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Identifying Indoor Air Quality: Ventilation in Healthcare Facilities Semarang

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Abstract

A building requires good ventilation planning, especially for health facility buildings. Ventilation plays a role in supplying clean air and creating good indoor air quality. This study identifies the air change rate that improves indoor air quality in health facility buildings in tropical areas. Direct field measurements were conducted in this study and then analyzed based on the appropriate recommendation standards. The results of this study show that some variables still need to meet the recommendation standards in meeting the requirements of good air quality. This proves that ventilation has an essential role in air conditioning in the room, creating clean and healthy air. This research provides an overview that ventilation needs to be carefully designed to achieve good air quality, so it is expected to reduce contaminants in the air.
Keywords: *Ventilation, Healthcare Facilities, Tropical, Indoor Air Quality, Air Change Rate*

1. Introduction

A well-ventilated building design is essential for a healthy indoor environment. It allows fresh air from outside to enter the room and influence the indoor climate. This is especially relevant for tropical climates like Indonesia, where the humidity and sunlight are relatively high all year round. The fresh air can alter the indoor climate through ventilation; for instance, it can reduce the room's temperature and relative humidity (1). As fresh air comes in, it lowers the room temperature and relative humidity in an inverse proportion. This also reduces fatigue and headache symptoms and improves performance when the room temperature and relative humidity are slightly lower (2), this is also related to the contaminants that come from indoor and outdoor sources. Therefore, it is necessary to know how to find solutions for optimizing air movement through natural ventilation suitable for tropical climates to create healthy air quality by lowering contaminants in the room.

Several previous studies have discussed ventilation in buildings and air circulation in spaces, such as the research conducted by Razali Thaib in 2020, which analyzes the operation of natural air ventilation in the Regional Hospital of Kota Langsa. The measured variables include indoor and outdoor air temperature, air velocity, and humidity (3). This study has yet to discuss the analysis of air quality.

The research conducted by Tri Woro Setiati, Sandra Eka Febrina, and Fajar Sadik Islami in 2022 re-investigated the air quality of classrooms that have changed from using artificial ventilation systems to natural ones. This investigation was carried out by measuring air quality with several parameters, including particulate concentration, air velocity, temperature and air humidity, as well as HCHO and TVOC (4). This study did not use the CO_2 parameter, and the analysis was not conducted on healthcare facility buildings.

Another study by Nur Airunnisa Virginia and Ayu Herzanita in 2023 analyzed the ventilation and air conditioning systems for retrofitting green buildings at the Faculty of Engineering, Universitas Pancasila (5). This study discusses the relationship between the ventilation system and green buildings concept related to comfort in detail.

From the previous studies mentioned above, none have linked the role of ventilation with the air quality condition in spaces, especially in healthcare facility buildings, which are closely related to contaminant issues, as well as the need for healthy air quality. This study aims to identify the air change rate to improve indoor air quality (IAQ), especially in health facility buildings, buildings closely related to health, and the need for good air quality.

2. Materials and Methods

This research applied descriptive quantitative methods by doing direct measurements in the field. The measurements were taken when registration room of the Pudakpayung Health Center, Semarang City, at Payung Mas Raya Street, was in service. The registration room is essential because various patients with possible diseases gather in the room before seeing the doctor. The registration area within this building is endowed with natural ventilation and is supplemented by a fan, eschewing the utilization of an air conditioning unit—this configuration serves as a research apparatus for in-situ empirical observations. A descriptive analysis was done after the measurement based on the suggested standard.

3. Results

The registration room of the Pudakpayung Health Center has natural cooling with a fan as an addition, and these are the measurements of the room;

Table 1. Existing Dimension of the Pudakpayung Health Center

Room Area	92,41 m^2
Ceiling Height	4,2 m
Ventilation Area	11,12 m^2 (12% of floor area)
Room Volume	377 m^3
Room Capacity	40 people
Occupancy Density	40/92,41 m^2 = 0,43/m^2
Building Orientation	East-West Building openings on the north-south side

