were used to compare the effectiveness of each cleaning method on reducing the number of germs and bacteria in the air.

The main variables in this study include air physical parameters consisting of temperature (°C), relative humidity (%), and illumination (lux), as well as microbiological parameters that include air germ numbers (in units of colony forming units per cubic metre or CFU/m³) and the presence of *Staphylococcus* sp. bacteria, especially *Staphylococcus aureus*. The independent variable in this study was the type of cleaning process performed, while the dependent variable was air quality based on predetermined parameters.

Data collection was conducted through three methods, namely direct observation of the cleaning process, measurement of physical parameters using standardised measuring instruments, and microbiological testing of air in the laboratory. Temperature and humidity measurements were taken using a digital thermohygrometer, while lighting was measured using a lux meter. Air sampling was conducted using the sedimentation method (open plate method), using nutrient agar media that was opened indoors for 15 minutes at a height of about 1 metre from the floor and 1 metre from the wall. After exposure, the media was incubated at 37°C for 24 to 48 hours. The growing colonies were counted to obtain the air germ number in CFU/m³. Bacterial identification was done through Gram stain and biochemical tests,

including coagulase test to confirm the presence of *Staphylococcus aureus*.

The cleaning process is carried out by hospital cleaning staff who have received training, and is carried out in accordance with applicable standard operating procedures (SOPs). The disinfection method is carried out with a dry cleaning technique (sweeping) followed by wet cleaning (mopping) using a chlorine-based disinfectant solution with a high concentration (≥500 ppm). Cleaning is done systematically from the inside of the room to the outside to prevent recontamination. Dry mist cleaning is carried out using an aerosol atomiser that disperses disinfectant in the form of a fine mist throughout the room, including areas that are difficult to reach by conventional methods.

The data obtained were analysed descriptively to describe the condition of each parameter before and after the cleaning process. The measurement results were compared with the applicable quality standards based on the Regulation of the Food and Drug Administration (BPOM) of the Republic of Indonesia Number 18 of 2022 concerning Guidelines for Good Manufacturing Practices in Human Cell and Tissue-Based Product Processing Facilities, which states the maximum limit of air germ numbers in sterile rooms is 10 CFU/m³. Analysis of the relationship between the physical parameters of the air and the number of microorganisms was carried out with a bivariate correlation test using a significance level of 0.05.

RESULTS AND DISCUSSION

The results of the examination of air germ numbers in the LAF room of Bhakti Dharma Husada Surabaya Regional General Hospital were carried out at three different stages, namely before the cleaning process, after the cleaning process using the disinfection method, and after cleaning with the *dry mist* method. The data was compared with the air quality standard of 10 CFU/m³ to determine the level of air quality conformity based on the established criteria.

Table 1
LAF Room Air Germ Count Examination Results

Total Germ Count	Inspection Result	Quality Standard (CFU/m³)	Criteria
Before Cleaning Process	16 CFU/m³	10 CFU/m³	Complies with the Standard
After Cleaning Process (Disinfection)	9 CFU/m³	10 CFU/m³	Complies with the Standard
After Cleaning Process (Dry Mist)	2 CFU/m³	10 CFU/m³	Complies with the Standard

The results of the air germ count examination in the LAF room before the cleaning process did not meet the requirements of 16 CFU/m³ and the two measurements after the cleaning process have met the requirements according to the Food and Drug Administration Regulation No. 18 of 2022 concerning Guidelines for Good Manufacturing Methods in Human Cell and Tissue Based Product Processing Facilities (Table 1).

Activities in the LAF room require high sanitary conditions to minimise contamination that can cause cross-infection through pharmaceutical preparations. The development of bacteria in the air is influenced by various factors in the environment. This is in accordance with a book entitled indoor air pollution oriented towards public health by Mukono (2014), which states that air germ numbers are influenced by physical factors including temperature, temperature can affect humidity. Both physical parameters are indirectly influenced by occupancy density. The discovery of the number of germs above the quality standard set because on that day many officers took turns in carrying out service activities, so that the occupancy density in the LAF room increased.

