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Comparison of Germ Count Levels Based on Zone at Central Operathing Theatre Facility Dr. Soetomo General and Academic Hospital

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ABSTRACT

Central of Disease Control state that Healthcare-Assoxiated Infections (HAI's) prevalence on Surgical Site Infection (SSI) reach up 121.800 in patient surgery cases and increase mortality risk up to 12-times. Surgical site infection (SSI) are one of the causes of morbidity, mortality, increased length of stay, costs, and patient complaints, including in orbital surgery. This study was conducted at Central Operating Theatre Facility Dr. Soetomo General and Academic Hospital as surgical service facility includes 22 operating room and supporting facilities. Therefore, the Central Operating Theater Facility is higher risk of nosocomial infection. The purpose of this study was to compare the floor germs and air germs based on zones in the Central Operating Theater Facility. This study was done from September 2023 to December 2024 with cross-sectional quantitative and observational method. Total population are 43 rooms with sample size of 26 rooms were calculated using Lemeshow formula and the locations are determined randomly. Data analysis used Kruskal-Wallis test to compare the variable and descriptive analysis used frequency distribution. The results show significant difference in the counts of germ floor based on zones (p-value 0.047) and there is significant difference in the counts of germ air based on zones (p-value 0.047) at Central Operating Theater Facility. The most common germ found on floors is Staphylococcus haemolyticus, while the most common germ found in the air is Staphylococcus epidermidis.

Introduction

Central of Disease Control state that Healthcare-Assoxiated Infections (HAI's) prevalence on Surgical Site Infection (SSI) reach up 121.800 in patient surgery cases and increase mortality risk up to 12-times. Surgical Site Infection (SSI) can be cause of morbidity and mortality, increase hospitalisations duration and cost, and increase patients demand including in orbital surgery [1]. World Health Organisation (WHO) states that SSI's occur in 2-5% of 27 million patients who operated each year and about 25% of all nosocomial infections. SSI incidents in several academic hospitals in Indonesia include Dr. Pringadi hospital (12%), Dr. Sardjito hospital (5,9%), Adam Malik hospital (5,6%) [1]. On the other hand, SSI incidents in Dr Soetomo hospital was 0,41% which ranged 2-4% for clean wound operation and 5-15% for contamined clean operation [2].

The operating room germs is a perioperative factor in hospital facility risk factors[3]. Although nosocomial infection can be caused by many factors, airborne contamination in operating room is a major source of exogenous germ infection. Air isn't a microorganism medium for growth but is a substance that carries germs and causes infection [4]. Based on Indonesian Minister of Health Regulation No. 2

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of 2023 concerning Environmental Health, the standard of maximum concentration of air germs in an empty operating room is 35 CFU/m³, an operating room with activity is 180 CFU/m³, and an ultraclean operating room is 10 CFU/m³. Meanwhile, the biological parameter for air germ count is 700 CFU/m³.

The treatment room's floor in the hospital can be a place for many types of microorganism growth. Based on Indonesian Minister of Health Regulation No. 2 of 2023, the floor clean levels are in the germ counts of 0-5 CFU/cm^2. So, the floor rooms need to be kept clean by sweeping, mopping, and applying certain disinfectants. In creating a healthy building at hospital, there are several requirements that must be fulfilled, such as (1) the floor must be made from strong and waterproof materials, flat surfaces, and easy to clean; (2) the floor that is always contact with water must have a sufficient slope (2-3%) towards the sewerage channel; and (3) the conjunction of the floor and wall must be conical/curved for easy cleaning [5].

The various incidences of nosocomial infection impact morbidity and mortality. Therefore, efforts are needed to decrease the germ transmission, especially in a hospital as a part of the highest health service. Efforts to control the infection are through personal hygiene, payying attention to decontamination, and applying disinfectant [6]. Controlling physical environment in hospital can also be done by keeping the room temperature and ensuring the air circulation using exhaust fan or air conditioner (AC) and also providing adequate lighting in the room [7].

