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Analysis of the Effect and Role of Indoor Environmental Quality in the COVID-19 Transmission

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Katharina Oginawati[1*], Rinaldy Jose Nathanael[1], Udjianna Sekteria Pasaribu[2], Utriweni Mukhaiyar[2], Afif Humam[2], Nisa Fadlilah Fathul Ilmi[2], Septian Hadi Susetyo[1*]

[1] Environmental Management Technology Research Division, Faculty of Civil and Environmental Engineering, Institut Teknologi Bandung, Indonesia
[2] Statistics Research Division, Faculty of Mathematics and Natural Sciences, Institut Teknologi Bandung, Indonesia

ABSTRACT

Infectious diseases such as COVID-19 have some risk factors. One of the most important factors is the environment. This research focused on risk factors concerning the house environment. This study aimed to evaluate the parameters of the 'healthy house' environment in controlling the spread of COVID-19. This study used environmental quality, namely ventilation, humidity, brightness, temperature, and personal space area as house environment parameters. The location of the study is Coblong District, Bandung City. The χ^2 test of independence was used to show the significance between environmental parameters required for the healthy house and disease transmission. The study found that one house environment parameter (ventilation) are significantly related to indoor transmission rate in recovered patients' houses ($p = 0.021$). Pearson correlation coefficient r was also investigated for each element of environment factor on the indoor transmission rate. Ventilation was found to be the most significant parameter correlated with indoor transmission ($r = –0.522$, $p = 0.002$). Personal Space Area also observed to have a significant correlation with indoor transmission rate ($r = 0.459$, $p = 0.008$). Humidity, brightness, and temperature were observed to have no significant correlation with indoor transmission rate ($p = 0.309$, 0.735, and 0.953, respectively. Linear regression is used to further investigate and predict the indoor transmission rate with significant environmental parameter as predictor. The linear regression model showed that 27.3% of indoor transmission rate variability are caused by its relationship with ventilation, the predictor used in the model.

Keywords: COVID-19, Environment, Risk factor, COVID-19 transmission, Ventilation

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*** Corresponding Authors:**
Katharina Oginawati
Katharina.oginawati@gmail.com
Septian Hadi Susetyo
aan.ppu@gmail.com

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1 INTRODUCTION

A variant of coronavirus was found in Wuhan, China, in December 2019, which caused an outbreak. The virus was named Severe Acute Respiratory Syndrome Coronavirus-2 (SARS-CoV-2), and the disease it causes later called Coronavirus-Disease-19 (COVID-19). Indonesia confirmed its first case on March 2, 2020. This disease spreads rapidly with a basic reproductive number R0 of 1.4–2.5. Infectious diseases have risk factors, any factor affecting the risk of infection of a disease (Offord and Kraemer, 2000). In the COVID-19 pandemic situation, World Health Organization (WHO) released guidelines articles for the public, considering the outbreak. In early 2020, WHO released some preventive measurements for the public, such as keeping distance, wearing masks in public places, practicing personal hygiene, and keeping the environment healthy, such as disinfecting surfaces and rooms. Those preventive measures were advised considering the transmission routes of COVID-19 (WHO, 2020a).

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Furthermore, WHO (2020b) released articles concerning the environment, such as ventilation in public spaces and buildings. Other studies pointed out that environmental factors, such as temperature, humidity, and sunlight exposure, impacts SARS-CoV-2 stability and half-time in ambient air. Several studies agree that higher temperature & humidity and more sunlight exposure is favorable condition for virus inactivation (Delikhoon *et al.*, 2021; Biryukov *et al.*, 2020; Schuit *et al.*, 2020). Environment parameters are an essential factor that can be regarded as COVID-19 risk factors when environmental parameters where people lives are in poor condition, supporting the transmission of COVID-19.

The indoor environmental condition of houses in the same area varies significantly with the ventilation system of the building. Temperature is one of the parameters controlled by a ventilation system engineered by humans (Janssen, 1999). Indoor relative humidity, dependent on ambient temperature, is also impacted by ventilation. Natural ventilation is also related to fresh air and sunlight penetration to control pathogens' airborne transmission (Hobday and Dancer, 2013).

While in the laboratory setting, the relationship between environmental factors and SARS-CoV-2 can be determined, environmental effects may become harder to trace in epidemiological spatial data and number of case monitoring. In other words, environmental factors that significantly affect virus stability do not necessarily show a significant effect on disease transmission. For example, it is confirmed that increasing temperature and humidity accelerate the inactivation of SARS-CoV-2 on surfaces (Biryukov *et al.*, 2020). Still, a study involving epidemiological data in China found that variation of environmental factors in question (ambient temperature and absolute humidity) did not limit the survival and transmission of the new virus (Poirier *et al.*, 2020). Thus, this study used a more localized measure, namely, residential transmission, as a dependent variable.

