The Effect of Ventilation and Cooking Activities during Peak Hours towards Indoor CO and NO_2 in Apartments: A Multilevel Approach

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ABSTRACT

Indoor CO and NO_2 pollutants resulting from cooking activities are the cause of sick building syndrome. Several studies had shown that window openings for ventilation can lead indoor air conditions worse due to infiltration. There have not been many studies on this possible condition. Therefore, this study was conducted to determine the effect of ventilation and cooking activities on indoor CO and NO_2 concentrations. The measured data were analyzed through a multilevel modelling operation using three models that allowed the coefficients to vary for each group. The model explored the effect of peak sessions, window opening size and cooking activities. The results of this study showed that the average CO and NO_2 concentrations in three apartment units meet the levels required by PERMENKES No. 1077 of 2011 in the amount of 9.00 ppm CO and 0.04 ppm NO_2. The average concentrations of CO and NO_2 measured on the day under study tended to increase when occupants were actively cooking indoors, especially with a Liquefied Petroleum Gas stove. The CO concentration increased by 0.35 ppm and 0.63 ppm when the window was opened by 25% and 50% when cooking, but decreased by 0.5 ppm for 100% openings. Otherwise, the concentration of NO_2 decreases by 0.001 ppm for 25% openings, 0.0004 ppm for 50% openings and 0.002 ppm for 100% openings. The CO and NO_2 concentrations in unit 3 on the high floor units decreased during activities while at the same time while windows were opened. The combination of indoor pollution sources and poor outdoor concentrations has an extremely health impact on the residents. The result of the study shows the importance of adjusting the time to close the window and the time to cook, so that the accumulation of CO and NO_2 concentration in the room can be avoided. Recommendations are given to apartment developers to provide exhaust cooker hood in each unit as an indoor air control strategy. Residents are suggested to cook during non-peak hours with opened windows and always turn on the cooker hood when cooking. Further observation is required to investigate the concentration of outdoor space near apartments continuously to confirm this result.

Keywords: *Ambient, Cooking, Air Pollution.*

1. INTRODUCTION

The issue of indoor air quality has become a concern in recent years because it is known that many people spend 80 – 90% of their time indoors [1]. Long human exposure time in narrow residential and apartment areas, frequent lack of adequate air exchange and damage to the ventilation system, the activities of residents and the lifestyle of each individual related to daily activities in the apartment, have a significant effect on the quality of the indoor environment [2,3]. WHO, (2010) stated thatthe increase in indoor pollutants can have a direct impact on health, such as Sick Building Syndrome (SBS) to cause 1.6 million deaths due to pneumonia, chronic respiratory disease, and lung cancer. The disease can be made worse by other activities such as cooking using biomass and there is no escape for smoke [4].

Indoor pollutants generated from burning biomass as cooking fuel are the most common and most significant causes of disease in the world [5]. Carbon monoxide (CO) and NO_2 pollutants are associated with combustion activities, heating and cooking with fossil fuels (gas, oil and coal) and smoking in closed rooms. NO_2 is a pollutant that is commonly found indoors and its exposure can cause respiratory disease [6]. The air in the

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room becomes more unsanitary due to the lack of ventilation in the building. Therefore, most residents of apartment units open their windows for more than half a day to regulate temperature and humidity conditions [7]. However, outdoor concentration also has an influence on indoor air conditions due to the area of window openings, the number and location of window openings, wind speed, differences in indoor or outdoor temperature and pressure levels. Several case studies state that ventilation [8], causes indoor pollution to be worse due toinfiltration, but these findings are rarely conducted.

Currently, research on indoor air quality related to housing and health problems in the general population is still rare, especially in Indonesia. The study is needed to determine the relationship between indoor conditions and activities as well as the effect of outdoor air conditions on the concentration of carbon monoxide (CO) and nitrogen dioxide (NO2) in the apartment room.

Living room with adjusted configuration's location so that it would remain safe and not interrupt the occupant's activities. The devices were warmed up 3-5 minutes to allow them to adjust to the indoor conditions for each measurement. The devices were placed at a height of ±1.5 meters from the floor to represent human inhalation of pollutants. Devices were set up for 24 hours to collect data at 10 minutes' intervals.

On average, residents of those apartment units have lived in their apartments for 2 years. Based on the results of interviews and questionnaires, it is known that the average apartment unit is occupied by one person who is a student. The residents of all three apartments are between 20-25 years old. The residents of unit 1 and 2 apartments are women and the residents of unit 3 are men who does not smoke. They cook in the apartment space using an electric and LPG stove.

Several variables were examined during one-on-one interviews to capture how these variables affect the pollutant's concentrations. The variables consisted of indoor conditions and inhabitants' activities, as explained in the Table 1, the characteristics of each apartment unit are described in Table 2.

2. MATERIAL AND METHODS

2.1. Data Collection

The data were collected via measurements and the interviews. The measurements consisted of the concentrations of CO and NO_2. The concentrations of pollutants were collected every 10 minutes by a factory-calibrated Aerocet S500. Since we did not calibrate with reference-method device such as High-Volume Sampler, in this paper we only focus on concentration pattern and statistical point of view. Measurements were conducted in 3 apartment units in Surabaya between October to November 2020. The devices were put inside each main