Hospital enviromental quality control is also done at Central Operating Theatre Facility Dr. Soetomo General and Academic Hospital as a surgical centre. This building has 5 devided zones namely public zone, semi-public zone, aseptic zone 2, aseptic zone 1, and aseptic zone 0. It's purpose to reduce the posibility of infection among patients, staffs, or others visitors. The Central Operating Theater Facility has 22 operating room includes digestive surgery, paediatric surgery, plastic surgery, urology, oncology, eye surgery, oral and maxillofacial surgery, thoracic cardiac and vascular surgery, head and neck surgery, orthopaedic surgery, ear nose throat surgery, neurosurgery, and obgyn surgery.

Based on the background, there is no previous data. So, it's important to examine and revel the comparison of the germ counts based on zones in Centrl Operating Theater Facility measured by swab instruments. Increased germ counts can lead to nosocomial infections that cause the length of the patient's healing process. This study can contribute to future research on operating room environmental quality control and infection prevention and control in hospitals.

Methodology

This is a quantitative study using a cross-sectional analytical observation design that was conducted at the Central Operating Theatre Facility Dr. Soetomo General and Academic Hospital from April to November 2024. The population in this study was all of rooms at Central Operating Theatre Facility, totalling 43 rooms. The sample counts were calculated by Lemeshow formula and found 26 rooms. The sample for rooms were determined by simple random sampling. Floor germ sampling is using a sterile disposable swab aseptically with 3 times wiping. While the air germ sampling is using a blood agar plate petri dish that was open for 10 minutes, after that, it was closed and sent to laboratory. The laboratory results data were analysed using Kruskal-Wallis through SPSS (Statistical Program for Social Science) software. This analysis compares the difference between independent and dependent variables significantly. Additionally, the data was analysed descriptively using frequency distribution.

The author processes the collected data using the following steps: Reading the research results from each national or international journal

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article from which data has been collected. Conducting a merger and evaluation by classifying journal articles according to inclusion criteria and those that do not meet exclusion criteria. Compiling the results and conclusions of several journal articles in the form of a research table consisting of the author's name, journal title, journal period, research results, research conclusions, and journal article database.

Results and Discussion

The laboratory results data were analysed using Kruskal-Wallis to compare the floor germs and air-germ count based on zones in Central Operating Theatre Facility. These Kruskal-Wallis results are presented in Table 1.

Table 1. Kruskal-Wallis Test on Floor and Air Germ Counts by Zones in Central Operating Theatre Facility

Germ Count	p-value	Details*
Floor	0,047	P-value < 0,050 the meaning that there is a significant difference
Air	0,002	P-value < 0, 050 the meaning that there is a significant difference

*α = 0,050

Table 1 shows the Kruskal-Wallis test of floor germs, for which the p-value is 0.047 (<0.050). These results show a statistically significant difference between the measurement of floor germ counts based on the zones in Central Operating Theatre Facility. Meanwhile, the Kruskal-Wallis test of air germs, which has a p-value of 0.002 (<0.050) show that is a statistically significant difference between the measurement of air germ counts based on the zones in Central Operating Theatre Facility. The results of the Kruskal-Wallis test are supported by the count of germ colonies found, as in tables 2 and 3 below.

Table 2. Frequency Distribution of Floor Germ Counts

Categories of Zone	Name of Rooms	Floor Germ Counts	Rank*
Aseptic zone 0	Eye surgery room 503	0	1
Aseptic zone 0	Eye surgery room 505	0	1
Aseptic zone 0	Thoracic cardiac and vascular surgery room 609	0	1
Aseptic zone 0	Head and neck surgery room 512	208	1
Semi-public zone	Female changing room for students	2000	1
Aseptic zone 0	Orthopaedic surgery room 610	2000	1
Aseptic zone 0	Ear nose throat surgery room 509	4000	1