Five parameters were investigated in this study: temperature, humidity, brightness, ventilation size, and personal space area. These five parameters vary in each of the survivors' houses. Data analysis was performed to demonstrate whether or not the parameters that significantly affect SARS-CoV-2 stability (mainly temperature, humidity, and sunlight exposure) also play an essential role in residential setting disease transmission. Indoor sunlight exposure is measured as natural brightness (in lux, without indoor lighting) that correlates with indoor solar radiation (Imam *et al.*, 2018). Additionally, ventilation size and personal space area were also measured and analyzed. The two additional parameters are mainly associated with the design and size of a house. Therefore, analysis on these two parameters may provide additional information of a good environmental setting of a house in the COVID-19 pandemic situation.

As the capital city of West Java Province, Bandung is often included in the top 5 cities with the most active cases in West Java. Coblong District is often included in the top 5 districts in Bandung City with the most active cases. Coblong is also a district with high recreational and educational activities, with more than 50 schools and 20 universities in the area. Coblong District is chosen for this study. The study aims to assess the effect and Role of Indoor Environmental Quality in the COVID-19 transmission.

2 METHODS

2.1 Research Location

The field study regarding the relation of residential environmental factors against COVID-19 was carried out from March to April 2021 in Coblong District. Coblong District was chosen as the research location based on data obtained from the Bandung City COVID-19 Information Center in March 2021. Coblong District had the second-highest total positive cases in Bandung City and the district with the highest total recovered patients in Bandung. In addition, Coblong District is also one of the districts in Bandung with a reasonably high population density with a density of 15617.37 people km^{-2} (Badan Pusat Statistik Kota Bandung, 2020). Then, from the six sub-districts in Coblong District, Dago Subdistrict and Sekeloa Subdistrict were chosen as representatives because the two are the subdistricts with the largest area and the largest population in Coblong District. The total area of the two subdistricts exceeded 50% of the total area of Coblong District. The population of the two subdistricts has exceeded 50% of the total population of Coblong District. The location study is shown in Fig. 1. In addition, the dots pinpoint the exact locations of survivors' houses that were visited.

