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Comparison of Honai and Other Traditional Houses' Physical Qualities on Respiratory Diseases

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Abstract

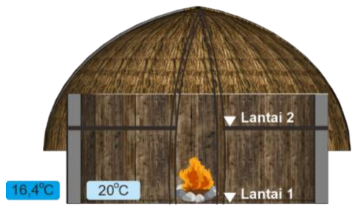
One of *Jayawijaya's* traditional houses, Honai, relies much on thermal comfort factors, as most residences are. Honai architecture conforms to *Jayawijaya's* environment and the Dani tribe's daily activities. The Dani people lit fires inside, and the smoke from the fires caused respiratory diseases among the residents. This study focused on the thermal comfort variables, such as air temperature, humidity, and wind velocity, of the Honai interiors and compared them with those of other traditional houses in Indonesia that also use hearth systems inside. CFD (Computational Fluid Dynamics) simulations were performed to illustrate how the air inside each type of house circulates. The result of the simulations shows that with an adequate area of openings, the smoke from the hearths inside the compared three houses tends to be carried out quickly, while in Honai houses, it requires a relatively longer time for the smoke to be distributed to the outside. This result strengthens the author's hypothesis, stating that the occupants of Honai houses had respiratory diseases due to the lack of air ventilation in their homes. At the end of the research, the author made a design recommendation for the occupants of Honai houses to add a sufficient area of ventilation to create healthier Honai houses so that the respiratory disease rate in Papua would possibly be reduced.

Keywords: *CFD; hearth; Honai; respiratory disease; thermal comfort; ventilation*

Introduction

Honai houses, one of the traditional house types in Jayawijaya, are situated in a mountainous terrain in Wamena City and inhabited by the people of the Dani tribe. These houses are specifically located in the area of Baliem Valley, near the Jayawijaya Mountain. Therefore, the average air temperature in the area is categorized as low. As an adaptive response to that, the occupants constructed their houses with no apertures, so there is no air movement inside.

Figure 1. Illustration of the air temperature inside and outside of Honai houses
Source: Author, 2022



Dani people have lived in Honai houses for a long time, and they have not undergone any significant modifications. These people have a tradition of burning fires inside their homes to stay warm, particularly from dusk until dawn. In addition, the house interiors are cluttered, which makes the warmth last longer. These two factors allegedly have made the burning

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fire tradition get the people's respiratory systems infected.

According to World Health Organization (WHO), respiratory tract diseases are the leading cause of mortality among children, particularly in underdeveloped countries. This type of diseases are classified as a severe sort of disease that may affect a portion of a person's respiratory system. When a person has the disease, he or she will have symptoms such as breathing difficulties, which affect the body's oxygen circulation. If a person lacks oxygen, the body's metabolic system becomes preoccupied, reducing the individual's productivity. Therefore, the focus of this research was on building materials and thermal comfort that hypothetically affect the health of the people living in the research loci.

In general, the objective of this research was to compare the physical conditions of Honai houses and three other traditional houses in Indonesia that have relatively similar characteristics, especially fireplaces inside the homes. The comparison was based on how their physical conditions affect the tendency of the occupants to suffer from respiratory tract diseases.

Literature Review

1. Vitruvian Triad

In the first century BC, Vitruvius was an architect, civil engineer, and author from Rome, Italy. De Architectura, a paper he composed, will forever be remembered as a classic work. In that paper, he outlined three aspects that all architects should always keep in mind when designing. These aspects are known as the Principles of Vitruvius or the Vitruvian Triad. The Vitruvian Triad is comprised of *utilitas* (functionality), *firmitas* (stability or strength), and *venustas* (aesthetics).

2. Thermal Comfort

Thermal comfort is the result of a person's thought process expressing satisfaction with his or her thermal environment. The American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE) defines thermal comfort as the state in which a person is satisfied with the ambient temperature. To determine the comfort of a zone or environment, we should consider the dominating perception felt by a group of individuals in a particular area as representative samples.

According to Fanger (1972), climatic and individual factors may also influence thermal comfort. The climatic factors that influence thermal conditions include air temperature, relative humidity, solar radiation, wind speed, and air circulation within a space. In this study, the author focused on air temperature, relative humidity, and wind speed.

3. Hearth-related Theory

Since a very long time ago, the existence of hearths or fireplaces has influenced the daily lives of a great number of people. Hence, it can be stated that the existence has had an effect on how human civilizations and cultures have grown. In Indonesia, hearths or fireplaces have been available in a variety of shapes. The variation is influenced by the topography and climate of the region, as well as the sociocultural condition of the surrounding population (Dewi et al., 2016).

Figure 2. Fireplace in a Honai house (left) and a house in Kampung Naga (right)
Source: Dewi, 2018

Dewi (2018) depicts Indonesian fireplaces ranging from firewood piles to tables. Later on, humans tried to shield fire from the wind; thus, they began using natural stones as a shelter. Today, the most common fireplaces in Indonesia are in the form of tables with different sizes, materials, and cooking holes. As the necessity for fireplaces increased, fireplaces in Nusantara houses changed, and it has made fireplaces portable. According to that research of Dewi's, the fireplaces found in Honai houses are considered first generation, which means they are among the most ancient. The ones in Kampung Naga, on the other hand, are from the third generation and are mostly made like tables.

