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Quality of Airborne Bacteria in Operating Theaters in Several Hospitals in Jakarta and Its Surrounding Areas in 2018-2019

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Nosocomial infection is an infection obtained by a patient or hospital staff while in hospital. This infection plays a role in causing morbidity and mortality in hospitals and can occur in various hospitals rooms, including operating theaters. Nosocomial infections can occur due to various factors, one of which is contamination from airborne bacteria. In some countries, regulations are set to limit the concentration of airborne bacteria, both in the operating theaters and other rooms in hospitals, hence the need for monitoring and supervision of air quality as areflection on the cleanliness conditions in hospitals. Based on this, it is necessary to know the bacteriological air quality in the operating theaters in several hospitals in Jakarta and surrounding areas as one of the steps to prevent nosocomial infections. The method uses an air sampler with the principle of impaction. Air sampler works by separating the particles from the air by utilizing the inertia of the particles to force the bacteria to settle to the surface of the medium. A total of 217 examinations in the operating theaters were carried out in 17 hospitals in Jakarta and surrounding areas during January 2018 to June 2019. The majority of the operating theaters in hospitals in Jakarta and surrounding areas have air quality that met appropriate quality standards. In 2018, 120 of 137 (87.59%) examination in the operating theaters met the quality standar. Meanwhile in 2019, 70 of 80 (87.50%) operating theaters met the standard determined by the Ministry of Health of the Republic of Indonesia.

Key words: air sampler method, operating theater, quality of air bacteria

Infeksi nosokomial adalah infeksi yang diperoleh selama pasien atau petugas rumah sakit berada di rumah sakit. Infeksi ini berperan dalam menyebabkan morbiditas dan mortalitas di rumah sakir dan dapat terjadi di berbagai ruangan rumah sakit, termasuk ruang operasi. Infeksi nosokomial dapat terjadi karena berbagai faktor, salah satunya adalah kontaminasi bakteri udara. Di beberapa negara, regulasi ditetapkan untuk membatasi konsentrasi bakteri di udara, baik di ruang operasi maupun ruangan lain di rumah sakit, sehingga perlu adanya pemantauan dan pengawasan kualitas udara sebagai refleksi dari kondisi kebersihan di rumah sakit. Berdasarkan hal tersebut, maka perlu diketahui kualitas bakteriologis udara di ruang operasi pada beberapa rumah sakit di Jakarta dan sekitarnya sebagai salah satu langkah awal pencegahan infeksi nosokomial. Metode pada penelitian ini menggunakan air sampler dengan prinsip impaksi. Air sampler bekerja dengan cara memisahkan partikel dari udara dengan memanfaatkan inersia partikel untuk memaksa bakteri mengendap di permukaan medium. Sebanyak 217 ruang operasi dilakukan pemeriksaan, berasal dari 17 rumah sakit di Jakarta dan sekitarnya selama Januari 2018 hingga Juni 2019. Sebagian besar ruang operasi di rumah sakit di Jakarta dan sekitarnya memiliki kualitas udara yang memenuhi standar kualitas yang sesuai. Pada tahun 2018, 120 dari 137 (87.59%) ruang operasi telah memenuhi standar. Sedangkan pada tahun 2019, 70 dari 80 (87.50%) ruang operasi telah memenuhi standar yang ditetapkan oleh Kementerian Kesehatan Republik Indonesia.

Kata kunci: kualitas bakteri udara, metode *air sampler*, ruang operasi

Nosocomial infection play a role in causing morbidity and mortality in most hospitals. This infection can occur in various rooms in hospitals, including operating theater as rooms in hospitals with high activity and patients with higher morbidity and mortality than other rooms (Denina *et al*. 2012). According to WHO, based on a recent study in Europe, patients who had infections in reached 51% where the case was dominated by nosocomial infections (Danasekaran and Annadurai 2014). An estimated 30% of inpatients in Europe have experienced at least one time nosocomial infection. It is known that the average prevalence of nosocomial infections in Europe was 7.1% and in the United Stetes 4.5% in 2002. This figure has increased significantly in developing countries, where the prevalence of nosocomial infections varies from 5.7% to 19.1%. It is estimated that out 100 inpatients, 7 of whom are invoved in nosocomial infections in developing countries

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(Vincent *et al*. 2009 and Leong *et al*. 2013).