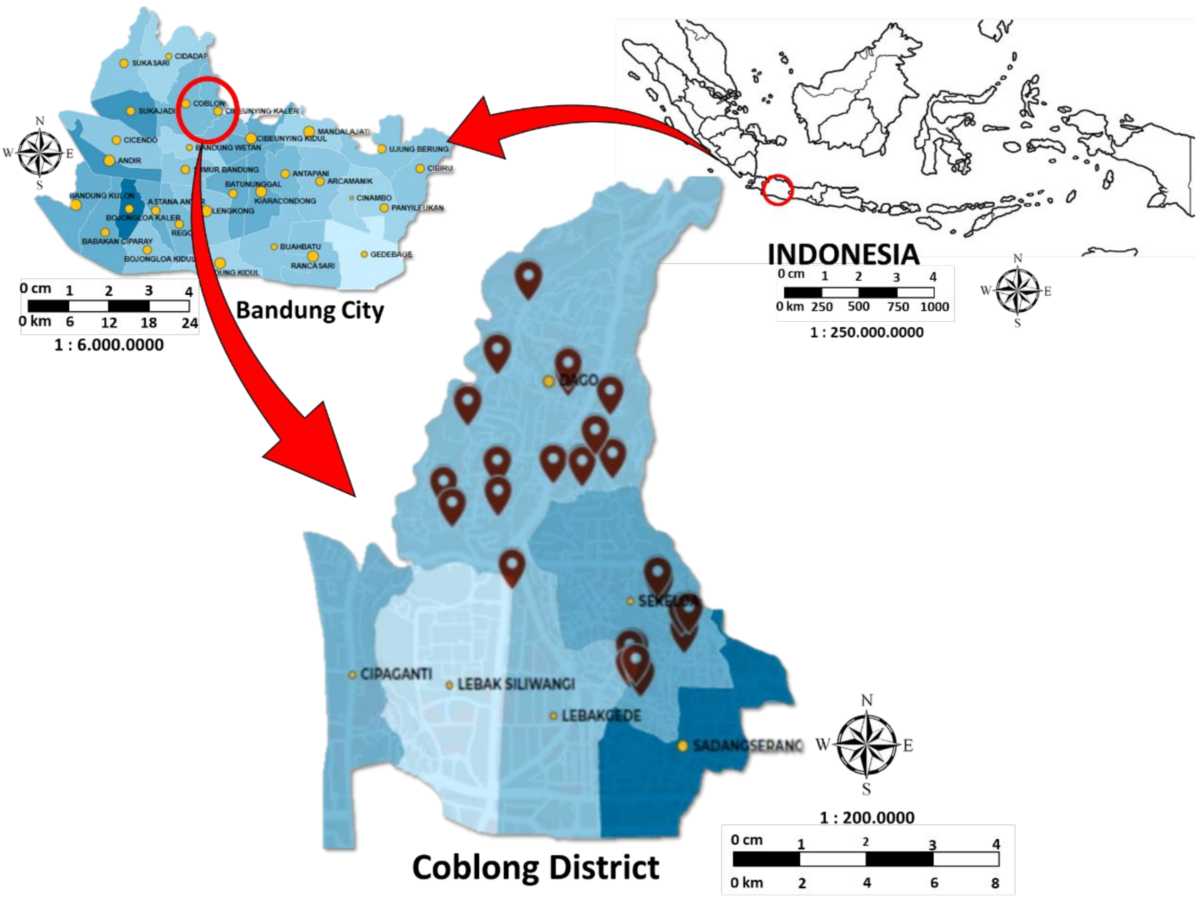

Fig. 1. Location study of samples.

2.2 Secondary Data Collection

As of April 2021, the number of positive cases in Coblong District alone has reached more than 800. This study collected COVID-19 recovered patients' addresses in Coblong District, Bandung City, from the local subdistrict offices and the neighborhood chief. Therefore, the sampling method used is convenient sampling. The local authorities first contacted COVID-19 survivors in the area and asked for their willingness to be visited in their house to support the study. Those willing to cooperate are then asked for their address and their free schedule. The addresses and visit schedule were then given to the team of authors and a surveyor. A total of 38 house addresses were given. 24 houses located in Dago Subdistrict and 14 houses located in Sekeloa subdistrict.

2.3 Primary Data Collection

The interview was conducted with COVID-19 recovered patients in Coblong District following the address collection. Their resident's environmental parameters were measured using guided questionnaires, interviews, and physical observations of the residential environment. The measurement of residential environmental parameters was carried out with a multifunctional environmental 4-in-1 measurement tool CEM DT-8820 to measure temperature, humidity, and brightness. A measuring tape is used to measure the ventilation size of residents visited. To reduce weather disturbance, measurements were taken in the living room of the recovered patients' house in sunny weather conditions only from 10 AM to 3 PM. In addition to continuous data on environmental parameters, data on transmission (total infected family member, total family member) were also obtained by direct interviews with recovered patients. The concept data collection is displayed in Fig. 2. The parameters are chosen considering their possible impact on the virus' fate in differing environmental conditions (humidity, brightness, temperature) and virus' transmissibility (ventilation and personal space area).

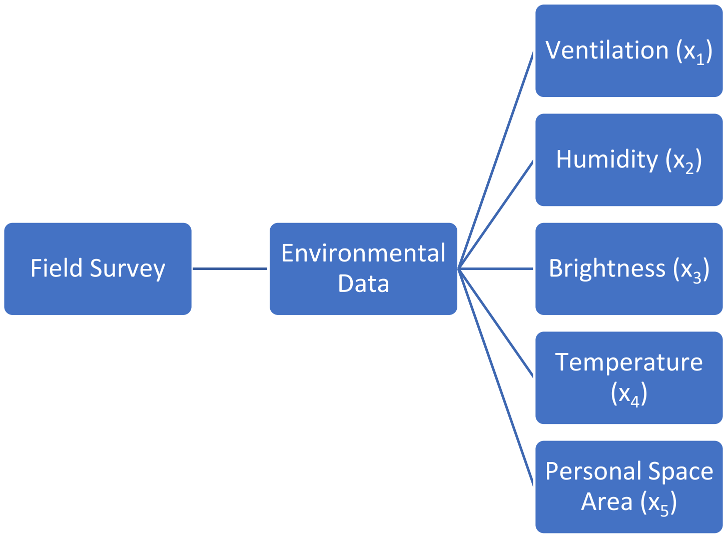

Fig. 2. Data collection diagram and key parameters.

2.4 Statistical Analysis

A Chi-square test of independence was performed to examine the relationship between two categorical/nominal variables. The main focus of this test is to investigate how significant COVID-19 transmission level in a resident is related to whether or not a house's environmental conditions meet the 'healthy house' standard set in regulations. The Correlation test was carried out for each environmental factor. The Pearson correlation analysis can determine the correlation coefficient and sample determination coefficient, also known as the coefficient of determination. The correlation coefficient shows the linear relationship between two variables as estimated by the sample correlation coefficient r. The sample determination coefficient R^2 states the proportion of the overall variation in the dependent variable, which can be explained by a linear relationship with the value of the independent variable. Multiple regression analysis was carried out to show the relationship between the dependent and independent variables. In this study, the independent variable is each determinant of environmental factors. Indoor transmission in recovered patients' houses is the dependent variable.