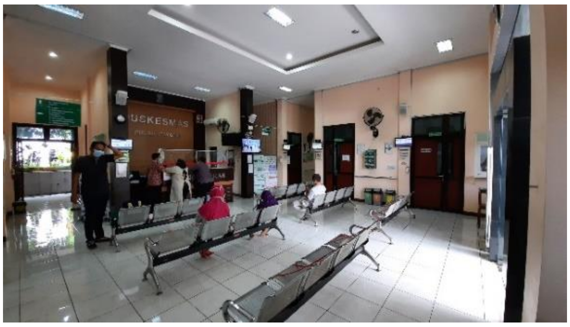

Figure 1. Existing Conditions of the Pudakpayung Health Center

We can see that the existing building condition taken on August 2nd, 2023 has a ventilation area of 12%, which should be at least 15% of the floor area, according to The Minister of Health Regulation no 75 of 2014. The position of the ventilation is seen in Figure 2, and its details are shown in Figure 3.

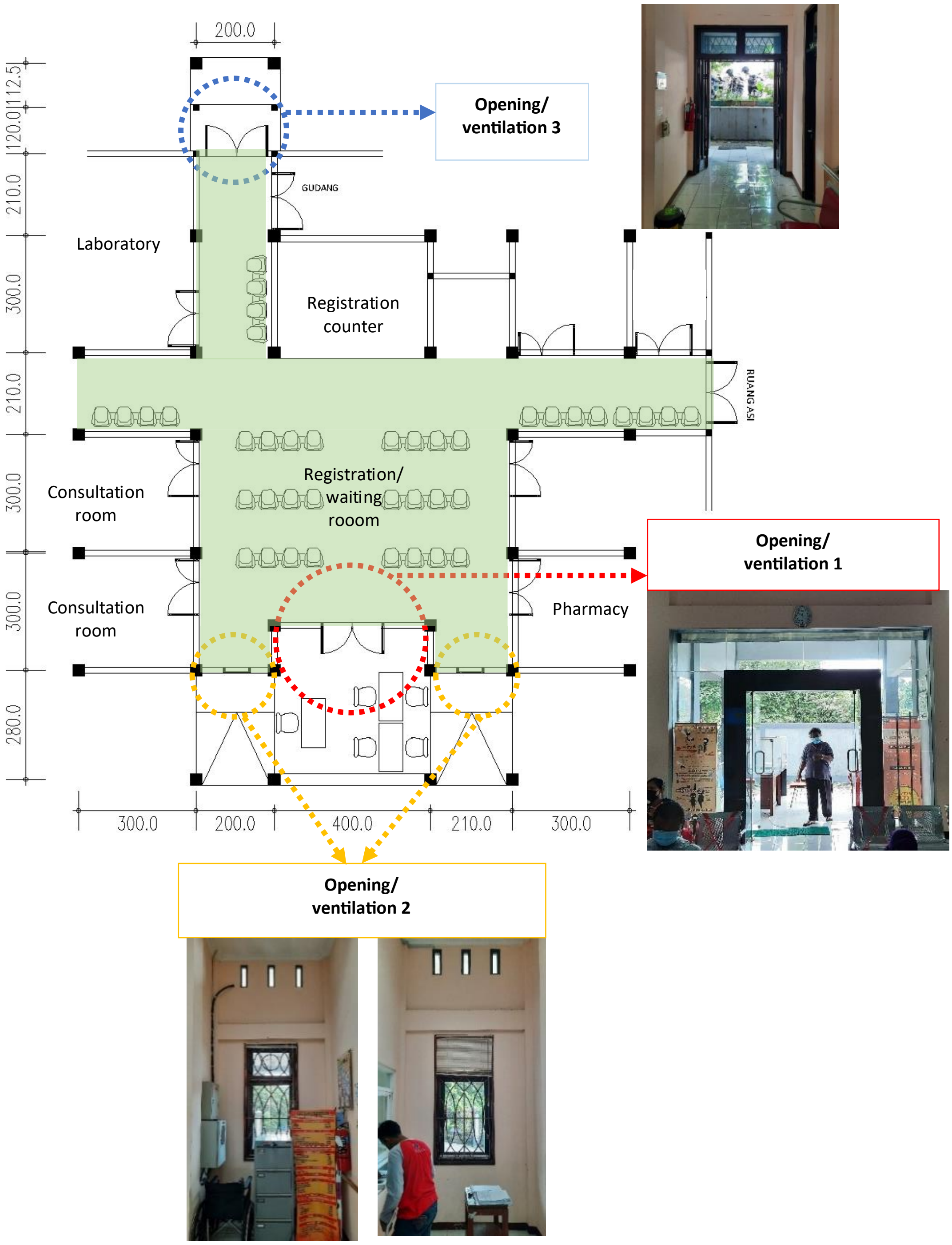

Figure 2. Pudakpayung Health Center Waiting Room Plan

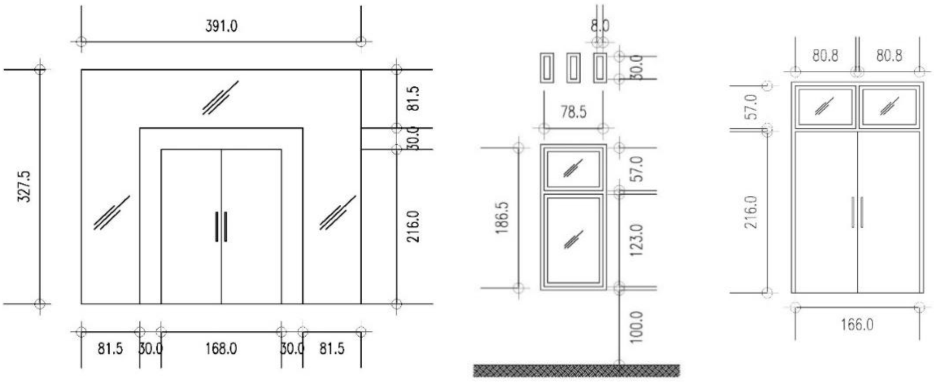

Figure 3. Detail of Openings/ Ventilation in the Pudakpayung Health Center Registration room. (a) Opening/ventilation 1, (b) Opening/ventilation 2, (c) Opening/ventilation 3