Nosocomial infections can occur due to various factors, one of which is contaminationfrom airborne bacteria. In some countries, regulations are set to limit the concentration of airborne bacteria, especially in the operating theaters (Eachempati 2017) Although nosocomial infections are multifactorial involving patient and procedural factors, airborne bacterial are considered as one of the main source of exogenous contaminant bacteria (Rajasekar *et al*. 2011). Air is not a medium in which bacteria grow, but rather substancs that can carry particles, including bacteria. During surgical procedures, airborne particles that can carry bacteria, including textiles fibers, dust, skin fragments and respiratory aerosols can contaminate surgical instruments or directly enter areas of the body that should be sterile, namely surgical wound and cause them to become infected (Hansen *et al*. 2005).

From previous studies, it is known that some operating theaters have air quality that does not rfer to established standars, Regulation of the Minister of Health of the Republic of Indonesia No. 7 of 2019 for the operating theaters and Decree of the Minister of Health of the Republik of Indonesia No. 1204/MENKES/SK/X/2004 (Permenkes 2019 and Permenkes 2004). Wismana (2016) in his research stated that 2 out of 4 operating theaters in Undaan Eye Hospitals in Surabaya did not meet the maximum air bacteria concentartions standards. The bacteria that were identified in the room were *Bacillus sp,* Gram-positive rod bacteria, Gram positive coccus bacteria, Gram negative rod bacteria and *Acinetobacter sp* which is pathogenic and also fungi (Rachel *et al*. 2014).

Various attempts were made to prevent nosocomial infections due to airborne bacterial contamination through dust and droplets, such as the use af antiseptics, disinfectant through cleaning and sterilization and isolation of patients with highly infectious diseases (Zaidi *et al*. 1995). However, maintenance of air quality is not good carried out routinely can be contributing factor in the in the occurence of nosocomial infections. Ishida *et al.* (2006) report that airborne bacteria in the hospital environment have become a major source and serious problem of postoperative infections. Many of these air bacteria are known to be resistant to antiseptics that are commonly used in many hospitals (Landrin *et al*. 2005). Therefore, there is a need reserach conducted to determine bacteriological air quality in the operating theaters as a room in a hospital that requires sterile conditions (Yagoub and Agbash 2010).

MATERIALS AND METHODS

Medium. Nutrient agar are used to breed airborne bacteria. Medium was prepared by using Oxoid medium consists of Lab lemco powder 1.0 gr, yeast ektraxt 2.0 gr, peptone 5.0 gr, Sodium chloride 5.0 gr and Agar 15 gr. The whole weighed 22.4 gr in 800 mL water then the sterilization process is carried out according to procedure (The Oxoid 2006).

Examination Airborne Bacteria. The tools used for this research is air sampler (Merck) with the principle of impaction. The air sampler works by separating the particles from the air by utilizing the inertia of the particles to force them settle to the surface of the medium (Yagoub *et al*. 2010 and Opertaor MAS 100 2019). The first thing to do is determine the volume of the room to be inspected. The number of points for air sampling per room is 10% of the volume of the room. At each sample point 1 liter of air was taken for 10 minutes (Stetzenbach 2015). At each point used four nutrient agar media (DIFCO and BBL 2018).

Incubate and Count Colonies. The nutrients were incubated in incubator (Thermo) at 35°C for 18-24 h. The number of bacterial colonies formed was calculated using a colony counter (WTW BZG 30) and was converted to conversion table (Opertaor MAS 100 2019). The average value of each sample point examined was expressed as the number of airborne bacteria in a room being inspected (Mara *et al*. 2018) The result are then compared with the criteria for the maximum number of colonies according to Minister of Health Regulation No. 1204 of 2004 by the Ministry of Health and Regulation of the Minister of Health of the Republic of Indonesia no. 7 of 2019.

RESULTS

From January 2018 to June 2019, 217 airborne bacteria were examined in the operating theater at 17 hospitals in Jakarta, West Java and Banten. The hospitals involved in this research were A Hospital , B, D, E, H, I, J, K, N and P in Jakarta, D Hospital, G, M and O in Banten and C Hospital, F, L and Q in West Java.