3 RESULTS AND DISCUSSION

3.1 Chi-Square Test Result

In the on-field survey, 38 houses of survivor/recovered patients were visited. Before the interview, house environmental parameters were measured. The data used for statistical analysis is the measurement results for house environmental parameters. Thus, 38 data were obtained for each environmental parameter studied and 38 data on the percentage of COVID-19 transmission in the recovered patients' houses. The transmission rate are divided into three levels: low (0%–50%), intermediate (50–99%) and high (100%). The transmission percentage is obtained from the number of family members who had COVID-19 compared to the total number of family members in the house. House environment data that was processed in the χ^2 test is categorical data (meet/does not meet the requirements) based on the requirements of a healthy house in Keputusan Menteri Kesehatan Republik Indonesia No. 829 tahun 1991 and Keputusan Menteri Permukiman & Prasarana Wilayah No. 403 tahun 2002, while the environmental data processed in Pearson correlation and multiple linear regression is in the form of continuous data.

Keputusan Menteri Kesehatan Republik Indonesia No. 829 tahun 1991 is a regulation made by the Indonesian Ministry of Health in 1991. It suggests the recommended value of several environmental parameters in a house to be maintained to promote health and well-being. Ventilation size, humidity, brightness, and temperature are included in this regulation. Keputusan Menteri Permukiman & Prasarana Wilayah No. 403 tahun 2002 is a regulation made by the

Table 1. Number of survivor's house that met the healthy standard.

Environmental Parameter	Healthy standard[1, 2]	'Healthy house' standard Met/Total
Ventilation (%room area)	≥ 10	31/38
Humidity (%)	40–70	25/38
Brightness (Lux)	≥ 60	6/38
Temperature (°C)	18–30	37/38
Personal Space Area (m^2 $person^{-1}$)	≥ 9	34/38

Table 2. Chi-square test result.

Parameters	P-value
Ventilation	**0.021***
Humidity	**0.096***
Brightness	0.163
Temperature	0.284
Personal Space Area	0.387

Indonesian Ministry of Residential and Infrastructure in 2002 as a technical guide to the construction of simple and 'healthy' buildings. Also included in this regulation is an idea of considering a healthy, minimum, comfy size of the house being built by taking into account how many people would live in a house being built, ending up in a parameter known as Personal Space Area.

The Table 1 shown summarizes how many houses out of 38 survivors' houses visited which environmental condition met the requirements of a healthy house in Keputusan Menteri Kesehatan Republik Indonesia No. 829 tahun 1999 and Keputusan Menteri Permukiman & Prasarana Wilayah No. 403 tahun 2002. Each of the parameters investigated and the results are shown in Table 2.

From the χ^2 independence test (H_0: two variables tested are independent/not related) of environment parameter factors and indoor transmission rate in Coblong District in Table 2, it is found that the requirements for the ventilation and humidity parameters for a healthy house set in the reference have a significant relationship to the transmission of COVID-19 in recovered patients' house in Coblong District at significance level > 0.021 and > 0.096, respectively. Meanwhile, the requirements for other environmental parameters do not significantly relate to the transmission of COVID-19 in recovered patients' houses in Coblong District. This result supports guidelines released by WHO and many other organizations emphasizing the importance of ventilation or air change in public areas and house environments (WHO, 2020b; CDC, 2021; U.S. EPA, 2021). Each of the environmental factors was then further analyzed in the next subchapters.

3.2 Data Enhancement and Correlation Result

The environmental parameters data are then further investigated. Table 3 summarizes the continuous environment parameter data obtained from the field survey. The minimum, mean, maximum, and three quartiles values of each parameter can be seen in the table. Standard deviation (SD), skewness as data symmetry measurement, and kurtosis as the degree of peakedness of each

Table 3. House environment parameter data.

