ORIGINAL ARTICLE

EFFECT OF EXHAUST FAN TO MICROORGANISM CONCENTRATION IN THE AIR-CONDITIONED ROOM

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ABSTRACT

Specific amounts of bacteria and fungi in the room can cause Sick Building Syndrome (SBS). The main reason for bacteria and fungi accumulation is a lack of air circulation in the air-conditioned room. Therefore, we study exhaust fan usage to microorganism concentration in the air-conditioned room. The objective of this study is to find the optimum exhaust fan running time for reducing microorganism concentration until below the threshold value. The quasi-experiment was using with repeated experiments and non-random methodology. The samples were consisting of four air-conditioned classrooms with six repeated measurements. The sampling instrument used a petri dish filled with NA (Nutrient Agar) and PDA (Potato Dextrose Agar) placed at five points in each room. The results showed that the variation of exhaust fan running time sig affected the concentration of bacteria (sig ~0) and fungi (sig 0.023) in the classrooms. We found that exhaust fan can reduce the bacteria concentration. Although we observed that the exhaust fan gives inconsistency effect to reduce the fungi concentration in the classrooms.

Keywords: *room air quality, exhaust fan, bacteria, fungi, air-conditioned room*

INTRODUCTION

Air is one of the essential needs to maintain life's existence. The atmosphere divided into outdoor air and indoor air. Indoor air quality dramatically affects human health due to ~90% of human activity is in indoor[1].

Healthy indoor air quality is indicating by the absence of pathogenic microorganisms in the air, such as bacteria and fungi (~0 CFU/m^3)[2]. The Indonesian government has set the minimum threshold concentration for bacteria and fungi in the indoor air, which is 0 CFU/m^3 and 1000 CFU/m^3, respectively[3].

A sufficient microorganism concentration in the room can cause Sick Building Syndrome (SBS)[4,5]. SBS is a disease caused by substandard indoor air quality. SBS is defined as symptoms that occur based on the user's experience when they are in the building, such as skin allergies, breathing difficulty, irritation of the eyes, nose and dry mucous layer, mental fatigue, headaches, acute respiratory infection, asthma, cough, flu, sneezing, and other hypersensitivity reactions[2,4].

According to the National Institute of Occupational Safety and Health (NIOSH) at 1997, several things can cause poor indoor air quality such as lack of air ventilation (52%), indoor contaminant (16%), outdoor contaminant (10%), microbes (5%), property materials (4%), and others (13%)[6]. Improving air quality can be made by exchanging air regularly, specifically: (1) houses equipped with ventilation, which has an area of >10% from floor area using the cross-ventilation system. (2) In an air-conditioned room, enhancing the air quality can be done by device maintenance and opening the window once a day. (3) Using an exhaust fan. (4) Room layout management[7]. In air-conditioned room, the bacterial and fungal concentration was higher compared to the well-air-circulated room[8]. Additionally, the bacteria and fungi can live in the air conditioner filter[9]. Although, the UV light can be utilized to reduce the bacterial and fungal concentration in the room. However, this strategy is risky to be applicable in the classroom since people are around. In the other hand, the exhaust fan was able to reduce the dust and unhealthy gas in the factory by improving the air circulating in that room[10].

Herein, we demonstrate the utilization of exhaust fan to improve the air-conditioned indoor air quality. The exhaust fan significantly reduces bacterial and fungal concentration by exchanging the air in the room. We seek to investigate the optimum time needed for running the exhaust fan to achieve sufficient air quality.

METHODS

This study used a quasi-experimental method, which uses non-randomized repeated experiments. The population in this study was air-conditioned classrooms in Campus A, Health Polytechnic of Ministry of Health, Pontianak. We used four air-conditioned classrooms equipped with an exhaust fan that has an airflow capacity of ~1728 CMH. Then, based on the volume of the classroom, we calculated the time needed of exhaust fan to fully circulate the classroom is 60 min. Based on the Federer formula, the experiment in each class repeated six times. The exhaust fan running time was varied to be 30 min, 60 min, 90 min, and 120 min. The bacterial and fungal concentration calculations performed before and after the exhaust fan running.

The sampling instrument used a petri dish filled with NA (Nutrient Agar) and PDA (Potato Dextrose Agar). The petri dish placed on the room based on the provisions of the National Standardization Agency SNI 7230: 2009. Briefly, it put in a small room with a length and width of fewer than 6 meters, which located at 5 points on the median of the diagonal line and the centre point of oblique intersection[11]. After 30 minutes of placing the petri dish, Laboratory officials collect, breed, and perform the calculation (time and procedure for breeding and prediction under Laboratory standards). This procedure executed at each class before and after the exhaust fan running.