Measurements in this study were carried out four times, namely at 8AM WIB (T1) with a capacity of ±15-20 visitors, at 10AM WIB (T2), at 12PM WIB (T3) with a capacity of ±5-10 visitors and at 2PM WIB (T4) with a capacity of ±0-5 visitors. The measurement points are at positions that are expected to change, with a height of ±50cm according to the height of the visitors when sitting/waiting. The initial data collection of the study used the measurement position shown in Figure 4 below.

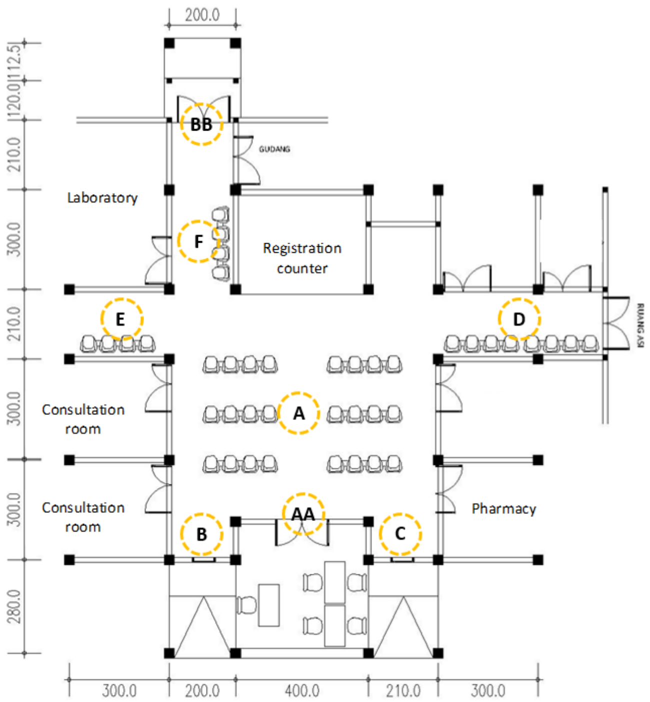

Figure 4. Position of Measurement Points in the Pudakpayung Health Center Registration room