(Response variable)	Min	Mean	Max.	SD	1st Quartile	2nd Quartile	3rd Quartile	Skewness	Kurtosis
Transmission (%)	10.00	57.97	100.00	32.78	25.89	50.00	100.00	0.20	–1.51
Env. Parameter	N = 38								
Ventilation (%room area)	0.44	14.53	30.80	6.38	10.68	13.33	17.46	0.66	0.90
Humidity (%)	50.10	66.44	78.60	6.70	63.53	67.00	71.40	–0.50	–0.12
Brightness (Lux)	0.00	35.97	196.00	33.86	16.92	26.92	41.29	3.12	13.07
Temperature (°C)	25.90	28.17	30.20	1.14	27.20	28.30	29.18	–0.18	–1.06
Personal Space Area (m^2 $person^{-1}$)	5.71	23.23	75.00	17.67	10.07	16.00	30.00	1.62	2.06

parameter's distribution are also included in the table. Box and whisker plots for each parameter are generated and shown in Fig. 3.

It can be seen that outliers were presented in each parameters' data, except for temperature. Outliers in humidity and brightness data may be due to inevitable daily weather variations and clouds. Measurement error might also happen to measure these variables involving using an automatic digital instrument with its level of measurement accuracy. Unlike the outliers of humidity and brightness data, the outliers in ventilation and personal space area data are more likely due to variation of house design and variation within sample, and not due to measurement error for only measuring tape was used to measure these two variables. In conclusion, outliers in humidity and brightness variables are excluded for better results.

Then, to further reduce disturbance of other factors, %Transmission as the dependent variable is investigated. Fig. 4 above shows that the transmission rate tends to decrease when family members in a house increase. Upon interview, it can be understood that when the first family member was detected to be infected by COVID-19, control measures were immediately done,

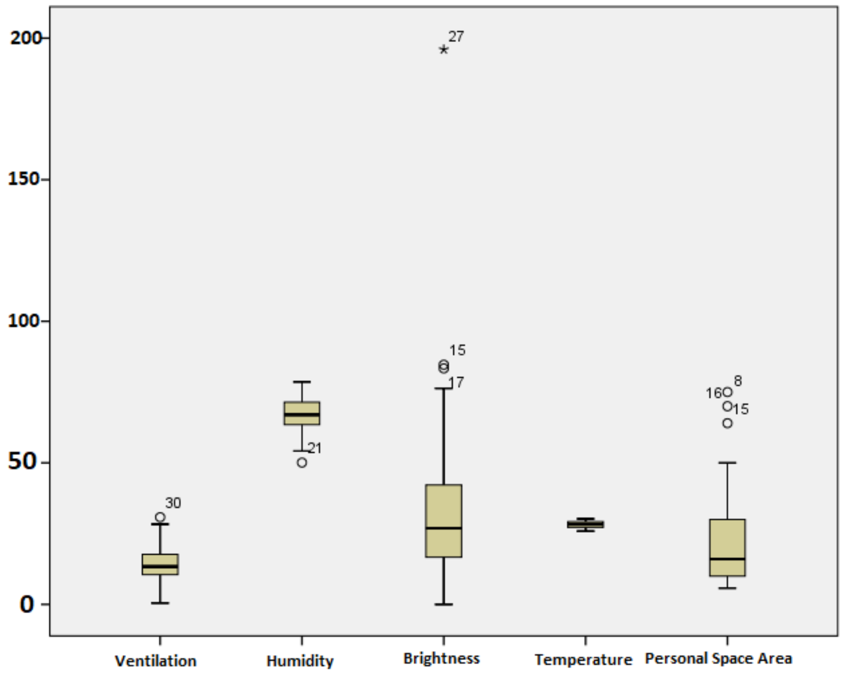

Fig. 3. Box and whisker plot of environmental parameters data.

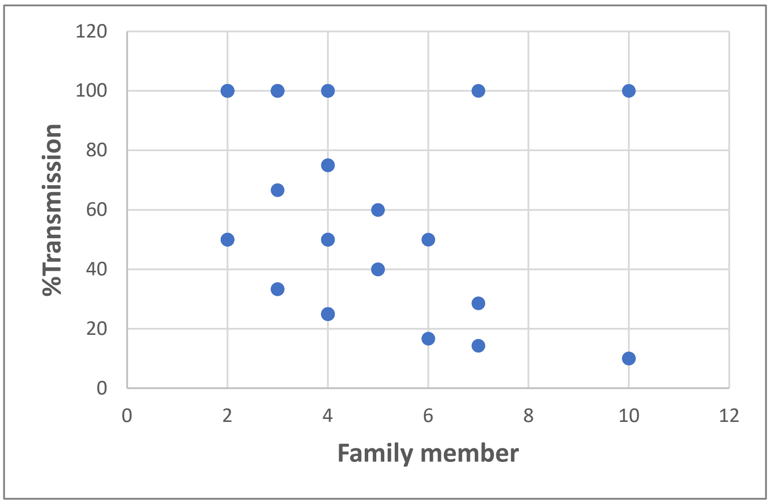

Fig. 4. Plot of %transmission and family member in each house.