The process of cleaning a room that is carried out according to standards and procedures can reduce the number of germs in a room, this is in accordance with the research of Sentosa (2019) stated that a good and correct sterilisation process will affect the microbiological air quality of a room. The sterilisation process affects the germ count in the LAF room. The state of sanitation and the room cleaning process have a close relationship with the air germ count. The presence of germs in the room is determined by several factors, one of which is the optimal cleaning process. So it is necessary to have good room management by cleaning staff to minimise the presence of microorganisms.

Table 2
LAF Room Air Bacteria Examination Results

Bacterial Identification	Examination Result		Criteria
	Staphylococcus sp.	*Staphylococcus aureus*	
Before Cleaning Process	Positive	Negative	TMS
After Cleaning Process (Disinfection)	Negative	Negative	Complies with the Standard
After Cleaning Process (Dry Mist)	Negative	Negative	Complies with the Standard

The results of the examination of airborne *Staphylococcus* bacteria in the LAF room before the cleaning process did not meet the requirements and both measurements after the cleaning process met the requirements (Table 2).

Staphylococcus is a bacterium that easily spreads through direct contact between individuals, for example through hands, clothing, or frequently touched surfaces such as door handles, tables, equipment in the room, and others. This is in accordance with research Amri (2022) explained that the level of *Staphylococcus* contamination in the air in a closed space such as a hospital depends on factors such as ventilation, cleanliness, and the number of people in the room. The presence of *Staphylococcus* bacteria in the air of the LAF room before the cleaning process can occur due to the density of the room which is accessed by several officers when carrying out service activities.

Research by Kozajda (2019) showed that *Staphylococcus* is found in the air which is influenced by several factors such as the level of relative humidity and temperature has a significant effect on the presence of *Staphylococcus* in the air. The relative humidity level and temperature are controlled by the room ventilation system. Other research by Madsen (2020) showed that the spread of airborne *Staphylococcus* microorganisms is strongly influenced by the use of active mechanical ventilation such as air conditioners, fans, and *exhaust* fans. So the use of good ventilation systems and strict hygiene practices are recommended to reduce the risk of contamination. Due to the great negative influence, pharmaceutical laboratories need to pay attention to hygiene and sterilisation to prevent the contamination of bacteria such as *Staphylococcus*. It is necessary to implement strict quality control measures to prevent contamination, including regular monitoring of the environment, staff training, and maintenance of sterile equipment.

The results of air temperature measurements in the LAF room with an average of the three measurements of 17.3 °C with criteria that meet the requirements according to the Technical Guidelines for Hospital Buildings Pharmacy Room 2014 (Table 3).

Temperature is one of the factors determining the quality of air germ numbers, as changes in temperature can affect the emission and accumulation of vapour in the room. When the temperature changes, the relative humidity in the room can also change, creating conditions that favour microbial growth in line with research by Anggraini (2020). Although the temperature is within a safe range, it is important to understand that temperature can affect air quality and the growth of microorganisms.

Table 3
LAF Room Air Temperature Measurement Results

Room Air Temperature	Inspection Result	Quality Standard (°C)	Criteria
Before Cleaning Process	17.2 °C	16-25 °C	Complies with the Standard
After Cleaning Process (Disinfection)	16,8 °C	16-25 °C	Complies with the Standard
After Cleaning Process (Dry Mist)	17,9 °C	16-25 °C	Complies with the Standard
Average	17,3 °C	16-25 °C	Complies with the Standard

Other research conducted by Susilawati (2021) also showed that there was a significant relationship between air temperature and airborne germ counts in hospital inpatient rooms. Although this study focused on inpatient rooms, the findings are relevant for sterile environments such as LAF rooms, where strict temperature control is necessary. Temperatures that are too high or too low can affect the microbiological stability of the air, potentially affecting the quality of products produced in the room.

Temperature management in LAF rooms is part of the hygiene and infection control strategy in healthcare facilities. Temperature and humidity monitoring should be done in an integrated manner. The temperature increases and decreases that occur during the cleaning, disinfection, and dry mist processes indicate the need for *realtime* monitoring to ensure that all environmental parameters remain within safe limits in line with the research of Noya (2020). With effective management, the risk of microorganism growth can be minimised, and the quality of room sterility can be maintained ensuring that the LAF room remains a safe and compliant environment for sterile pharmaceutical production.