The researcher officially accepts the calculation results from the laboratory officer. Calculation of microorganism colonies based on Polish Standard PN 89/Z-04008/08, using the formula[8]:

$$CFU/M3 = a.1000/p.t.0.2$$

With **'a'** is many colonies in Petri dishes, **'p'** is a surface area of a petri dish, and **'t'** is Petri dishes exposing time.

Before the Manova analysis was carried out, a homogeneity test with the Lavene method obtained sig. values of >0.05. Therefore, Benferroni's method used as the Post Hoc test. This method enables to de-convoluted that the exhaust fan was significant or not to reduce the bacterial and fungal concentration in the air.

We also measure temperature, humidity, and light intensity. The class condition controlled to running the experiment. We set the classroom with air conditioner power of 18,000 BTU; the temperature was 26–28 °C, the humidity was 70.16–75.81%, light intensity was 175.10–177.34 Lux, and there were 36–44 persons in that room. Data were analyzed using manova to determine the effect of exhaust fan running time on bacterial and fungal colonies number.

RESULTS

We observed that there is no significant variation in the bacterial and fungal concentration in the classroom before running the exhaust fan that shown in the Figure 1 and Figure 2.

After running the exhaust fan at different times, there is a notable difference in the bacterial and fungal concentration. A sign of the effectiveness of exhaust fan usage to reduce improve air quality by decreasing the bacterial and fungal levels. Levels of bacteria and fungi in the classroom by turning on the Exhaust Fan seen in the Table 1.

Table 1: Bacterial and fungal concentration result

Running time (min)	Average bacterial concentration (*CFU*/M^3)		Shift	Average fungal concentration (*CFU*/M^3)		Shift
	PRE/CONTROL	POST		PRE/CONTROL	POST	
30'	1.756,53	1.493,01	-261,51	1.009,67	548,35	-461,32
60'	2.167,44	1.760,37	-407,07	667,67	802,08	+134,20
90'	1.328,41	812,56	-515,84	363,82	382,69	+18,87
120'	972,98	712,96	-260,02	456,08	310,35	-145,74
Variable	**Sig.-Values in bacterial concentration**			**Sig.-Values in fungal level**		
Different exhaust fan running time (Manova Analysis)	0,000			0,023		

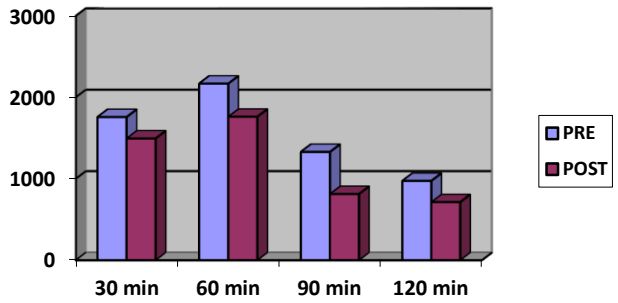

Figure 1. Average bacteria concentration at pre and post exhaust fan running

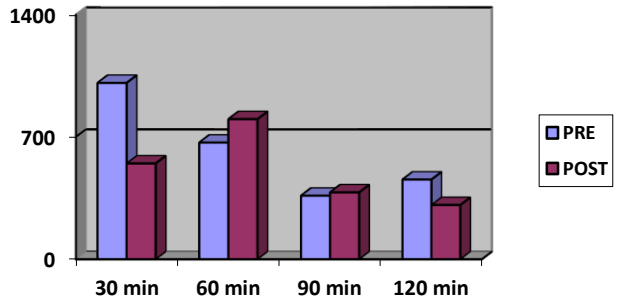

Figure 2. Average fungal concentration at pre and post exhaust fan running

After 30 min of running the exhaust fan, the decrement in bacterial and fungal concentration was 261.51 and 461.32 CFU/m^3. While for 60 min running time of exhaust fan, the bacterial level decreased for 407.07 CFU/m^3, and the fungal concentration increased for 134.20 CFU/m^3.

For 90 min of running exhaust fan, the bacterial concentration was decreased for 515.84 CFU/m^3, while the fungal level increased for 18.87 CFU/m^3. The decrement in bacterial and fungal strength observed after 120 min of running the exhaust fan, with a decrement value of 260.02 and 145.74 CFU/m^3, respectively.

This result shows that the bacterial concentration was still slightly above the threshold level (>700 CFU/m^3), with reach 712.96 CFU/m^3 after solely 120 min running time of exhaust fan. The significant decrement in bacterial concentration observed after exhaust fan running for 90 min while the level of fungi notably decreased after solely 30 min of running time of exhaust fan.
Table 1 shows that the bacterial and fungal concentration was significantly affected by running the exhaust fan, with both sig. value (0.000 and 0.023, respectively) demonstrate the value below 0.05. For bacterial concentration, there is a significant difference in sig. value between exhaust fan running time of 30 and 90 min, with sig. 0.040; between 30 and 120 min, with sig. 0.015; between 60 and 90 min, with sig. 0.003; between 60 and 120 min, with sig. 0.001. For fungal concentration, notable differences in sig.-value Observed between exhaust fan running time of 60 and 120 min, with sig. 0.030.