Table 1. Variables in the Model Input

Variables	Explanation
Humidity (%)	Humidity affects pollutants' reactions indoors, and activities also affect humidity. We wished to capture the relationship between humidity and pollutant's concentrations.
Temperature (°C)	Indoor temperature may affect pollutants' behavior. These data were collected from the device.
Air Conditioner (AC) time on (1=when AC on; 0= when AC off)	Air conditioning lets clean air flow inside and allowing further dilution of pollutants.
Window opening (1=when window opens; 0=window closes)	It is expected that when the window is open, it will allow the transfer of pollutants to the outside environment. Respondent states in the questionnaire the time in which he/she opens window(s) every day. We did not measure number of windows and which windows opened.
Cook time (1=cooking; 0=not cooking)	Cooking can increase the concentration of CO and NO_2 in the room. Respondent states in the questionnaire the time in which he/she cooks every day. All cooking activities were assumed to be done in kitchen and the distance from the device was made almost equal.
Cooking fuel (1=LPG; 0=electric)	Cooking with LPG fuel is estimated to increase the concentration of pollutants in the room than cooking using an electric stove.
Cooker hood (1=on; 0=off)	The using of cooker hood are expected to reduce the concentration of CO and NO_2 during cooking activities.
The width of the window opening (100=100%; 50=50%; 25=25%)	The width of the window opening is thought to have an influence on the level of indoor pollutant concentration.
Day (1=weekday; 2=weekend)	Differences in occupant activity on weekdays and weekends allow different patterns of pollutant concentrations
Frying technique	Cooking by frying can produce higher pollutants

Variables	Explanation
Boiling technique	Boiling allows for a reduction in pollutants resulting from cooking activities

Table 2. The Characteristic of Apartment Unit.

	Unit 1	Unit 2	Unit 3
Type	2 BR	studio	2 BR
Floor plan	2 bedrooms, 1 living room	a bedroom with living room	2 bedrooms, 1 living room
Spacious room	58.9 m^2	21 m^2	36 m^2
Floor height	± 30 m	± 35 m	± 70 m
The distance from the building to the street	± 200 m	± 200 m	± 200 m
Sunlight	Afternoon	-	Morning
Construction material	light brick walls; aluminum door and window frames	light brick walls; aluminum door and window frames	light brick walls; aluminum door and window frames
Living room ventilation type	the door overlooking the balcony	the door overlooking the balcony	double casement windows
The area of the ventilation opening	25% of the size of the vent	50% of the size of the vent	100% of the size of the vent
Cooking fuel	LPG	Electric stove	LPG
Cooker hood	yes	no	yes

2.2. Multilevel Model

The data analysis was performed by operating a multilevel model (multilevel model) with R Studio software. Indoor CO and NO_2 gas concentrations in this context not only differ between time sessions but also vary in the ventilation conditions (percentage of window opening width) and the cooking activity used by the occupants. Variable analysis was carried out based on three specified peak times, namely morning (06.00 am - 10.00 am), peak time in the afternoon (16.00 - 19.00 pm) and non-peak times (other than morning and evening peak times).

Multilevel models can process data that has a hierarchical structure, meaning that data is classified into groups. The model also allows the coefficients to be varied for each group. Three models were operated to explore the effect of peak sessions, the size of window openings that represented ventilation and cooking activities to determine their effects on indoor CO and NO_2 concentrations.

Model 1	:	Model using all variables with varying intercept coefficients.
Model 2	:	A model using a variable that allows the coefficient of cooking activity to vary with the width of the window opening.
Model 3	:	Models using variables in the condition onlywhen the window is open are used as data.

This model allows for varying intercept coefficients for different peak sessions (morning peak, evening peak and non-peak).

The equation used is equation 1 which explains the estimated CO and NO_2 concentrations with various interceptions (Model 1). Equation 2 depicts a model where the intercept and slope vary by group (cooking activity and window opening width) as illustrated by Models 2 and 3.

$$y_i = \alpha_{j[i]} + \beta x_i + \epsilon_i \qquad (1)$$

$$\alpha_j = \alpha + bu_j + \eta_j$$

$$y_j = \alpha_{j[i]} + \beta_{j[i]} x_i + \epsilon_i \qquad (2)$$

$$\alpha_j = \alpha_0 + b_0 u_j + \eta_{j1}$$

$$\beta_j = \alpha_1 + b_1 u_j + \eta_{j2}$$

y_i	=	Gas (indoor CO and NO_2 concentrations in mg / m3 from measurement variable i).
$\alpha_{j[i]}, \beta, \beta_{j[i]} x_i$	=	Unknown parameters.
x_i	=	Explanatory variables listed in Table 1.
i	=	Data observation of concentration.

$j[i]$ = for Eq. 1 it refers to allowing intercept to varyby peak sessions (morning, evening, and non- peak session), whereas for Eq. 2 it reflects allowing intercepts and slopes of cookingactivities vary by the width of the window opening. The random components be normally distributed and variances in the random components, which are assumed to be uncorrelated.

2.3. Statistical Analysis

The multilevel model is used in statistical analysis by creating scripts that will be rolled out with the R software. R is a free software for data and graphics analysis based on the S programming language developed by Rick Becker, John Chambers, and Allan Wilks from AT&T Bell Laboratories (1976). R language is a high-level language (very high-level language) for computing. The R language allows us to calculate, view data and programs interactively with fast feedback so that it allows us to read and understand data.

Analysis was carried out based on the operation of a multilevel model (multilevel model) with R Studio software. Compared the performance of the three models with conditional R-square. Modelling is run based on the lmer command (fit linear mixed-effect models) to describe the fixed and random effects of the model. The model used will describe how the variables will affect the concentration of CO and NO_2 in the room. The results of the analysis are expected to provide data on factors that can increase and decrease CO and NO_2 concentrations and their correlation to cooking activities including variations in cooking fuel by residents (LPG or electricity), use of cooker hood, window opening width, and peak time sessions.

3. RESULTS AND DISCUSSION

3.1. Indoor Concentration of CO and NO_2

144 data on CO and NO_2 concentrations were obtained for each apartment unit through measurements using the Aeroqual Series 500 for 24 hours with a measurement interval of 10 minutes. Measurements were taken for 2 working days (weekday) and 2 days off (weekend) for each apartment unit. Furthermore, the identification of comparisons between the measurement results and the quality standard value was carried out by PERMENKES No. 1077 of 2011 in each apartment unit.