The examination result in each room are divided into several groups of air bacteria per m^3 (CFU/m^3) which are 0-10 CFU/m^3, 11-35 CFU/m^3, 36-100 CFU/m^3, 101-180 CFU/m^3, 181-300 CFU/m^3 and >300 CFU/m. In 2018, 102 out of 137 examinations are 0-10 CFU/m^3, 18 examination are 11-35 CFU/m^3, 7 examination are 36-100/m^3 , 4 examination are 101-180 CFU/m^3, 1 examination are 181-300 CFU/m^3 and 5

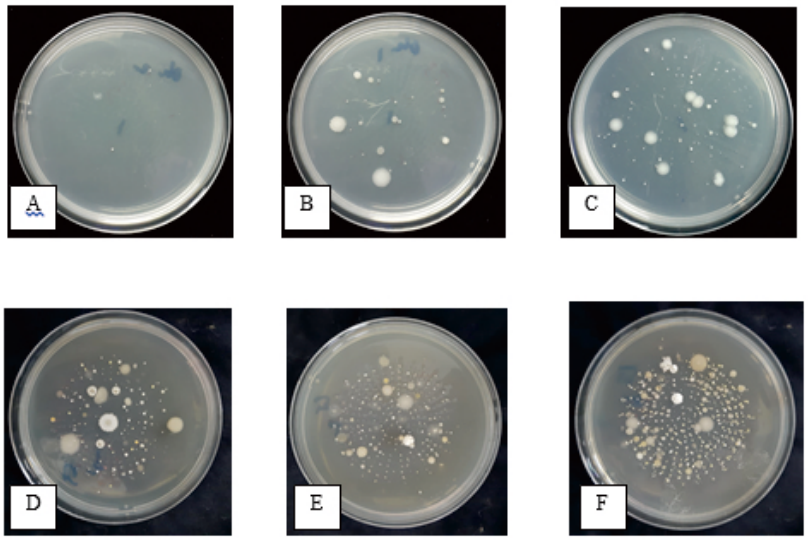

Fig 1 Various culture result of examination of air bacteria on nutrient agar with air sample method. A. The number of bacteria 0-10 CFU/m^3. B. The number of bacteria 11-35 CFU/m^3. C. The number of bacteria 36-100 CFU/m^3. D.The number of bacteria 101-180 CFU/m^3. E. The number of bacteria 181-300 CFU/m^3. F.The number of bacteria >300 CFU/m^3.

examination are >300 CFU/m^3 (Table 1). In 2019, 60 out of 80 examinations are 0-10 CFU/m^3, 10 examination are 11-35 CFU/m^3, 5 examination are 36-100/m^3, 2 examination are 101-180 CFU/m^3, 1 examination are 181-300 CFU/m^3 and 2 examination are >300 CFU/m^3. The overall results these years can be seen in Table 1.

The result of the study in 2018, showed that, the number of air bacteria in 120 operating theaters (87.59%) was in 0-10 CFU/m^3 and 11-35 CFU/m^3. These result meet the maximum concentration of airborne bacteria determined by the Ministry of Health of The Republic of Indonesia in the Ministry of Health Regulation of the Republic of Indonesia 2019 No.7. In 2019, this figure is not much different, around 87.50 % of operating theaters are in the same group as the previous year. An aexample of the results of an examination of air bacteria can bee seen in Fig 1.

The study was also conducted to compare the average concentration of airborne bacteria in several operating theaters in several hsopitals for time to time. The hospitals are A, B, C, D, E, G, J, K, N and P. Comparison cannot be done in other hospitals for hospitals F, H, I, L, M, O and Q because data collection was only carried out once in the hospital in the period January 2018- June 2019.

During Januari 2018-June 2019 of the 10 hospitals examined only 3 had an average concentration of airborne bacteria thet never exceed the Ministry oh Health's Republic Indonesia (35 CFU/m^3) standard, that are A hospital, B and D. The average concentration of air bacteria in A Hospital is 5.58 CFU/m^3 (Table 2). Overall, the average monthly inspection results meet the quality standard.

The average airborne bacterial concentartion of B Hospital was 6.19 CFU/m^3 (Table 3). In general, the average monthly examination results meet the quality standard. It was reported thet in April, the process of cleaning the room, especially the air conditioner and HEPA filter was carried out routinely according to applicable procedures. This condition is considered as one of the main factors thet play role in maintaining bacteriological air quality in the operating theaters at this hospital.

The average airborne bacterial concentration of D Hospital was 15.5 CFU/m^3 (Table 4). During 2018-2019, four examinations were recorded and all of them met quality standard. However, it was noted that there was only one operating theaters examined at each examination so that the bacterial air quality of the entire operating theaters could not be conclude.