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Categories of Zone	Name of Rooms	Floor Counts	Germ Rank*
Aseptic zone 0	Neuro surgery room 607	4000	1
Aseptic zone 0	Common use surgery room 506	6000	1
Aseptic zone 0	Oral surgery room or common use surgery room 508	7000	1
Semi-public zone	Materials sterilisation room (CSSD)	9000	1
Aseptic zone 1	Corridor OK 4th floor	9000	1
Public zone	ICU	16000	1
Aseptic zone 2	Recovery room	16000	1
Aseptic zone 2	Burn unit room	16000	1
Aseptic zone 1	Corridor OK EVANI 005	24000	1
Aseptic zone 1	Corridor OK EVANI 004	25000	1
Aseptic zone 0	Head and neck surgery room 514	29000	1
Semi-public zone	Transfer area	310000	2
Aseptic zone 0	Orthopaedic surgery room 612	320000	2
Semi-public zone	Male changing room for staff	350000	3
Public zone	Public elevator	420000	3
Aseptic zone 0	Ear nose throat surgery room 511	430000	3
Aseptic zone 0	Orthopaedic surgery room 614	780000	5
Aseptic zone 0	Neuro surgery room 603	920000	6
Aseptic zone 2	Patient elevators (2 units)	1020000	6

*The ranking categories are as follows.

1. 1st rank = 0 - 170.000
2. 2nd rank = 170.001 - 340.001
3. 3rd rank = 340.002 - 510.002
4. 4th rank = 510.003 - 680.003

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5. 5th rank = 680.004 - 850.003

6. 6th rank = 850.004 - 1.020.004

Table 2 shows the count of floor germs. The lowest floor germs count was found in 3 surgery rooms such as eye surgery rooms 503 and 505 and thoracic cardiac and vascular surgery rooom 609 which is zero germ. Meanwhile, the highest floor germs count were found in neurosurgery room 603 and patients elevator. This opererating rooms condition is contra to standard is zero germ.

Table 3. Frequency Distribution of Air Germ Counts

Categories of Zone	Name of Rooms	Air Germ Counts	Rank*
Aseptic zone 0	Eye surgery room 505	0	1
Aseptic zone 0	Oral surgery room or common use surgery room 508	0	1
Aseptic zone 0	Neuro surgery room 607	0	1
Aseptic zone 0	Thoracic cardiac and vascular surgery room 609	0	1
Aseptic zone 0	Orthopaedic surgery room 614	0	1
Aseptic zone 0	Orthopaedic surgery room 610	2500	1
Aseptic zone 0	Eye surgery room 503	10000	1
Aseptic zone 2	Recovery room	17500	1
Aseptic zone 2	Burn unit room	17500	1
Aseptic zone 0	Head and neck surgery room 512	20000	1
Aseptic zone 0	Ear nose throat surgery room 511	22500	1
Aseptic zone 0	Head and neck surgery room 514	22500	1
Semi-public zone	Materials sterilisation room (CSSD)	25000	1
Aseptic zone 0	Ear nose throat surgery room 509	25000	1
Aseptic zone 0	Orthopaedic surgery room 612	27500	1
Aseptic zone 1	Corridor OK 4th floor	35000	1
Aseptic zone 1	Corridor OK EVANI 005	37500	1

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Categories of Zone	Name of Rooms	Air Germ Counts	Rank*
Aseptic zone 0	Neuro surgery room 603	50000	1
Aseptic zone 2	Patient elevators (2 units)	57500	1
Semi-public zone	Transfer area	62500	1
Public zone	ICU	62500	1
Aseptic zone 1	Corridor OK EVANI 004	825000	3
Public zone	Public elevator	1175000	4
Aseptic zone 0	Common use surgery room 506	1250000	4
Semi-public zone	Male changing room for staff	1350000	4
Semi-public zone	Female changing room for students	2050000	6

*The ranking categories are as follows.

1. 1st rank = 0-341.666
2. 2nd rank = 341.667-683.333
3. 3rd rank = 683.334-1.025.000
4. 4th rank = 1.025.001-1.366.667
5. 5th rank = 1.366.668 – 1.708.334
6. 6th rank = 1.708.335- 2.050.001

Table 3 shows the count of air germs. The lowest air germs count was found in 5 surgery rooms such as eye surgery rooms 505, oral and maxilofacial surgery room / common use surgery room 508, neurosurgery room 607, thoracic cardiac and vascular surgery room 609 and orthopaedic surgery room 614 which are zero germ. This is suitable with the standard of operation room is zero germ. Meanwhile, the highest air germs count were found in female changing room for students.