It is known that the average CO concentration in unit 1 by 0.03 ppm, unit 2 by 0.34 ppm and unit 3 by 0.03 ppm so that the concentration in the three units meets the quality standard of 9.00 ppm. As well as the concentration NO_2 of the three units that meet the quality standard of 0.04 ppm, namely in unit 1 by 0.033 ppm, unit 2 by 0.033 ppm and unit 3 by 0.037 ppm. It can be seen that the concentrations of CO and NO_2 in all apartment units are below the concentration levels required for indoor air quality. Therefore, it can be concluded that the air quality with CO and NO_2 parameters in the three apartment units is not polluted. This conclusion is in accordance to Pradana [9], which states that the average concentrations of CO and NO_2 in 40 apartment units in the city of Surabaya are below the quality standard with the status not polluted.

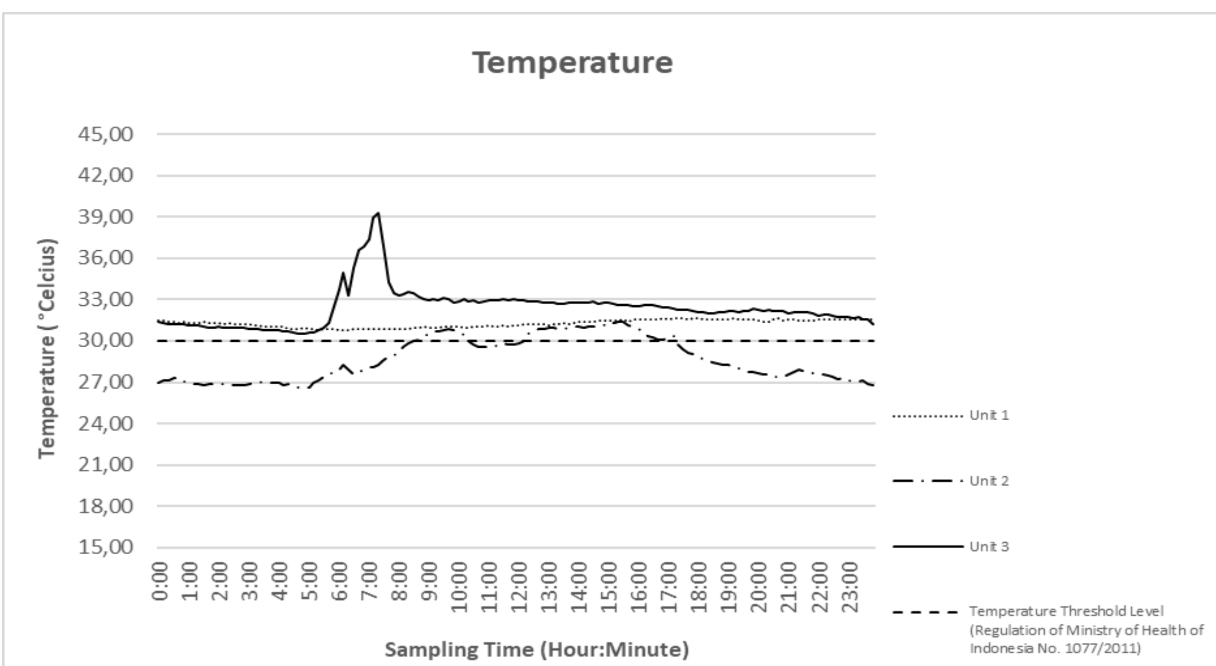

Figure 1 Temperature in the Apartment Unit (˚C).

On the contrary, as can be seen in Figure 1 that the average temperature of the three apartment units exceeds the maximum level of physical requirements for indoor air quality, namely 18 – 30 °C. The average temperature for 4 days of measurement in unit 1 and unit 2 exceeded 30 °C, even the highest temperature in unit 3 was recorded reaching almost 40 °C. Based on figure 2 it is known that the average humidity of the three apartment units exceeds the maximum level of physical requirements for indoor air quality, namely humidity 40 – 60% Rh. The mean humidity in the three units after 8:00 a.m. tends to increase to a maximum of 60% Rh. The lowest humidity only occurs in unit 3, which is in the range of 07.00 – 08.00.

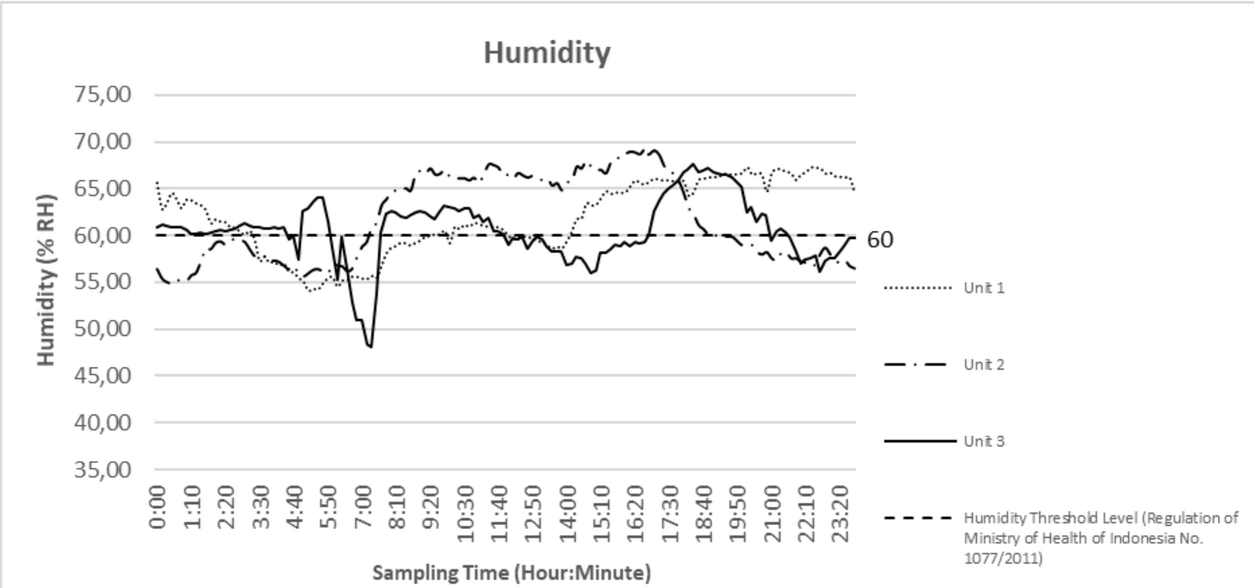

Figure 2. Humidity in the Apartment Unit (% RH).