The average conentration of air bacteria in hospitals that did not meet the Indonesian Ministry of Health's standards was 67 CFU/m^3 at C Hospital (Table 5). The results showed that the average concentration of air bacteria in each examination did not meet the quality standard.

Besides that the hospital that did not meet the other standards was E Hospital with an average number of airborne bacteria 69.75 CFU/m^3 (Table 6). Examination at E Hospital were only carried out during 2018 four times, two of which were carried out in March. In March, two examination results showed that the concentration of airborne bacteria did not meet the

Table 1 Result of air bacteria examination in operating theaters in various hospitals in Jakarta surrounding areas in January 2018-Desember 2018 and January-June 2019

	Amount of air bacteria per m^3 of air (CFU/m^3)					
	0-10	11-35	36-100	101-180	181-300	>300
Number of examination (n=137)	102 (74.45%)	18 (13.14%)	7 (5.11%)	4 (2.92%)	1 (0.73%)	5 (3.65%)
Number of examination (n=80)	60 (75%)	10 (12.50%)	5 (6.25%)	2 (2.50%)	1 (1.25%)	2 (2.50%)

Table 2 Result of air bacteria examination in the operating theaters in A Hospital in January 2018-June 2019

Operating theaters	Consentration of air bacteria (CFU/m^3)																	
	Jan 18	Feb 18	March 18	Apr 18	May 18	Jul 18	Augt 18	Sep 18	Oct 18	Nov 18	Des 18	Jan 19(1)	Jan 19 (2)	Feb 19	March 19	Apr 19	May 19	June 19
1	10	2	5	7	2	2	10	16	9	3	2	23	7	4	2	6	3	2
2	9	5	4	19	2	2	9	7	6	3	18	26	6	2	-	3	3	7
3	5	3	8	4	3	3	4	17	7	4	4	22	3	2	-	4	2	2
4	6	3	5	2	2	3	4	5	3	2	3	3	-	3	-	2	2	3
5	3	3	6	6	3	2	6	6	10	3	6	23	5	2	-	3	3	2
6	10	7	8	10	3	3	24	10	2	2	3	3	-	2	-	3	7	4
Average	7.17	3.83	6.0	8.0	2.5	2.5	9.5	10.17	6.17	2.83	6,0	16.67	5.25	2.5	2	3.5	3.33	3.33
	5.58																	

Table 3 Result of air bacteria examination in the operating theaters in B Hospital in January 2018-June 2019

Operating theaters	Consentration of air bacteria (CFU/m^3)																
	Jan 18	Feb 18 (1)	Feb 18 (2)	March 18	Apr 18	May 18	Jul 18	Augt 18	Oct 18	Nov 18	Des 18	Jan 19	Feb 19	March 19	Apr 19	May 19	June 19
1	8	30	9	2	3	3	3	4	8	4	5	7	5	3	4	6	10
2	4	32	3	13	4	3	7	2	8	5	4	5	3	5	3	3	4
3	8	21	15	10	6	4	3	6	7	6	3	5	3	4	12	3	4
4	3	16	4	10	6	3	7	4	3	2	3	3	3	2	18	5	5
Average	5.75	24.75	7.75	8.75	4.75	3.25	5	4	6.5	4.25	3.75	5	3.5	3.5	9.25	4.25	6
	6.19																

Table 4 Result of air bacteria examination in the operating theaters in D Hospital in 2018-2019

Operating theaters	Concentration of air bacteria (CFU/m^3)			
	March 18	May 18	Nov 18	Jan 19
1	-	-	12	6
2	13	31	-	-
Average	13	31	12	6
	15.5			

Table 5 Result of air bacteria examination in the operating theaters in C Hospital in 2018-2019

Operating theaters	Concentration of air bacteria (CFU/m^3)		
	March 18	August 18	April 19
1	-	-	63
2	72	66	-
Average	72	66	63
	67		

Table 6 Result of air bacteria examination in the operating theaters in E Hospital in 2018

Operating theaters	Concentration of air bacteria (CFU/m^3)		
	March 18	May 18	Jul 18
1	91	15	3
2	298.5	9	2
Average	194.75	12	2.5
	69.75		

quality standard, but in subsequent examinations the average concentration of airborne bacteria dropped significantly so that it met the quality standard.