Table 4
Air Humidity Measurement Results of LAF Room

Room Air Humidity	Inspection Result	Quality Standard (°C)	Criteria
Before Cleaning Process	36%	35-50%	Complies with the Standard
After Cleaning Process (Disinfection)	43%	35-50%	Complies with the Standard

After Cleaning Process (Dry Mist)	46%	35-50%	Complies with the Standard
Average	42%	35-50%	Complies with the Standard

The results of air humidity measurements in the LAF room with an average of the three measurements of 42% with criteria that meet the requirements according to the Technical Guidelines for Hospital Buildings Pharmacy Room 2014 (Table 4).

High air humidity can create a favourable environment for the growth of microorganisms. According to research Susilawati (2021) According to the World Health Organisation (WHO), relative humidity levels that are too high can favour the growth and spread of biological pollutants, including bacteria and fungi. Humidity that exceeds the ideal limit can accelerate the development of microorganisms in a sterile environment.

Although the humidity after the *dry mist* process is still within standard limits, the value of 46% indicates that the humidity in the LAF room is close to the upper permitted limit. This condition can increase the risk of microorganism growth, especially if there are areas that are less exposed to sterile airflow. Research Pratiwi (2020) showed that high indoor air humidity can increase the potential for contamination, especially if the space is used for activities that require a sterile environment. Therefore, it is necessary to closely monitor the post-dry mist air humidity to ensure that there is no increased risk of contamination.

In order to keep the air humidity within safe limits and reduce the risk of contamination, an effective control strategy is required. One important step is to ensure that ventilation and temperature control systems are working optimally to regulate air humidity. In addition, regular and periodic monitoring of air humidity is also very important to detect changes that could increase the risk of microorganism growth. The use of dehumidifiers or other humidity control devices may also be considered if the air humidity tends to increase beyond the set limits. (Ginting, 2022).

With proper supervision and maintenance, the risk of contamination due to high humidity can be minimised.

The results of lighting measurements in the LAF room with an average of three measurements of 110.6 Lux with the criteria not meeting the requirements according to the Technical Guidelines for Hospital Buildings Pharmacy Room 2014 (Table 5).

Table 5
LAF Room Air Lighting Measurement Results

Room Lighting	Inspection Result	Quality Standard (Lux)	Criteria
Before Cleaning Process	109.8 Lux	Minimum 500 Lux	Fails to Comply with the Standard
After Cleaning Process (Disinfection)	110.4 Lux	Minimum 500 Lux	Fails to Comply with the Standard
After Cleaning Process (Dry Mist)	111.6 Lux	Minimum 500 Lux	Fails to Comply with the Standard
Average	110.6 Lux	Minimum 500 Lux	Fails to Comply with the Standard

The presence of sufficient lighting in the sterile room is very important in reducing the risk of microbial contamination. As explained in Widiantara's research (2022), a lack of light in a room can cause humid conditions, thus creating an environment that supports the growth of microorganisms including bacteria and germs.

This is very important to note in setting up a sterile environment in a pharmaceutical laboratory, where the presence of microorganisms must be kept to a minimum. Research conducted by Anggraini (2020) supported this research by stating that poor lighting creates ideal conditions for microorganisms to thrive. Microorganisms generally grow better in dark conditions or with minimal lighting. In contrast, natural lighting from sunlight not only provides sufficient light but also emits ultraviolet rays that are known to have a lethal effect on microbes.

The lighting in the LAF (Laminar Air Flow) room is sourced from three main lamps used for illumination. However, the measurement results show that this lighting does not meet the set standards, signalling the need for improvement in lighting design. Efforts to optimise lighting in sterile rooms can be made through several steps. For example, the use of lamps with higher light intensity or the implementation of lighting technology that can adjust intensity based on needs can be effective solutions. Thus, lighting improvements not only improve visibility but also contribute significantly to maintaining sterility and preventing contamination in pharmaceutical and healthcare environments.