3.2. Indoor CO and NO2 Concentration Pattern

The pattern of average CO concentrations in the three apartment units is shown in Figure 3. It can be seen that the average CO concentration in units 1 and 2 has a more fluctuating pattern compared to unit 3. Unit 1 and unit 2 are at relatively the same floor height, which is ± 30 m from the base of the apartment building while unit 3 is on the floor with a height which is quite different, namely ± 75 m. In addition, based on the results of filling out the questionnaire, residents of units 1 and 2 open windows with a width of 25-50% of the window size, while residents of unit 3 open windows with 100% opening width so that the average wind that enters is stronger every day. The location of the floor height and also the percentage of windows opened are assumed to affect the average measured CO concentration in the apartment unit. There is a positive correlation between the concentration of gaseous pollutants in the room with the concentration of outdoor pollutants and the rate of air exchange in the room [10], [11]. In addition, Lawrence et al. [12], stated that the value of the air exchange rate is not only influenced by the width of the windows and doors open but also the height of the floor where the windows are located.

Results of a monitoring study by James et al., [13] showed that it can be assumed that most of the COindoors comes from outside the building. Although therehas not been a clear relationship between wind speed andindoor concentration, the results show that increasing wind speed has decreased indoor CO concentration as well as the I/O ratio. The data show that the type and level of buildings can be protective factors against exposure toCO pollutants. Where possible, people are advised to spend time on higher floors to reduce exposure to air pollution.

In addition, the average CO concentration in unit 2 experienced a significant increase around 08:00; 12:00 and 18:30 and in unit 1 at 3:30 pm. Based on the results of questionnaires and interviews, it is known that the residents carry out cooking activities with frying techniques and are also used to opening windows for an average of 4 - 6 hours. Based on Fadhilah [14], cooking time and window opening in an apartment space increase the concentration of CO and NO_2.

In addition, the largest average CO concentration occurred in unit 2, which was 0.35 ppm. Based on the results of the questionnaire, it is known that the occupants in unit 2 do not use the cooker hood or exhaust fan when cooking while in unit 1 the cooker hood is used every time they cook. This condition is in accordance with Dobbin et al., [15] which states that the use of exhaust fans in the kitchen has been known to reduce the concentration of pollutants produced during cooking. However, the CO concentration in unit 3 was only read for a few times when the occupants were cooking with the windows closed. It is known that the occupants carry out cooking activities occasionally using the cooker hood because the exhaust fan condition is considered to be inadequate.

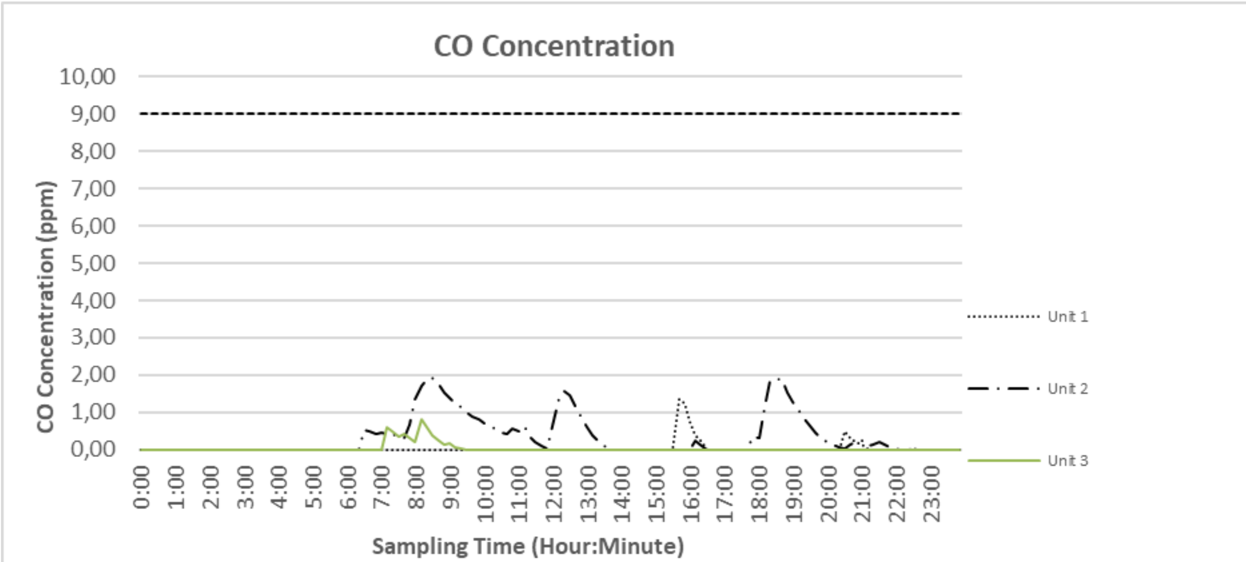

Figure 3 Average CO Concentration in all ApartmentUnits.

Figure 4 below shows that the average concentration curve of NO_2 in unit 1 and unit 2 tends to have the same pattern with the same average concentration of 0.033 ppm. Whereas in unit 3 it can be seen that the pattern of NO_2 concentration tends to be higher in the morning to evening with an average concentration that is also higher, namely 0.037 ppm. There is a significant difference in the concentration pattern between unit 1 and unit 2 and unit 3, as well as the height of the units. As stated by Levy *et al*., [16] stated that indoor NO_2 concentration levels on personal exposure are integrated with existing pollutant sources in the room, geographical conditions, and demographic characteristics. In addition, wind direction and speed at different building levels have a positive correlation with NO_2 measurements. This study shows that the NO_2 concentration on the 29th floor is measured to be higher than on the 2nd and 16th floors [17].