Table 4. Types of Germs Found

Categories of Zone	Name of Rooms	Types of Germs
Public zone	Public elevator	*Staphylococcus haemolyticus*
	ICU	*Staphylococcus saprophyticus*

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Categories of Zone	Name of Rooms	Types of Germs
Semi-public zone	Transfer area	*Staphylococcus haemolyticus*
	Female changing room for students	*Staphylococcus epidermidis*
	Male changing room for staff	*Staphylococcus haemolyticus*
	Materials sterilisation room (CSSD)	*Staphylococcus haemolyticus*
	Patient elevators (2 units)	*Staphylococcus haemolyticus*
Aseptic zone 2	Recovery room	*Staphylococcus saprophyticus*
	Burn unit room	*Staphylococcus haemolyticus*
	Corridor OK EVANI 004	*Staphylococcus haemolyticus*
Aseptic zone 1	Corridor OK EVANI 005	*Staphylococcus haemolyticus*
	Corridor OK 4th floor	*Micrococcus luteus*
	Eye surgery room 503	*Staphylococcus hominis*
	Eye surgery room 505	There is no bacterial growth
	Common use surgery room 506	*Staphylococcus epidermidis*
	Oral surgery room or common use surgery room 508	*Staphylococcus sciuri*
	Ear nose throat surgery room 509	*Staphylococcus hominis*
	Ear nose throat surgery room 511	*Moraxella osloensis*
Aseptic zone 0	Head and neck surgery room 512	*Exiguobacterium aurantiacum*
	Head and neck surgery room 514	*Staphylococcus capitis*
	Neuro surgery room 603	*Staphylococcus warneri*
	Neuro surgery room 607	*Staphylococcus haemolyticus*
	Thoracic cardiac and vascular surgery room 609	There is no bacterial growth
	Orthopaedic surgery room 610	*Staphylococcus epidermidis*
	Orthopaedic surgery room 612	*Staphylococcus haemolyticus*
	Orthopaedic surgery room 614	*Bacillus cereus group*

` Table 4 shows the types of germs were found in several rooms in Central Operating Theater Facility. *Staphylococcus haemolyticus* was found in all zones. In addition, there are 6 different types of germs, such as *Micrococcus luteus*, *Staphylococcus sciuri*, *Moraxella osloensis*, *Exiguobacterium aurantiacum*,

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Staphylococcus capitis, *Staphylococcus warneri*, and *Bacillus cereus group*

Discussion

The Difference in Floor Bacterial Count Levels Based on Zonal Divisions in Central Operating Theater Facility

The Kruskal-Wallis test results indicated a statistically significant difference in floor bacterial count levels based on zonal divisions in Central Operating Theater Facility (p-value 0.047). The findings revealed that the lowest bacterial count was predominantly observed in Aseptic Zone 0, specifically in 10 rooms. Aseptic Zone 0, which includes operating rooms, is a high-risk area for nosocomial infections, with floor bacterial counts restricted to 0–5 CFU/cm² [7]. Conversely, the highest bacterial count was recorded in Aseptic Zone 2 at the patient elevator. The patient elevator, is cleaned only once daily in the morning, experiences high traffic, which likely contributes to the elevated bacterial count. Uneven floor cleaning process, such as leaving footprints after mopping without re-cleaning, exacerbate the issue [8].

This study highlights differences in room cleanliness maintenance in Central Operating Theater Facility at Dr. Soetomo General and Academic Hospital based on zoning. Cleaning in Aseptic Zones 0, 1, 2, and semi-public areas utilizes a disinfectant solution containing 0.5% concentration (100 ml disinfectant mixed with 900 ml water). Public zone cleaning employs a 0.05% disinfectant solution (100 ml disinfectant, 900 ml water, and 200 ml fragrance). This aligns with Wulandari, Sutomo, and Iravati's (2015) findings that Aseptic Zones 0, 1, and 2 have stricter sterilization protocols compared to public and semi-public zones [9]. Operating room floors are cleaned with a 0.05% chlorine solution, diluted from a 0.5% stock solution prepared by the pharmacy. In cases of blood spills, a 0.5% chlorine solution (spill kit) is used prior to mopping with 0.05% chlorine [8].