Table 6
Observation Results of the LAF Room Cleaning Process

No	Assessment Criteria	Max Score	Total Score
1	Cleaning Method	5	5
2	Cleaning Frequency	6	4
3	Tools	4	4
4	Cleaning Materials	5	5
	Rate	20	18
	Percentage	90%	

The results of the observation of the cleaning process in the LAF room with a percentage of 90% with the criteria fulfilled (Table 6).

The cleaning process carried out in the LAF room uses disinfection and dry mist cleaning methods. The frequency of routine cleaning in the room is carried out every day at the end of service activities. However, if during service activities there is an incident of spillage, then cleaning can be done at any time. Cleaning with disinfection is carried out on wall and floor surfaces and hard objects such as tables, cabinets, chairs in the room. The disinfection process starts with a dry method (sweeping) then continues with a wet method (mopping) wiping / mopping using high chlorine disinfectant liquid. The cleaning route by cleaning staff starts from the innermost room then moves towards the outside. Space cleaning tools are provided specifically in each room to avoid mixed use.

Housekeeping activities such as cleaning tools and materials, emissions from buildings, the use of fragrances, dust or airborne dirt from sweeping (vacuuming) greatly affect the high and low presence of microorganisms, in by Pratiwi (2020) said that there was an effect of the room sterilisation process with a decrease in the number of air germs in the room.

Table 7
Analysis of Air Physical and Microbiological Quality Factors

	Temperature	Humidity	Lighting
Microorganism Presence	Sig (0.567) > α 0.05	Sig (0.144) > α 0.05	Sig (0.12) > α 0.05

The results of the analysis of physical and microbiological air quality factors, with the relationship between the presence of microorganisms and three physical variables, namely temperature, humidity, and lighting with a significance level (α) of 0.05 (Table 7).

Physical parameters under certain conditions can be a factor in the growth of microorganisms in the air. Air temperature plays an important role in determining the growth rate and spread of Staphylococcus in LAF Rooms. At lower temperatures, such as below 20°C, the growth of Staphylococcus will slow down significantly. The room temperature before and after cleaning drops lower, this is in line with research by Amri (2022) which states that the lower the temperature, the number of microbes will decrease. After the dry mist was applied, the temperature rose again, but the bacteria decreased as a result of the dry mist process.

Based on humidity measurements before and after cleaning, there was an increase of 10% and a decrease in the number of bacteria. The increase in humidity is because the disinfection process involves water vapour to kill bacteria so that the humidity rises, resulting in a decrease in existing bacteria. Room lighting, especially the type and intensity of light used, can affect the development of Staphylococcus bacteria in the air. The measurement results in the room found that the lighting level was below 500 Lux or below the quality standard. This is one of the causes of the development of Staphylococcus bacteria.

Of the three physical parameters, namely temperature, humidity, and room lighting. The greatest potential for the development of Staphylococcus bacteria is room lighting that is below 500 Lux, so that bacteria can develop. Good lighting can damage the DNA of Staphylococcus bacteria and other microorganisms, thus inhibiting their ability to multiply and spread. (Anggraini, 2020).

CONCLUSION

Based on the measurement results, it can be seen that the air germ number value before the cleaning process is still high above the required quality standard, for measurements after the cleaning process has met the requirements. Measurements of room temperature and humidity before and after the cleaning process have met the quality standards. However, the lighting parameter does not meet the quality standards.

SUGGESTIONS

Based on the conclusions obtained above, recommendations or suggestions that can be given are that sanitarians monitor room cleaners to comply with Standard Operating Procedures (SOPs) by using Personal Protective Equipment (PPE) and ensuring room lighting is up to standard, including increasing intensity or modifying lighting if necessary. Cleaning staff can monitor wall cleanliness regularly at least twice a year and can repaint if they find dirty walls or peeling paint. For future researchers, it is recommended to conduct research in high-risk rooms such as ER, ICU, or

Haemodialysis, and add variables such as ventilation rate and air chemistry parameters.

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