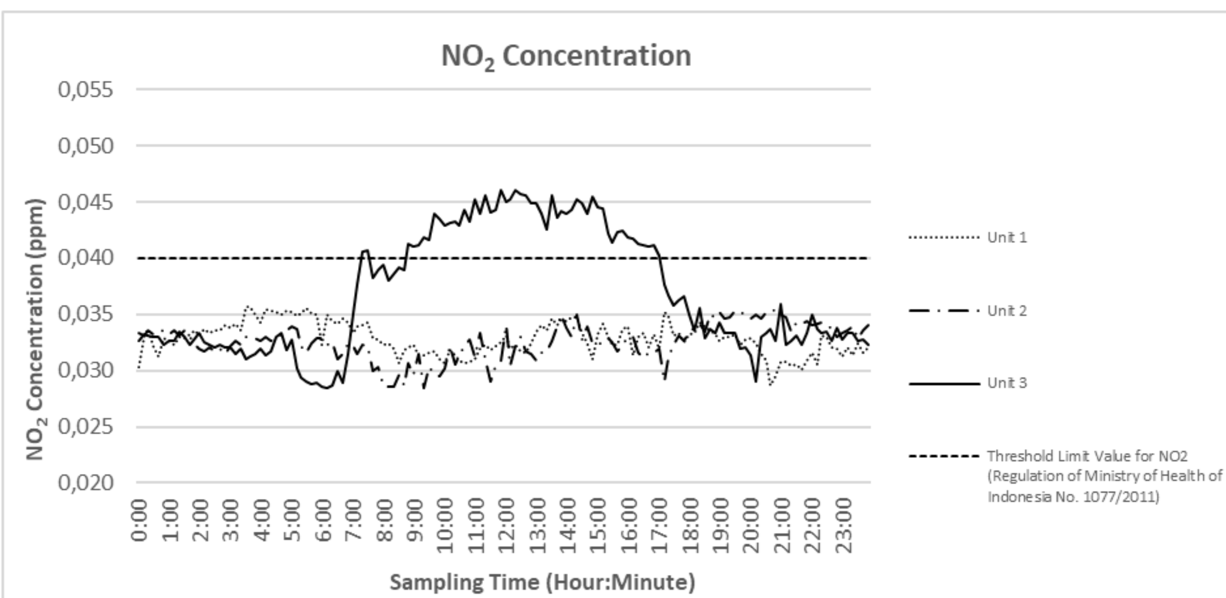

Figure 4. Average NO_2 Concentrations in all ApartmentUnits.

Based on Figure 4, it can be seen that the average NO_2 concentration in the three apartment units tends to be high and approaches the required maximum level of 0.04 ppm. Based on measurements in apartment units, it is known that the average room temperature of the three units exceeds the required temperature which is assumed to be one of the causes for the increase in indoor NO_2 concentrations. This trend is consistent with Kulkarni &

Patil [18] which states that personal exposure to NO_2 is significantly greater in seasons with higher temperatures and humidity and respondents who live in smaller homes or rooms are exposed to higher levels of NO_2. These emissions may come from the elemental nitrogen content of the fuel and in the combustion chamber air. This was observed in the research of Fakinle et al., [19] that when the ambient air and temperature in the combustion zone increase, the formation of NO_2 will also increase.

In addition, the average humidity in the three units which tends to be high and exceeds the required level is also assumed to be a factor in the high average NO_2 concentration in the room. Algar et al., [20] stated that indoor NO_2 concentration is quite high with the main determinants of energy sources, cigarette smoke, ventilation and humidity. Low air humidity means that the water vapor contained in the air is small, at that time the air can move faster without being hindered by water vapor so that the NO_2 concentration around the study site is low. High humidity describes the condition of high water vapor in the air so that it will slow down the air flow both horizontally and vertically so that the NO_2 concentration becomes high [21]. In addition, high humidity levels can also increase the likelihood of pollutant emissions from the building materials and furniture used [22].

3.3. The Effect of Cooking Fuel and Window Opening Width on Indoor CO and NO2 Concentrations

Based on the modelling analysis, the results of model 2 can be assumed that cooking activity by opening the window can increase the CO concentration (0.223). The two units (units 1 and 2) that are in this condition are units located on the lower floor of the building, which is approximately 30 m from the ground floor of the building with the window opening facing the vehicle parking area. Based on direct observations in the field, it is known that the parking lots around the locations of units 1 and 2 are crowded car parking areas every day. The highest average rhythm of vehicles in and out is in the range of 07.30 - 09.30 and 17.30 - 20.30 both at unit 1 and 2 locations vehicles that must park in parallel. CO pollutants can be generated indoors, including from heating devices, gas stoves and smoking activities. In addition, traffic emissions and industrial activities are sources of CO pollutants that come from outdoors [23]. Several case studies state that ventilation [8] causes indoor pollution to be worse due to infiltration.

Conversely, the CO concentration in the room can be lowered (-0.572) when cooking is done by fully opening the window (100%). This condition occurs in unit 3, namely the apartment unit which is on the highest floor of the building, which is 75 m from the ground floor of the building compared to other units. Based on direct observation at the site, it was found that every day the wind was blowing quite hard from the direction of the double casement windows to the living room and kitchen area without the partition in between. Research conducted by Jo and Lee [24] shows that in the absence of other important sources around the surveyed area such as industrial areas, it is assumed that the difference in CO levels in outdoor air between low and high floors is mainly due to the vertical concentration gradient of emission pollutants. vehicles generated from vehicles in nearby apartment and street parking lots.

These results are supported by Ilgen et al. [25], who observed vertical variations in the concentration of pollutants generated by motorized vehicles on roads around multi-storey buildings, that residents of low-floor buildings may be more exposed to motor vehicle emissions from outdoors than residents in apartments on higher floors.