Wulandari, Sutomo, and Iravati (2015) also noted that the frequency of mopping and comprehensive cleaning influences floor bacterial counts9. In this study, operating room floors are cleaned after each procedure, and a thorough cleaning occurs weekly. Other rooms are cleaned once daily, with additional cleaning as needed for visible dirt. These practices are consistent with Pitoyo, Rachmaawati, and Lundy (2018), who emphasize routine and periodic cleaning to maintain operating room sterility and prevent nosocomial infections [8].

According to Novita (2018) in Junaidi et al. (2024), floor bacterial counts are affected by lighting, temperature, occupancy, and floor cleaning frequency [10]. Public zone rooms, characterized by higher foot traffic and lack of specialized footwear, present a greater contamination risk than Aseptic Zone 0. Poor lighting (<250 lux) can increase bacterial colony growth, as lighting impacts temperature and humidity [11]. Effective lighting requires ventilation equal to at least 10% of the room's floor area [12].

Temperature also plays a role in bacterial growth and proliferation in floor. The optimal temperature could accelerate the proliferation of bacteria, although bacterial thermal tolerance varies by species, with most bacteria surviving low temperatures better than high ones [13].

In this study, the most common floor bacteria identified was *Staphylococcus haemolyticus* in patient elevators. This bacterium, commonly found on human skin, especially in axilla, perineum, and inguinal [14]. *Staphylococcus haemolyticus* is generally non-pathogenic but can cause infections in immunocompromised individuals by forming biofilms resistant to antibiotics [15]. Despite lacking of virulence factors, *Staphylococcus haemolyticus* is able to exhibits multidrug resistance, posing a significant clinical challenge compared to other *Staphylococcus sp.* [16].

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Previous studies, including Pitoyo, Rachmaawati, and Lundy (2018), have shown the differences in number bacterial colonies comparing before and after the cleaning of the floor rooms for clean-contaminated surgery and contaminated surgery, with the result of laboratory swab identified the same bacteria *Escherichia coli* on operating room floors [8], while Sari (2017) reported species such as *Proteus sp., Klebsiella sp.,* and *Enterobacter sp*. in ICU floors of Dr. H. Abdul Moeloek Hospital at Bandar Lampung [17]. Other hospitals, including Dr. Wahidin Sudirohusodo Hospital Makassar, CiptoMangunkusumo Hospital at Jakarta, Dr. Kariadi Hospital at Semarang, Hasan Sadikin Hospital at Bandung and Harapan Kita Hospital have reported the frequent bacterial in ICU settings are *Pseudomonas aeruginosa* and *Klebsiella pneumoniae* [18]. The study that has been held by Gobel, Rares, and Homania (2016) at Robert Wolter Monginsidi Hospital at Manado showing 8 bacteria, *Bacillus sp.* (33%), *Staphylococcus sp.* (27%), *Enterobacter aglomerans* (13%), *Escherichia coli* (10%), *Streptococcus sp.* (10%), *Serratia marcescens* (3%), *Neisseria sp.* (2%), and *Klebsiella pneumoniae* (2%) [19].

Differences in Airborne Bacterial Count Levels Based on Zonal Divisions in Central Operating Theater Facility

Airborne bacterial count measurements are crucial for assessing surgical room air quality, as it directly impacts patient safety and hospital service standards [20]. The Kruskal-Wallis test resulted a statistically significant difference in airborne bacterial counts across zones in Central Operating Theater Facility (p-value 0.002). The variation in airborne bacterial counts reflects differing air quality among zones. National Institute of Occupational Safety and Health (NIOSH) stated the causes that influenced air quality are lack of ventilation (52%), external contaminants (10%), microbial presence (5%), and building materials (4%) [21].

The study result indicated the highest rank with the lowest airborne bacterial counts were recorded in Aseptic Zone 0, encompassing 13 operating rooms, where weekly air circulation system cleaning (AHU, AC and exhaust) and restricted personnel access in operating rooms, thus the airborne bacteria could be minimized. Operating rooms are hospital facilities that are separated with other facilities, therefore could only be accessed by authorized personnel [22]. The more physical contact with the personnel or medical instruments could increase the bacterial contamination and the number of airborne bacteria [21].