Table 4. House environment parameter data, outliers excluded.

(Response variable)	Min	Mean	Max.	SD	1st Quartile	2nd Quartile	3rd Quartile	Skewness	Kurtosis
Transmission (%)	10.00	58.42	100.00	32.59	25.00	50.00	100.00	0.18	–1.54
Env. Parameter	N = 32								
Ventilation (%room area)	0.44	14.44	30.80	6.80	10.51	13.00	17.06	0.68	0.65
Humidity (%)	54.20	67.46	78.60	6.29	64.18	68.40	71.73	–0.49	–0.27
Brightness (Lux)	6.50	29.04	76.30	16.82	16.42	25.34	36.02	1.15	0.98
Temperature (°C)	25.90	28.03	30.20	1.17	27.05	28.15	29.13	0.08	–1.11
Personal Space Area (m^2 $person^{-1}$)	6.67	22.36	75.00	17.00	10.22	16.00	25.88	1.90	3.37

Correlations

		Ventilation	Humidity	Brightness	Temperature	PersonalSpaceArea	Transmission
Ventilation	Pearson Correlation	1	-.273	-.145	.179	-.182	-.522**
	Sig. (2-tailed)		.131	.428	.326	.319	.002
	N	32	32	32	32	32	32
Humidity	Pearson Correlation	-.273	1	-.415*	-.559**	-.090	.186
	Sig. (2-tailed)	.131		.018	.001	.625	.309
	N	32	32	32	32	32	32
Brightness	Pearson Correlation	-.145	-.415*	1	.186	.217	.062
	Sig. (2-tailed)	.428	.018		.307	.233	.735
	N	32	32	32	32	32	32
Temperature	Pearson Correlation	.179	-.559**	.186	1	.158	-.011
	Sig. (2-tailed)	.326	.001	.307		.388	.953
	N	32	32	32	32	32	32
PersonalSpaceArea	Pearson Correlation	-.182	-.090	.217	.158	1	.459**
	Sig. (2-tailed)	.319	.625	.233	.388		.008
	N	32	32	32	32	32	32
Transmission	Pearson Correlation	-.522**	.186	.062	-.011	.459**	1
	Sig. (2-tailed)	.002	.309	.735	.953	.008	
	N	32	32	32	32	32	32

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

Fig. 5. Environmental parameter – transmission correlation matrix.

such as isolating the patient in a room or separating healthy family members from infected ones hence the decrease in transmission rate. However, two family cases in (7, 100) and (10, 100) raise attention to probable negligence to immediate control measures. It was decided then those two data are also excluded for the high transmission rate are likely due to failure in mitigation effort of disease prevention within the family, and not due to environmental factors (Table 4).

The correlation matrix for each pair of the relation of predictors and response variable in question is displayed in Fig. 5. While summarizes the correlation r, determination coefficient R^2, and significance value of each environmental parameter to indoor transmission rate shown in Table 5.

3.3 Ventilation

Based on Table 5, different correlation values are obtained for each house environment parameter. The ventilation parameter has a significant negative correlation value. This means that the size of ventilation in the house is, inversely, significantly related to the transmission of COVID-19 in the house. Calculation of the correlation value for this ventilation parameter supports

Table 5. Pearson correlation result.

Parameter	Correlation coef. (r)	Determination coef. (R^2)	Sig.
Ventilation	–0.522	0.272	0.002
Humidity	0.186	0.034	0.309
Brightness	0.062	0.003	0.735
Temperature	–0.011	< 0.001	0.953
Personal Space Area	0.459	0.21	0.008

the statement and recommendation from WHO that poorly ventilated buildings pose a high risk to the community during the COVID-19 pandemic and suggests a good ventilation system in buildings (WHO, 2020b). The ventilation parameter is calculated by comparing the size of the permanent, available vent hole in a house and the home's total area. A bigger vent hole size will provide a better air change rate per hour (ACH) in the house. Increasing ventilation can also reduce risks from particles resuspended during cleaning, including those potentially carrying SARS-CoV-2 or other contaminants (U.S. EPA, 2021). Ventilation size, affecting ACH, is also a critical house environment aspect to control microbiological infectious agents. A previous study showed the correlation of ventilation with other respiratory disease agents (Ningsih and Oginawati, 2020).