Model 3 shows that cooking with an open window at peak time in the morning (1.078) and peak in the afternoon (0.023) can contribute to an increase in CO concentration, while cooking at other than peak time does not result in an increase in CO concentration in the room (-1.101). It is known through interviews and filling out questionnaires that residents actively carry out various activities, especially cooking and opening windows during the peak hours of the morning (06.00 - 10.00) and peak in the evening (16.00 - 19.00). According to WHO's International Program on Chemical Safety (1999),carbon monoxide is produced indoors through sources of combustion (cooking and heating) and also through the infiltration of carbon monoxide from outside air to the indoor environment. CO emissions can increase during the morning (07.00 - 09.00) and evening (16.00 - 18.00) peak hours. The effect of these emissions is largely due to the increase in the volume and rate of entry and exit of vehicles based on the type of residential area where they live [26].

Table 3. Coefficient CO Estimate with Random Intercept (T-Value in Bracket).

Variable	CO (model 1)	CO (model 2)	CO opened window (model 3)
Fixed Part			
(Intercept)	-0.234 (-0.453)	1.767 (2.762)	-0.571 (-1.147)
Humidity (%) (X1)	-0.013 (-3.986)	-0.020 (-5.857)	-0.010 (-3.161)
Temperature (°C) (X2)	0.043 (3.036)	-0.005 (-0.348)	0.046 (3.388)
AC usage (1=on; 0=off;) (X3)	0.035 (0.684)	-0.074 (-1.403)	0.044 (0.892)
Window opening time (1=opened; 0=closed) (X4)	0.445 (6.738)	1.999 (5.912)	0.573 (8.926)
Cooking time (1=cooking; 0=no) (X5)	0.603 (2.341)	1.999 (5.912)	0.798 (1.155)

Variable	CO (model 1)	CO (model 2)	CO opened window (model 3)
Cooking fuel (1= LPG; 0=electricity) (X6)	0.416 (7.396)	0.068 (1.016)	
Cooker hood (1=on; 0=off)(X7)	-0.908 (-5.260)	-1.422 (-4.224)	
Width of window opening (100=100%; 50=50%; 25= 25%; 0= closed) (X8)	-0.002 (-3.610)	0.003 (0.676)	
Day (1=weekday; 0=weekend) (X9)	-0.232 (-5.396)	-0.183 (-4.112)	
Frying method (1=frying; 0=no) (X10)	1.921 (8.532)		
Boiling method (1=boiling; 0=no;) (X11)	-0.249 (-0.917)		
Random Coefficient			
Morning peak (intercept)	0.113		
Afternoon peak (intercept)	-0.054		
Non-peak (intercept)	-0.059		
Closed window: intercept		-0.030	
Closed window: Cooking: 1, No: 0		-0.283	
Opened window 25%: intercept		0.118	
Opened window 25%: Cooking: 1, No: 0		0.350	
Opened window 50%: intercept		0.585	
Opened window 50%: Cooking: 1, No: 0		0.638	
Opened window 100%: intercept		-0.436	
Opened window 100%: Cooking: 1, No: 0		-0.572	
Morning peak: Cooking: 1,No: 0			
Afternoon peak: Cooking: 1, No: 0			
Non-peak: Cooking: 1, No: 0			
Random Part			
Apart from Peak Hours	0.011		
During Peak Hours	0.533		
Peak Hour: Cooking: 1, No: 0			
Opened Window (intercept)		0.233	
Cooking within Opened Window		0.223	
Within Opened Window Session		0.565	
Model Performance			
AIC	3910.388	4004.315	

Variable	CO (model 1)	CO (model 2)	CO opened window (model 3)
BIC	3986.754	4080.681	
-2 * Loglikelihood	3882.388	3976.315	

The provided Table 4 gives a breakdown of coefficient NO_2 with random intercept. It can be seen that there is an increase in NO_2 concentration of 0.002 ppm at the peak of the morning and the peak of the evening of 0.0006 ppm, and a decrease in the time other than the peak of 0.001 ppm. This is possible because of the many activities carried out by residents which causes an increase in NO_2 in the room in the afternoon compared to the morning. Activities that can be a source of indoor NO_2 are cooking or smoking [27].

Similar to Model 1, cooking activity also makes indoor NO_2 concentration high (0.0014) in Model 2. It is known that indoor NO_2 concentration can be reduced if cooking activities are carried out at peak morning time (-0.0002) and non-peak time (-0.0020). Based on the conditions of the apartment studied, cooking when opening windows with a width of 25%, 50% and 100% is also known to reduce concentration in the room. On the other hand, indoor NO_2 concentration will increase when cooking activities are carried out with closed windows.

As it is known that in Kuwait, Al-Hemoud et al., [28] found a statistically higher mean concentration of NO_2 in modern buildings when doors are closed. Cooking is also an activity that is known to increase indoor pollutant concentrations. One of the pollutants of concern is the concentration of NO_2 which is generated from gas combustion during cooking.

The use of exhaust fans in the kitchen has been shown to reduce the concentration of pollutants produced during cooking [14]. However, based on the research results, it can be seen in models 1, 2 and 3 which are shown in Table 4 that the use of the cooker hood actually increases the NO_2 concentration. This may be due to several things, such as the type, size, placement of the exhaust fan, flow rate, exhaust fan channel and the habit of using the exhaust fan [29-32].

Based on the operation of the three models, it is known that cooking with LPG fuel has a greater effect on increasing the concentration of NO_2 in the room compared to the use of an electric stove. In the research of Kornartit et al. [33], houses that use gas stoves have a higher indoor NO_2 concentration than those using electric stoves. According to Ministry of Housing, Community and Local Government (2019) indoor NO_2 concentrations in the kitchen were also found to be higher than in the living room.