Hospitals that do not meet the other standards are G hospital with an average number 410.5 CFU/m^3 (Table 7). The examination was carried out once in aech year in 2018 and 2019. The results of the first examination showed thet the air bacteria was far above the quality standard which is 730 CFU/m^3, while the results of the second examination showed a very significant decrease to 91 CFU/m^3, although these results still do not meet quality standards.

J hospital has an average of bacteria was 147.33 CFU/m^3 (Table 8). The examination was carried out in 2018 only. The examination showed a significant decrease concentrations from August to September, which was 353 CFU/m^3 to 46 CFU/m^3. The concentrations decreased again to 43 CFU/m^3 at subsequent in October. However, the three examonations did not show result that met the quality standard.

In K hospital the average was 54 CFU/m^3 (Table 9). The results showed that did not meet the quality standard but the second showed an improvement with the average that met quality standard.

N hospital has an average 39.25 CFU/m^3 (Table 10). The concentration at the first examination was 30 CFU/m^3, but at a subsequent an increase concentration to 48.5 CFU/m^3.

The next was P hospital with average of 309.33 CFU/m^3 (Table 11). All examinations showes taht did not meet quality standard. Based on monitoring, the process of cleaning has been done routinely in accordance with procedures, but the tools in the room are very dense and not neatly arranged.

DISCUSSION

Distribution of concentration into 4 groups which are 0-10 CFU/m^3, 11-35 CFU/m^3, 36-100 CFU/m^3, 101-180 CFU/m^3, 101-180 CFU CFU/m^3, 181-300 CFU/m^3 and >300 CFU/m^3 are based on Decree of the Minister of Health of the Republic of Indonesia No. 1204/Menkes/SK/X/2004 and Regulation of the Minister of Health of the Republic 2019 No. 7, the standard quality in the operating theater is 35 CFU/m^3.

The media used in this study was nutrient agar media. It is a comman medium that contains s source of nitrogen, vitamins and carbohydrates, used to grow various species of Gram positive and negative bacteria and even fungi can grow well in this medium. In this study, the dominant bacteria found were *Bacillus* sp, *Staphylococcus aureus* and *Staphylococcus epidermidis* while *Aspergillus* sp was the dominant group of fungi found. These microbes that are most commonly found in various rooms in hospitals and even communities

Table 7 Result of air bacteria examination in the operating theaters in G Hospital in 2018-2019

Operating theaters	Concentration of air bacteria (CFU/m^3)	
	March 18	May 18
1	730	91
Average	730	91
	410.5	

Table 8 Result of air bacteria examination in the operating theaters in H Hospital in 2018

Operating theaters	Concentration of air bacteria (CFU/m^3)		
	Augt 18	Sep 18	Oct 18
1	353	46	43
Average	353	46	43
	147.33		

Table 9 Result of air bacteria examination in the operating theaters in K Hospital in 2018 - 2019

Operating theaters	Concentration of air bacteria (CFU/m^3)	
	Oct 18	March 18
1	105	3
Average	105	3
	54	

Table 10 Result of air bacteria examination in the operating theaters in N Hospital in 2019

Operating theaters	Concentration of air bacteria (CFU/m^3)	
	Jan 19	Feb 19
1	35	57
2	25	40
Average	30	48.5
	39.25	

Table 11 Result of air bacteria examination in the operating theaters in P Hospital in 2019

Operating theaters	Concentration of air bacteria (CFU/m^3)		
	March 19	Apr 19 (1)	Apr 19 (2)
1	547	224	157
Average	547	224	157
	309.33		

(Kandy *et al*. 2019 and Leong *et al.* 2013). The discovery of these microbes shows that the room being examined needs to be carried out a more intensive sterilization process.

During the examination (2018), regulation No. 7 of 2019 has not yet been issued so that so that the standard still refers to the Decree of No. 1204 of 2004. Based on these regulations, the maximum quality standarad is 10 CFU/m^3, so that the examination that meets the quality standard in 2018 is only the 0-10 CFU/m^3 group, which is 74.45%. However, in general the examinations have shown good results.

Hospitals recorded with a concentration that did not exceed the standard quality were A Hospital, B, and D. In the D Hospital only one operating theater was eximed at ehamination so that it could be it is considered for the hospital to examine the entire operating theater to obtain more conclusive examination results.

Each hospital is equipped with a heating, ventilation and air conditioning (HVAC) system that has a high-efficiency particulate air filter (HEPA filter) as one of its componenet. HVAC is an air conditionng systems that plays a role in maintaining the appropriate warmth and air quality in the room. It is works based on mechanical engineering subdiscipline by involving the principles of thermodynamics, fluid mechanics and heat transfer.