3.4 Humidity

The humidity parameter has a positive correlation value with the transmission. This means that if the humidity level is higher and personal space is larger, the higher the percentage of transmission in the house. This humidity-COVID-19 correlation result disagrees with previous studies that stated the correlation is negative (Wang *et al.*, 2021; Ward *et al.*, 2020). When aerosol containing the virus is formed in humid air conditions, the particles tend to fall faster than particles in dry air conditions (Ward *et al.*, 2020). Previous research explains the reduced risk of COVID-19 infection in humid air conditions. However, humidity as one of the environment parameters, especially with high value, is also a potential agent to other health conditions, such as the feeling of low energy or lethargy due to increased heat index (Sarmiento, 2016). In environmental epidemiology, this condition (i.e., environmental changes cause the host to be more vulnerable) is one of the four ways an epidemic can occur (Soemirat, 2005). The theory may explain the positive correlation, although the differing result is more likely due to disturbance of other factors such as weather or measurement error, not to mention the significance value indicating that humidity-transmission correlation is insignificant here.

3.5 Brightness

For the brightness parameter, the correlation value is positive but close to zero and sig. Value is high, indicating the brightness-transmission correlation is insignificant. Previous research states that simulated sunlight rapidly inactivates SARS-CoV-2 (Schuit *et al.*, 2020), for the ultraviolet light from the sun has disinfectant properties and can help kill bacteria and viruses. However, it can be concluded that the result disagrees, for no significant negative correlation was observed. While the indoor brightness parameter might represent sunlight penetrated in the house (all other artificial lights are turned off before measurement), it might not represent ultraviolet light. Glass window greatly blocks UV-B radiation. Some kind of glass used in house windows also blocks UV-A to some degree (Duarte *et al.*, 2009). Virus inactivation by ultraviolet sunlight might be significantly reduced indoors. It is safe to say that minimum 'brightness' set in reference as a parameter for 'healthy house' does not mean to represent sunlight penetrating a house to protect its inhabitant from the infectious microbiological agent, but for the importance of eyesight health.

3.6 Temperature

For the temperature parameter, the correlation value is negative but close to zero and sig. Value is high. This means that temperature has an inverse relationship with the transmission of COVID-19 in recovered patients' houses. The temperature parameter results agree with previous studies stating that high temperature reduced the prevalence of COVID-19 in some areas (Bhattacharjee, 2020) even though the relationship is weak. The insignificant, low correlation value may also be due to lack of variability, considering the measurement of environmental parameters, including temperature, are done in homogenous weather conditions and in the same range of time daily. A real-life residential setting of disease transmission may not provide adequate information on how temperature impacts the virus as in a laboratory setting. It is important to remember that although exposure to high temperatures may kill some infectious microbiological agents, a higher temperature is not preferable in areas with a tropical climate, like Indonesia. The temperature within the house is also significantly related to humidity (Fig. 5) and impacts occupant comfort. So, further research-based, area-specific discussions about the best house temperature setting during a pandemic are needed.

3.7 Personal Space Area

As for personal space area (PSA), a significant, positive correlation value result was found. With the 'm^2 $person^{-1}$' unit set in reference, the personal space area expresses the reciprocal house population density (person m^{-2}). A previous study found that urban density has affected the timing of the outbreak in several locations, with denser locations more likely to have an early outbreak (Carozzi, 2020). However, there was no evidence that population density is linked with COVID-19 cases. SARS-CoV-2 was transmitted through human-to-human contact (Chan *et al.*, 2013), so the general perception is that COVID-19 spreads more rapidly in high-density areas.

Nevertheless, several mediating factors might explain why the direction of this relationship is somewhat ambiguous. For example, variation in urban density might affect the behavioral responses to the pandemic, which can then affect the transmission of the disease. Additionally, each house's space area value is calculated by dividing the total area of a house by total occupants/family members. In contrast, the transmission rate as a dependent variable is calculated by dividing the number of people infected by total occupants/family members. Therefore, comparing these variables only gives information on how the total area of a house would affect the total person infected by the disease in a house. To conclude what has been stated so far, the significant, positive correlation can be interpreted that a bigger house in the research area tends to be owned by large families or inhabited by more than one family, meaning that more people in the house are susceptible to be infected, hence the positive correlation. Other dependent variables are needed to investigate further the importance of PSA as a 'healthy house' parameter in pandemic situations.

3.8 Linear Regression

Based on the results of the χ^2 test of independence and correlation analysis, it can be seen that the primary, most critical environmental parameter set in Indonesian reference for a 'healthy house' in the pandemic situation is ventilation. Although PSA also has a significant correlation, its value compliance to the reference was not significant, and further investigation of its relationship is still needed. Then, linear regression models are formed to predict indoor transmission with the ventilation-to-floor-area ratio as the predictor. The equation is as follows.

$$\hat{Y} = \beta_1 + \beta_1 X_1 + \varepsilon \quad (1)$$

$$\hat{Y}\ (\%\text{transmission}) = 94.562 - 2.503\ (\%\text{ventilation})$$

The sig. value of the model is found to be 0.002, indicating the model is significant. It was found that the determination coefficient for the model is 0.273. It can be interpreted that 27.3% of the total variation (overall) in the transmission rate of COVID-19 in recovered patients' houses in Coblong District can be explained by a linear relationship with the house ventilation. The plot of predicted transmission and observed transmission rate is shown in Fig. 6 below. The residual for this model is tested to be normally distributed (sig. = 0.2). The residual plot is shown in Fig. 7.