It should be noted in this study that the indoor NO_2 concentration can increase when cooking activities are carried out. If seen in Model 2, cooking activity with closed windows causes NO_2 concentration in the room to increase, although it turns out that cooking is done during the peak morning time to decrease the indoor NO_2 concentration (Model 3). The thing most likely to cause indoor NO_2 concentrations to fall during peak times is the possibility of circulation from the ventilation. The concentration of NO_2 in the room when cooking by opening the window at the peak of the morning, evening, or during non-peak times, is a concern in this study. It appears that indoor NO_2 concentrations can be overcome by opening windows or indoor ventilation. Research [34] states that during working hours it is known that indoor NO_2 concentrations are lower in rooms that have natural ventilation compared to mechanical ventilation. The main function of ventilation is to make the room in optimal conditions for carrying out activities in the presence of air circulation [35]. As said by Zhang et al., [8] stated that ventilation can help improve indoor air quality provided that outdoor air quality is not bad.

Based on the results of data analysis in Table 3 and Table 4, it is known that the use of a stove with LPG fuel has an effect on increasing the concentration of CO and NO_2 compared to the use of an electric stove. Based on the LPG specifications issued by the Directorate General of Oil and Gas No. 26525.K / 10 / DJM. T / 2009, the composition of the minimum LPG product contains a mixture of Propane (C3) and Butane (C4) of 97% and a maximum of 2% is a mixture of Pentane (C5) and heavier hydrocarbons.

According to WHO guidelines for indoor air quality for CO pollutants, the combustion of high-grade fuels such as natural gas, butane or propane typically produces far less carbon monoxide, provided that sufficient air can be provided to ensure complete combustion. However, WHO, (2010) said that devices that use these fuels can still cause deadly carbon monoxide poisoning if not maintained, ventilated properly or if the air-fuel ratio is not adjusted properly. Natural gas and propane stoves produce a wide variety of pollutants during use, including carbon dioxide, carbon monoxide, nitrogen dioxide, formaldehyde, and particulate matter.

Table 4. Coefficient NO2 Estimate with Random Intercept (T-Value in Bracket).

Variable	NO_2 (model 1)	NO_2 (model 2)	NO_2 opened window (model 3)
Fixed Part			

Variable	NO_2 (model 1)	NO_2 (model 2)	NO_2 opened window (model 3)
(Intercept)	0.008 (19.517)	0.006 (10.999)	0.008 (19.449)
Humidity (%) (X1)	-0.004 (-17.191)	-0.004 (-15.231)	-0.004 (-17.072)
Temperature (°C) (X2)	-0.0002 (-1.830)	0.0007 (0.690)	-0.0002 (-1.789)
AC usage (1=on; 0= off;) (X3)	-0.0003 (-0.737)	0.006 (1.732)	-0.003 (-0.742)
Window opening time (1=opened; 0=closed) (X4)	-0.002 (-4.842)	-0.006 (-6.824)	-0.002 (-4.669)
Cooking time (1=cooking; 0= no) (X5)	0.001 (0.959)	0.001 (0.055)	0.003 (1.421)
Cooking fuel (1=LPG; 0=electricity) (X6)	0.001 (2.309)	0.001 (2.437)	0.001 (2.273)
Cooker hood (1=on; 0= off) (X7)	0.004 (2.996)	0.003 (1.470)	0.004 (3.263)
Width of window opening (100=100%; 50=50%; 25= 25%; 0= closed) (X8)	0.012 (20.241)	0.001 (0.155)	0.012 (19.914)
Day (1=weekday; 0=weekend) (X9)	-0.0004 (-1.402)	-0.0006 (-1.836)	-0.0004 (-1.453)
Frying method (1=frying; 0=no) (X10)	0.0005 (0.300)	0.0001 (0.068)	0.0001 (0.703)
Boiling method (1=boiling; 0=no;) (X11)	0.0007 (0.340)	0.0001 (0.688)	0.0001 (0.557)
Random Coefficient			
Morning peak (intercept)	0.002		-0.002
Afternoon peak (intercept)	0.0006		0.0004
Non-peak (intercept)	-0.001		-0.001
Closed window (intercept)		0.002	
Closed window: Cooking: 1, No: 0		0.0002	
Opened window 25% (intercept)		-0.002	
Opened window 25%: Cooking: 1, No: 0		-0.001	
Opened window 50% (intercept)		-0.005	
Opened window 50%: Cooking: 1, No: 0		-0.0004	
Opened window 100% (intercept)		-0.006	
Opened window 100%: Cooking: 1, No: 0		-0.002	
Morning peak: Cooking: 1, No:0			-0.0002
Afternoon peak: Cooking: 1, No:0			0.002
Non-peak: Cooking: 1, No:0			-0.002
Random Part			
Apart from Peak Hours	0.0004		
During Peak Hours	0.003		0.004

Variable	NO_2 (model 1)	NO_2 (model 2)	NO_2 opened window (model 3)
Peak Hours: Cooking: 1, No:0			0.005
Open Window (intercept)		-0.003	
Cooking within Open Window		-0.004	
Within Open Window Session		-0.003	
Model Performance			
AIC	-12741.48	-12783.81	-12741.4
BIC	-12665.12	-12696.53	-12654.13
-2 * Loglikelihood	-12769.48	-12815.81	-12773.4

3.4. Recommendations for Control Strategies in Controlling Indoor Air Pollution by CO and NO_2

Based on the results of the identification of the effect of occupant activities on the concentration of CO and NO_2 in the three apartment units studied, it can be seen that the wider the windows are opened when cooking, the more CO concentration in the room increases. This occurs in apartment units located on the lower floors (units 1 and 2). The unit has a main door or window for ventilation that opens onto the balcony and overlooks the courtyard of the apartment parking area. It is known through a field survey that the density of the parking area by vehicles occurs in the morning and evening when the average occupants have routines in and out of the parking area at the same time. It is suspected that pollutants in the outdoor area of the apartment unit, namely the parking area and the nearest road, are one of the causes of the increase in indoor CO concentrations. On the other hand, the indoor NO_2 concentration tends to decrease when the occupants cook by opening the window wider. In addition, the concentration of CO and NO_2 is also reduced when the window is maximally opened (100%) when the occupants cook. This condition occurs in a unit located on the floor which is twice as high as the other units (unit 3) so that it has a long distance from the parking area or the nearest road. Based on the field survey, this unit has an average daily wind that is strongest compared to other units.