Hepa filters play a role in filtering air very efficiently through its use in areas that need contamination control. However, it cannot filter odorous gases and molecules. HVACs equipped with HEPA filters are important in maintaining air conditioning systems in hospitals as areas that require sterile conditions but it is known that often HVCA and HEPA filters are contaminated so that the contaminated air also flows into the room.

Although every examination is equipped with an advise and input, suspected that not all hospitals do what is recommended to reduce the concentrationof airborne as happened to C Hospital on February 2018, July 2018 and April 2019; E Hospital on March 2018, G Hospital on Mei 2018 and March 2019, J Hospital on August 2018, September 2018 and October 2018; K Hospital on October 2018, N Hospital on February 2019 and P Hospital on March 2019 and April 2019.

Based on a study conducted by Liu *et al* (2005), bacteriological contamination with HVAC significantly higher compared to natural air ventilitaion (VUA). The use of HVAC which aims to maintain the air system can cause bacteriological contamination, because the HVAC system is an efficient location as a place for bacterial colonization when cleaning is not done routinely (Kandy *et al*. 2019). This finding was also reported by Guo *et al* (2003). It is known that thi air filtration technique has a mechanism that should play a significant role in protecting air from bacterial contamination so that it is necessary to carry out regular cleaning of HVAC and HEPA filters to maintain good air quality (Kemenkes 2012).

Based on observations, hospitals that have decreased concentrations of airborne bacteria such as C Hospital, E, G, J, S, K, S, N and P had carried out extensive cleaning involvong sterilization of equipment, cleaning of HVAC and HEPA filters, lamp replacement and the use of hypochlorite as disinfectabts that are known to be most effective in eradicating microorganisms.

In G Hospital, The average concentration of airborne bacteria in the theaters room reaches 730 CFU/m^3 on May 2018 and in P Hospital 547 CFU/m^3 on March 2019, 224 CFU/on April 2019 and 157 CFU/m^3 on the second examination in April 2019. It should be noted that the steps to clean the theaters room must be done more comprehensively because of the high risk of nosocomial infection.

A similar study conducted by Hailemariam *et al* (2016) in Etiopia showed that the average concentration in the passive and active 13.12 CFU/dm^2 and 87.27 CFU/dm^2 respectively. Considered acceptable based on the Fisfer index in this study, where the active theaters room quality standard is devided into 3 group, such as optimal (0-60 CFU/dm^2), acceptable (61- 90 CFU/dm^2) and unacceptable (>91 CFU/dm^2), while the findings in the passive theaters room are considered unacceptable based on standard quality to be optimal (0-4 CFU/dm^2), acceptable (5-8 CFU/dm^2) and unacceptable (>9 CFU/dm^2) (Pasquarella *et al.* 2000).

Similar results were found in a study conducted in Nothern Etiopia by Gebremariam Kibrom (2015), where the concentration was 91.8 CFU/dm^2 in the active theaters room and 17.2 CFU/dm^2 in the passive theaters room, but in this study accordingly, the concentration of airborne bacteria in the active theaters room slightly more higher than the Fisher index. The average concentration was known to be highest in the morning, 63.3% of the samples belong to unacceptable group. In the afternoon 45% of the samples belong to unacceptable. This is allegedly because in general, the morning is the time with the highest activity, such as changing patient clothes, bathing patients, changing diapers and gicing medicine. In general, 60% of the theaters room examines do not have good bacteriological air quality (Sulistiyo *et al*. 2017).

Another study conducted by Sulistiyo *et al* (2017) reported that the concentration of airborne bacteria in the theaters room at RSUD Tugurejo Semarang was 54.57 CFU/m^3, where this number did not meet quality standars. After sterilization, the concentration of airborne bacteria decrease to 24 CFU/m^3, however this number still does notmeet quality standards (Hailemariam *et al*. 2016).

The majority of theaters room in hospitals Jakarta, West Java and Banten have met air quality standards. In 2018, 87.59% of bacterial air quality examination in the theaters room meet the quality standars whereas in 2019, 87.50% of examination in the theaters room meet the quality standars. It can be concluded that hospitals in Jakarta and surrounding areas have maintained goos procedures in mainstaining sanitation and monitoring air quality in the theaters room.

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