We also measured the temperature, humidity, and light concentration of the room at the time of the experiment was conducted which was summarized in Table 2. There is no significant different in temperature, humidity, and light concentration at before and after exhaust fan running process, which indicate that the shift of bacterial and fungal concentration was due to exhaust fan process.

Table 2. Temperature, humidity, and light concentration of the room at the time of the experiment was conducted

Condition Rooms:	Average temperature (^{0}C)		
30'	27,2	28,7	+1,5
60'	26,3	28,2	+1,9
90'	27,1	27,4	+0,3
120'	26,5	27,9	+1,4
	Average humidity (%RH)		
30'	72,1	77,8	+5,7
60'	76,3	75,8	-0,5
90'	72,0	70,2	-2,2
120'	78,2	70,1	-8,1
	Average light intensity (Lux)		
Lux in 30'	204,6	192,2	-12,4
Lux in 60'	266,2	247,4	-18,8
Lux in 90'	182,2	165,4	-16,8
Lux in 120'	224,6	215,6	-9,0

DISCUSSION

In pre exhaust fan treatment value as shown in Table 1, the bacterial and fungal concentration in the classroom is above the threshold which sign that the exhaust fan was necessary to further reduce the bacterial and fungal concentration. The different decreasing ratio obtained with modified exhaust running time due to different ventilation condition and people population in the room, according to Hayleeyesus's, Wamedo's, and Graudenz's experiment in 2014, 2012, and 2005, respectively[12,13,14].

There is inconsistency in fungal concentration between 30 and 120 min of exhaust fan running time that the decrement in fungal level after 30 min was higher compare to after 120 min of running the exhaust fan. Moreover, after 60 and 90 min of running the exhaust fan, the fungal concentration

was increased, which may be owing to a person's activity that opens the door several times.

Ponce-Caballero's experiment, 2013, demonstrated that the fungal concentration was significantly affected by fungal levels from outside of the room. The fungi can enter the room from the opened window or door, which leads to the increment in indoor fungal concentration. Therefore, opening the door from person activity can cause the fluctuation the indoor fungal concentration[15].

Additionally, according to Adams experiment in 2015, the people population in the room was an essential factor to the indoor microorganism concentration, especially in poorly circulated room[16].

The threshold of bacterial concentration was below 700 CFU/m^3. Therefore, although the exhaust fan was running for 30, 60, and 90 min, the bacterial level was still above the threshold value. However, with the exhaust fan running time of 120 min, the bacterial concentration was reduced to slightly above the threshold value. This result indicates that the exhaust fan usage in this experiment still not be able to reduce the bacterial level to below the threshold. We posit that may be originated from human number and activity in the room, as shown in the Fox experiment in 2013, Mahyuddin in 2013, and Meadow in 2014[17,18,19]. They also demonstrate that CO_2 concentration in the place also gives a significant improvement in microorganism concentration in the air. Although the microorganism concentration was affected by outdoor air quality additionally, however, human factor give impact to almost two times higher to microorganism concentration in indoor air[19].

For fungal levels in the air, the threshold was below 1000 CFU/m^3. With running the exhaust fan for 30-120 min, the fungal concentration of below threshold can be achieved. The exhaust fan can reduce the fungal concentration by increase the air circulation in the classroom. Therefore, the exhaust fan method is an effective way to reduce the fungal level in the air, which solely required 30 min to reach below the threshold.

The Barberan study in 2015 and Adams in 2013 showed that mold in indoor air was lower than in outdoor air[20,21]. Goh's study in 2000 with a sample of libraries in Singapore also stated that the rate of mold in indoor air was about 50 times lower than outdoor air[22].

CONCLUSION

We demonstrate the simple exhaust fan to improve indoor air quality by reducing the bacterial and fungal concentration. Exhaust fan significantly reduces fungal concentration to below the threshold solely required 30 min. While the required exhaust fan running time to reduce the bacterial concentration to near the threshold was 120 min. This reduction in the bacterial and fungal concentration was owing to the improvement of air circulation by exhaust fan. This exhaust fan strategy will be easily applicable due to simple and cheap.

ACKNOWLEDGEMENTS

We would like to thank the Director of Health Polytechnic of Ministry of Health, Pontianak, Indonesia that provides laboratories facilities to analysis the sample. We also thanks for the support and advice from our health associates, so that makes this research well.

CONFLICT OF INTEREST

The authors declare no potential conflict of interest.

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