In contrast, the lowest rank with the highest counts were observed in semi-public zones, specifically the women's (student) changing room, which is 18.48 m² and houses storage lockers for external items. AHU and exhaust are used for ventilation. Area for the women changing room is located with other rooms, therefore many activities are conducted around this area.In the studies that have been conducted by Mathias et al (2000) and Solomon et al (2017) in (Tamocha, Oyinloye and Rahube, 2019) stated that the places that most often cause infections are delivery rooms, changing rooms and operating rooms [22]. Factors that cause germs to grow in the air can be caused by poor room sanitation, poor circulation, substandard building construction, increasing occupant density, and the number of people in the room [23].

Staphylococcus epidermidis was the most common airborne bacterium in the women's changing room. This finding aligns with studies from Dr. Wahidin Sudirohusodo Hospital at Makassar, where *Staphylococcus epidermidis* was the most frequently isolated airborne bacterium (40%) [18]. *Staphylococcus epidermidis* often causes surgical wound infections (SWIs), which are a type of nosocomial infection, in addition to those caused by the use of medical devices [24]. The most common type of bacteria found in surgical wounds at Abdul Wahab Sjahranie Hospital Samarinda is *Staphylococcus epidermidis* (33.3%) [25]. *Staphylococcus*

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epidermidis is a commensal bacterium that is found in the human skin epithelium and is less invasive. *Staphylococcus epidermidis* is generally harmless, but this bacterium causes nosocomial infections that are often found in the last 20 years. This bacterium can be dangerous because of extrinsic factors that cause the genes of this germ to change and may be due to the patients' weak immunity. Non-sterile health workers, improper suturing of surgical wounds can be a source of *Staphylococcus epidermidis* germs [25].

Staphylococcus epidermidis has been identified as the most common cause of latent infections at surgical sites characterized by the slow development of clinical symptoms that are often mistaken for post-surgical back pain, which allows germs to multiply at the surgical site and cause deeper infections. The infection can also come from surgical equipment contaminated with *Staphylococcus epidermidis* from patients or from surgical personnel during surgery even though cleaning and aseptic techniques have been applied to surgical instruments [26].

Research by Mayasari et al. (2020) in (Putrayana et al., 2021) stated that the growth of bacteria in the air that does not meet standards will lead to poor air quality and HAIs to the patients are treated in the roomfor 7 x 24 hours, and can cause secondary infections other than the primary infections [27]. The discrepancy in the value of airbornebacteria numbers can occur due to several factors. Factors that can cause the high growth of airborne bacteria colonies are temperature, humidity, lighting, sanitation and maintenance [28]. High room temperatures can affect the temperature in the air and facilitate the process of air evaporation and increase the number of air particles that can contain small particles such as dust on the surface, while bacterial infections can be caused by dust carried by the wind [29].

In this study, the average humidity in the Central Operating Theater Facility rooms of Dr. Soetomo General and Academic Hospital from January to October 2024 that did not meet the requirements were the operating rooms, ICU, recovery room and burn unit. Meanwhile, the Central Operating Theater Facility rooms that met the standard humidity was the CSSD. The standard humidity in health care facilities according to the Regulation of the Minister of Health of the Republic of Indonesia No. 2 of 2023 is 40-60. Humidity has an impact on the growth of bacteria in the air. The more humid, the more microbial are contented in the air because water particles can move cells in the room [30]. Low lighting in the room is also a factor for bacteria to grow. Room sanitation is also a supporting factor for the presence of bacteria in the air of the room. Room sanitation that includes environmental cleanliness can reduce the risk of airborne bacteria. Poor room sanitation can cause a dirty and dusty room. Dust particles contain various types of bacteria [31]..

Conclusion

This study yielded the following conclusions:

1. Statistical analysis using the Kruskal-Wallis test revealed a significant difference in floor bacterial count levels based on zonal divisions in Central Operating Theater Facility.

2. Statistical analysis using the Kruskal-Wallis test demonstrated a significant difference in airborne bacterial count levels based on zonal divisions in Central Operating Theater Facility.

3. The most frequent identified bacterium on floors was *Staphylococcus haemolyticus*, while *Staphylococcus epidermidis* was the most prevalent airborne bacterium.

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