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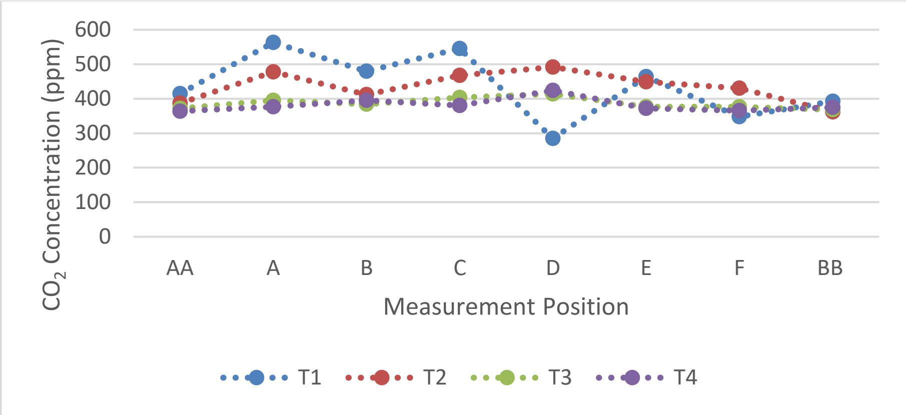

Figure 5. CO_2 Concentration Measurement of Pudakpayung Health Center

Based on the results obtained, it can be seen in Figure 5 that the CO_2 concentration level in registration room of the Pudakpayung Health Center fluctuates quite a bit, ranging from 285 ppm to 563 ppm.

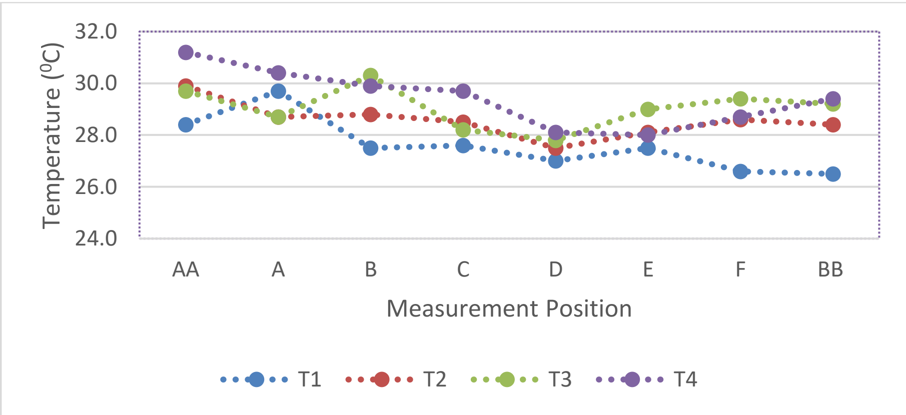

Figure 6. Temperature Measurement of Pudakpayung Health Center

Natural ventilation and four fans are used in the registration room of the Pudakpayung Health Center. The temperature in the room is exceptionally fluctuating as seen in Figure 6. Point AA, outside the room, has the highest temperature, while Point BB, also located outside the room, has a low temperature compared to other points. This is caused by shade in the form of tree vegetation, canopy/shading and a wall approximately 1.5 meters high near Point BB. There is also a canopy/shading at Point AA without other shade, such as vegetation, so there is a possibility that solar radiation heat will enter the room. It can also be seen in Graph 6 that the room temperature tends to decrease from point A to point F. Some fluctuations can be influenced by the density of visitors at the point of occurrence of fluctuations or the influence of air movement and airflow rate in the room. When the measurement was done, the fan was not turned on.

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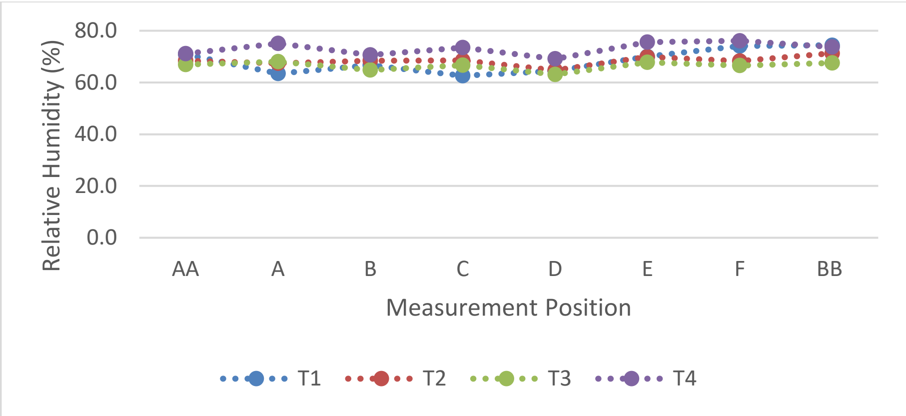