In addition, the average CO and NO_2 concentrations at peak hours were higher than during non-peak hours. Based on the results of the survey and filling out the questionnaire, it is known that residents are more active in doing indoor activities during peak hours, including cooking and opening windows. Based on the identification results, doing cooking activities at peak hours tends to increase CO and NO_2 concentrations compared to hours other than peak.

Cao et al., [36] stated that ventilation has an effect on individual exposure when doing cooking activities, namely cooking when the window is closed has a higher exposure than when doing cooking activities when the window is opened. However, there are differences in the results and conditions in the study which are in accordance with several studies which state that there is a decrease in indoor air quality when the windows are opened. This is due to the tendency to open windows when the outside temperature is moderate [37]. Outdoor air quality is in poor condition, namely during traffic congestion at peak hours where peak hours are in the morning and evening [38]. It is known that the peak hours in the city of Surabaya are based on air monitoring stations, namely 07.00- 09.00 and 16.00-18.00 [39].

Therefore, residents are advised to open windows at a time other than the peak hours of the morning and evening to get a more effective air circulation. In addition, recommendations are given to apartment residents to choose apartment units that are located on a higher floor, so that window and door openings as the main ventilation of the room are not close to the parking area or highway. Residents can carry out cooking activities by fully opening the window to get the maximum air circulation effect. Based on the study of James et al., [13] the results show that increasing wind speed has decreased indoor CO concentrations as well as the I/O ratio. The data show that the type and level of buildings can be protective factors against exposure to CO pollutants. Where possible, people are advised to spend time on higher floors to reduce exposure to air pollution.

The results showed that the use of a cooker hood or exhaust fan for cooking can reduce the CO concentration but also cause the NO_2 concentration to increase. Relying on windows as the only means of ventilation does little to remove oil particles and other pollutants from uncontrolled air exchange. One of the ways to ensure proper ventilation and extraction functions in the kitchen is by properly controlling the air exchange. Therefore, the cooker hood is used to increase the ventilation function and remove air from the kitchen. Cooker hood accelerates air exchange in the kitchen, filters oil particles and various chemical pollutants and neutralizes odors. Based on these conditions, residents are recommended to cook by turning on the cooker hood and always paying attention to the installation, maintenance and condition, so that the exhaust fan for cooking can carry out the air circulation function effectively.

Indoor air quality control strategies can be carried out by developers and constructors of apartment buildings to provide exhaust gases from the exhaust cooker hood in each apartment unit. This facility can be an encouragement for apartment residents to install a cooker hood and be able to use it with effective results.

Based on modelling analysis and field identification, the use of LPG fuel is known to have an effect on increasing the concentration of the two parameters, namely CO and NO_2, compared to the use of electric stoves. Therefore, the use of electric stoves can be an important consideration for residents to be able to control the potential decline in indoor air quality. Cooking on an electric stove in a commercial kitchen will reduce CO and NO_2 concentrations by about 37% – 40% and 35% – 42%, respectively. The ambient concentrations of CO_2, NO, and NO_2 measured in kitchens using electric fuel also produce lower values than those using natural gas [40,41].

This finding and literatures suggests us to conclude that during high outdoor concentration it is advisable that windows were shut and during non-peak session such as early in the morning or even at the night windows can be opened for a limited time to allow fresh air displace dirty indoor air. The condition of indoor during ventilation is even worse when occupant is cooking. The findings from this paper confirm the effect of ventilation if it is opened with inappropriate width and timing eg. cook by fully opening the windows when the concentration outdoors is worse than indoors. Researchers need further research to determine the effect of indoor air quality by outdoor air.

4. CONCLUSION

This paper examines the effect of window opening width and cooking fuel on CO and NO_2 in apartment spaces. It was found that the use of LPG stoves for cooking had an increased effect on CO and NO_2 concentrations compared to electric stoves. The concentrations of CO and NO_2 increase when opening the window while cooking is done in a low floor apartment unit with a window close to the parking area, but on the other hand the concentration decreases when it is done in a unit on a high floor. In addition, cooking with the windows open at non-peak times contributed negatively to CO and NO_2 concentrations.

Therefore, the investigators noted that the significantly higher concentrations during the peak session may be due to occupant activity at that time and higher outside concentrations. According to many previous literatures, cooking activities increase pollutants and opening windows especially during the morning peak session has worse indoor pollution due to accumulated particulate infiltration (outside sources) and direct emissions from cooking (indoor sources) at the same time. Furthermore, closing the windows during peak sessions is then recommended as our observations show less pollution in this scenario. Opening windows to the maximum size is recommended in an indoor location away from outdoor pollutant sources such as vehicle traffic around buildings.

Future research can be carried out to investigate indoor air quality with a larger number of samples with a wider variety of occupant activities. Quantitative identification of the influence of outdoor ambient air is necessary to determine the effect of outdoor concentration on indoor. Identification of wind direction and speed as well as the rate of air exchange on different building floors that may have an effect on increasing indoor concentrations of CO and NO_2 pollutants is also necessary to strengthen the results obtained in this study.

The conclusion connects the findings to a larger context, such as the wider conversation about an issue and the journal theme. It suggests the implications of your findings or the importance of the topic. Asking questions or suggesting ideas for further research and revisiting your main idea or research question with new insight.

AUTHORS' CONTRIBUTIONS

Nadinda carried out the research, wrote and revised the article. Rana anchored the review, revised and approved the article submission. Arie conceptualised the central research idea and provided the theoretical framework. Joni designed the research and supervised research progress.

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