3.9 Limitations

There are some critical limitations of this study, the first being the rapidly mutating SARS-CoV-2, the agent of COVID-19. It is known that mutation of the virus also changes the transmissibility and severity of the disease and may also alter its fate in the environment or how it is affected by environmental conditions. The data taken and analyzed in this study were taken between March–April 2021 in Bandung, Indonesia, when Delta (B.1.617.2) variant and Omicron (B.1.1.529) variant

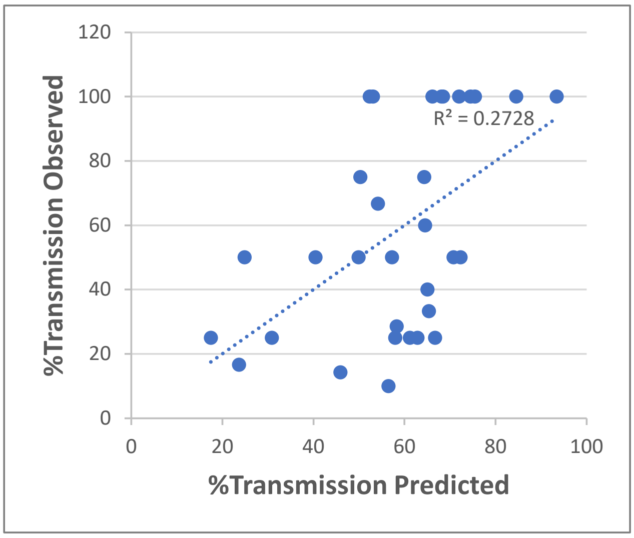

Fig. 6. The plot of %Transmission observed and predicted.

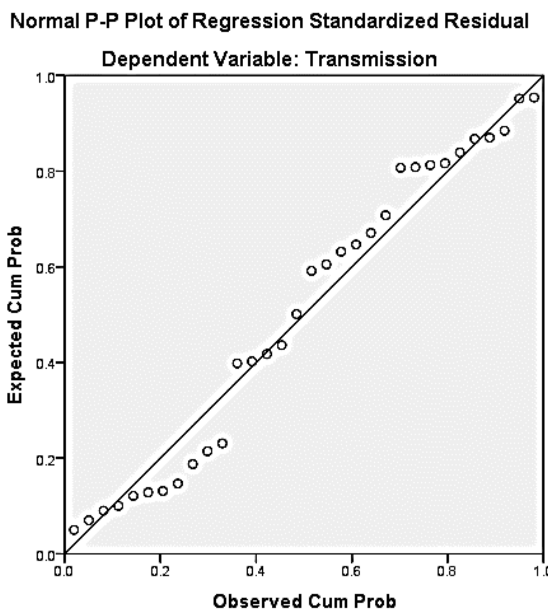

Fig. 7. Normal P-P plot of regression standardized residual.

were not even found yet. Thus, the result of this study may not explain the change in transmissibility of variants found in infected people after the period of study data collection.

Secondly, other factors play a role in residential transmissions, such as the behavior of the infected, behavior of other family members, quarantine methods and period, disease severity of the first infected person in a house, and other unavoidable intricate things that were not taken into consideration. Therefore, there may be essential explanations other than environmental factors to the difference between the transmission of the disease in different houses.

4 CONCLUSIONS

The environmental parameter that has a significant relationship with indoor transmission was only ventilation. Correlation analysis also found that only ventilation has a significant, inverse relationship with the transmission. It was also found that several environmental factors set in the reference (humidity, brightness, and temperature) as 'healthy house' parameters are not critical in the pandemic situation as they might mean other meaning of 'healthy' or insignificant in the actual residential setting of disease transmission. PSA parameter correlation and its significance value provide no further information on the risk of infection of a denser population. It only gave information that physical distancing in self-isolation scenario does not significantly prevent transmission to uninfected family members. It is advised to avoid quarantine of infected individuals in a same house together with anyone healthy (self-isolation) without any strict contact restriction for residential transmission is likely to occur. In case of no other option available, ventilation and air change are critical aspects to consider to avoid transmission to uninfected family members/ housemates.

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