Figure 7. Relative Humidities Measurement of Pudakpayung Health Center

The relative humidity in the registration room of the Pudakpayung Health Center were not vary much among the points, as shown in Figure 7, with the lowest relative humidity of 60% and the highest of 72.8%.

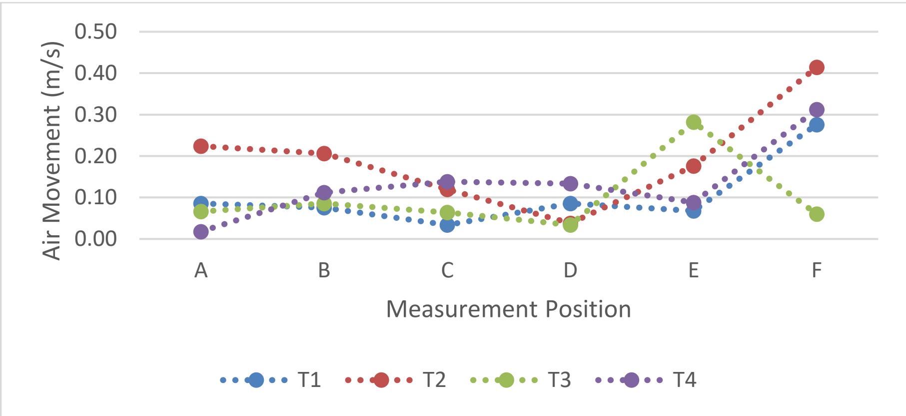

Figure 8. Air movement Measurement of Pudakpayung Health Center

In registration room of the Pudakpayung Health Center, the air movement fluctuates (see Figure 8) between 0.02m/s and the highest 0.41m/s at point BB. The fluctuating air movement is influenced by the wind that blows when the measurement is done. The room only relies on natural ventilation in the form of doors, windows and boven open wide during service hours. Fans can aid air movement, but the measurement was done without them to understand better how well the natural ventilation moves the air.

The airflow rate measures the amount of fresh air that comes into the room. The wind outside the room can affect the airflow rate. The airflow rate also depends on the size and location of the opening where the air enters the room. The stronger the wind that comes in, the higher the airflow rate; using a fan can also improve the airflow in and out of the room. The airflow rate at the Pudakpayung Health Center varies from 0.03 m^3/s to 1.13 m^3/s. The centre has 20 rooms, each with one person, so the airflow rate per person ranges from 0.0015

m^3/s/person to 0.0565 m^3/s/person or 0.09 m^3/minute/person to 3.39 m^3/minute/person. This airflow rate is essential for indoor air quality, as it helps to remove pollutants from the room and to replace the air with fresh air. The formula below used to calculate air changes per hour(6);

$$N = \frac{3600\,Q}{V} \qquad (1)$$

where:

N is the air change rate for each hour (times/hour)

Q is the ventilation rate or airflow rate (m^3/s)

V is the volume of the room (m^3)

3600 is the conversion factor (from second to hour)

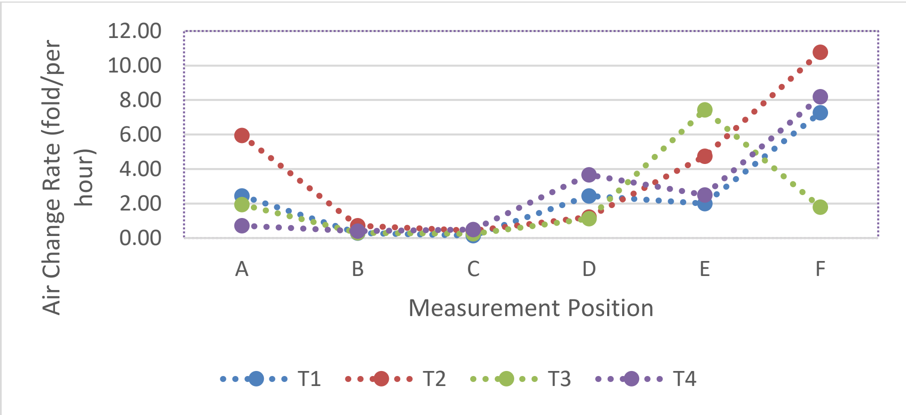

Figure 9. Air Change Rate of Pudakpayung Health Center

The air change value in registration room of the Pudakpayung Health Center, seen in Figure 9, tends to decrease from point A to point B, then stabilize until point C and start to increase at point D. At T1 (8AM) and T4 (12PM) point D decreases to point E and increases again at point F. In contrast, at T2 (10AM), point D increases to point F. However, at T3 (12PM), point D increases to point E and decreases at point F. The highest air change occurs at the point position near the opening. Meanwhile, the air change value is lower at points B and C, which are also close to the opening. This can be influenced by the type of window, a casement window that allows less optimal air to enter. Air exchange through building ventilation is needed to provide oxygen for breathing and remove respiratory products (CO_2, water vapour) and contaminants produced by various processes (7).

4. Discussion

4.1 Indoor Air Quality (IAQ)

Much time is spent by people indoors. IAQ is still a significant problem affecting occupants' health, such as Sick Building Syndrome, especially with the impact of the COVID-19 pandemic. The need to focus on design strategies to enhance IAQ is highlighted by the health conditions of the room users because inefficient ventilation causes poor air quality. It is claimed that occupants have a higher chance of getting diseases in rooms with lousy ventilation than in rooms with good ventilation. Moreover, new proof has been discovered that indicates high infection rates in rooms with inadequate ventilation (8). Ventilation is essential for reducing the spread of diseases (9). By bringing in fresh air from the outside, ventilation creates a healthy indoor environment. The fresh air entering the room can influence the indoor climate. The room’s temperature and relative humidity can be lowered by the fresh air entering the room, which can also decrease fatigue and headache symptoms and increase performance (10).

IAQ has always been a critical factor in evaluating how different buildings perform and can be measured by the number of air pollutants in the indoor environment. However, this approach must be backed up by specific policy changes in the public health, urban planning, and architectural design sectors (11).

4.2 Ventilation Related to IAQ

Ventilation is a place where air freely enters and exits (12). Ventilation also “a combination of processes that result in the supply and removal of air from inside a building” (13). Outdoor air is brought in, conditioned, mixed with indoor air, and distributed in the building. Some indoor air is also moved outside. The indoor air quality depends on how well these processes are done. If they are done well, the indoor air quality will improve.

There are two main categories of ventilation: natural and mechanical. Mechanical ventilation involves central Air Conditioner (AC) and non-central AC (like window and single split types). AC can influence how infectious agents spread and cause diseases in buildings and health facilities (14). Based on the research conducted by Baurès et al, it shows low pollution in health facility buildings likely related to ventilation and air conditioning systems (15).

Ventilation plays a vital role in indoor air quality. This is when the wind and temperature differences create a pressure difference outside a building, which makes hot gases flow through the ventilation ducts. Natural ventilation consists of permanent openings, windows, doors or other open means. Wide and open ventilation and better airflow. Adding exit holes improves air quality.

We can see form the result above, that the building has a ventilation area of 12%, which should be at least 15% of the floor area, according to The Minister of Health Regulation no 75 of 2014. Meanwhile, the existing room density is 0.43/m^2, which is still too crowded according to ANSI / ASHRAE Standard 62.1-2019. The high density of the occupant in indoor spaces can cause an increase in carbon dioxide (CO_2) levels in the air. CO_2 is a gas humans produce when breathing and burning fossil fuels. If CO_2 accumulates indoors, it can lower air quality and disrupt the health of occupants. To reduce the risk of CO_2 accumulation indoors, it is by optimizing ventilation in the room (16). How well the ventilation system works relies significantly on how it distributes the air. Many studies have shown that raising the ventilation rate is insufficient to eliminate pollutants in the room if the air distribution system is inappropriate (17).

Based on the results obtained, the CO_2 concentration level in registration room of the Pudakpayung Health Center meets the standard recommended by DOSH (Department of Safety and Health, Malaysia) and ANSI/ASHRAE Standard 62.1-2019, which is below 1000 ppm. The CO_2 level in the room will rise based on various factors, such as the number and activity of users, the room's density or occupancy, how long they stay in the room, and the amount of fresh air (air flow rate) coming into the room (18).

The room's temperature is from 27°C to 28.9°C, which is higher than the ANSI/ASHRAE/ASHE Standard 170-2017 Ventilation of Healthcare Facilities with a temperature of 21°C-24°C and also higher than the standard of Permenkes RI No 216/Menkes/SK/1998 on Environmental Health Requirements for Work which is from 18°C-26°C. This is because the air conditioning only uses natural ventilation and no AC.

According to Minister of Health Regulation in Indonesia and ANSI/ASHRAE/ASHE Standard 170-2017, the humidity in the registration room of the Pudakpayung Health Center is higher than the standard, which is between 40%-60% or not be more than 65%. The room's humidity level and humidity risk also depend on the ventilation rate. The humidity can be lowered by increasing the ventilation rate, but it also varies with different climate zones (19).

The air movement in the registration room of the Pudakpayung Health Center were not fully comply with the Indonesian National Standard (National Standardization Agency of

Indonesia 2001) on the procedures for designing ventilation and air conditioning systems (SNI 03-6572-2001) and the Minister of Health Regulation of the Republic of Indonesia Number 261/Menkes/SK/II/1998 on Environmental Health Requirements for Work, which recommend that the air movement should be from 0.15-0.25 m/s. This air movement is required to bring fresh air into the room and remove dirty air. This movement of air will affect the ventilation rate and the air change value in the room.

4.3 Ventilation Rate and Air Changes per Hour

Ventilation rate is influenced by the average air speed, strong wind direction, variation of speed and wind direction seasonally and daily, and local obstacles, such as adjacent buildings, hills, and trees (20). The ventilation rate is based on the number of air changes per hour if the number of users has yet to be discovered. This depends on the building type and function. Air changes per hour mean how much air in a room is replaced every hour. It is when fresh or clean air takes the place of dirty air. Air changes per hour significantly impact how temperature and air quality are controlled in the house.

The minimum exchange for work environments is 0.283 m^3/minute/person, according to the Minister of Health Regulation of the Republic of Indonesia Number 261/Menkes/SK/II/1998 on Environmental Health Requirements. The ANSI/ASHRAE Standard 62.1-2019 Ventilation for Acceptable Indoor Air Quality suggests an ventilation rate of 3.8 litres/second/person or 0.0038 m^3/second/person. This means that the Pudakpayung Health Center needs to increase the airflow rate in the room to meet the minimum standard, while the area outside or near the opening is already adequate. A high airflow rate in the room can help to reduce the humidity, harmful bacteria, viruses, and chemical compounds, as well as the amount of particulate matter (PM) in the air (21).

The ventilation depends on the natural air from outside, which causes the results to vary. The air change value increases when the wind brings fresh air into the room and down when there is no wind. The fan can assist in circulating the air in and out of the room, improving the comfort of the visitors.

According to ANSI/ASHRAE/ASHE Standart 170-2017 Ventilation of Healthcare Facilities and the 2019 Guidelines for Environmental Infection Control in HealthHealthcare Facilities by the U.S. Department Of Health And Human Services and Control, the air change per hour should be at least 12 times/per hour (22)(23).

The registration room of the Pudakpayung Health Center needs to meet this standard. The air change value depends on the airflow rate and the impact of the outside air. Without cross ventilation, there is not enough air exchange between the room and the outside, which leads to the build-up of polluted air from the outside environment in the room and affects the Indoor Air Quality.

5. Conclusions

This research showed that insufficient natural ventilation resulted in the room not meeting the standards related to indoor air quality. The ventilation conditions influence the conditions in the room. Ventilation design, including window type, position, and dimension, should be given more attention in buildings to enhance indoor air quality. Proper ventilation can reduce contaminants in the air. It also affects the ventilation and air change rates, which are essential for maintaining clean and healthy air quality. This research also demonstrated that ventilation strongly correlates with air change rate.

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