4. Respiratory Tract Disease

Respiratory tract diseases or respiratory tract infections (RTIs), known as ISPA (*Infeksi Saluran Pernapasan Akut*) in Indonesian, are among the world's most contagious and leading causes of morbidity and mortality. It has a very high mortality rate, and the majority of those affected are infants, children, and the elderly, particularly those living in countries with low to moderate income per capita (WHO, 2007).

Oliva and Terrier (2021) defined RTIs as infections of the upper respiratory tract (rhinitis, sinusitis, pharyngitis, or tracheitis) and/or lower respiratory tract (mostly bronchitis and pneumonia), caused by viruses, bacteria, and fungi. They also stated that influenza viruses, Respiratory Syncytial Virus (RSV), and SARS-CoV-2 are the types of microorganisms that can cause RTIs.

Oktaviani (2009) mentioned that humans are prone to respiratory tract diseases if their homes comprise the following conditions.

i. The air temperature is below 18ºC
ii. The relative humidity is above 70%

5. Physical Factors in Thermal Comfort

According to Prayoga and Kusumawanto (2019), the physical factors in thermal comfort are the elements of a building that influence the thermal comfort felt by the occupants of the building. The physical factors include construction elements, building materials, and ventilatory systems.

A. Construction Elements

Construction elements include floors, walls, ventilation or openings, roofs, and building density. If a home's flooring does not meet regulatory requirements, it may lead to the development of respiratory tract diseases. Aftab et al. (2022) discovered that living in homes with natural flooring and walls, cooking in outdoor or separate buildings, and using unclean cookstoves significantly increase the likelihood that children under the age of five may experience ARI symptoms. The research showed that children under the age of five are 18% more likely to have ARI (acute respiratory infection) symptoms (rapid, short, or difficult to breathe) in homes with natural flooring.

Walls are the other element of construction. Walls can have a significant impact on the air quality in the surrounding area if they are not waterproofed, as this can result in a high relative humidity within the formed space. Walls with rough-textured surfaces and/or uneven surfaces, as well as temporary walls, have a tendency to expose surface-derived fine particles. In addition, wall gaps may affect the exposure of external substances such as smoke, dust, and so forth (Suryanto, 2003).

The next element of construction is roofs. Poor-quality roofs with conditions such as cracks and lack of decency may generate dust that can float in the air, be inhaled by building occupants, and then result in respiratory disease.

The final aspect of construction is the building density. It would have an effect on the rate of carbon dioxide (CO^2) concentration within a building, and the building's occupants would lack oxygen (O^2). Population density may also influence the airborne transmission of respiratory tract diseases from a building to its surroundings. In the Ministerial Decree of the Republic of Indonesia No. 829/Menkes/SK/VII/ 1999 regarding the requirements for a healthy house, it is stated that no more than two individuals should occupy 8 m^2 of space. The purpose of the rule was to stop the spread of disease and to facilitate the daily activities of the people.

B. Material Elements

According to the Decree of the Minister of Health No. 829/Menkes/SK/VII/1999, a number of requirements must be met in order to form healthy houses, including building materials, spatial organization, architectural elements in a house, lighting, air quality, ventilation, water supply, food storage facility, and waste management. The decision or rule requires Indonesian citizens to utilize building materials that meet the following two requirements.

i. Not composed of any material that could expose harmful particles, such as dust tinier than 150 µg/m^2, asbestos tinier than 0.5 fiber/m^3/day, or lead (Pb) lesser than 300 mg per kg of the material.
ii. Not composed of any material that could stimulate the growth and development of pathogenic microorganisms.

C. Ventilatory System

Air significantly impacts home comfort. Comfort gives the occupants of a home a fresh sensation, and if the air circulates constantly through the ventilatory holes, it would lead to the house becoming healthy (Mukono, 2008).

Using a natural ventilatory system, there are a variety of strategies for achieving good air circulation inside a space. Cross-ventilation that achieves the following requirements is one of the strategies.

i. The air entering the house must be equivalent to the air leaving it.
ii. The air entering the house is not contaminated by cooking smoke and/or bathroom odors.
iii. The outlet does not disturb the comfort within the building.

The Regulation of the Minister of Health of the Republic of Indonesia No. 1077 of 2011 on Guidelines for Air Sanitization in Home Space mandates ventilation to cover at least 20% of the floor area, with 10% of ventilatory holes fixed and 10% hinged. A poorly ventilated building can harm its occupants. If bacteria and/or chemicals pollute the air inside a building, the number of bacteria will grow, negatively affecting more people.

Ventilation has a significant impact on both thermal comfort and indoor air quality as it can remove indoor contaminants and supply fresh air, thereby managing and increasing indoor air quality. In some cases, ventilation can be used to change the temperature and relative humidity inside by bringing in new air. This makes the mechanical systems run less and use less energy (Jia et al., 2021).

6. Subjective Factors in Thermal Comfort

Subjective factors are those that influence thermal comfort based on the impressions of the building occupants (Prayoga & Kusumawanto, 2019). The following are a few of them within this research:

A. Clothing Insulation

Thermal comfort may be determined by the occupants' clothing insulation. 1 clo, the international standard for clothing insulation, equals 0.155 K m2/W. Clo may vary depending on the type and material of the clothes. Thicker clothes have higher clo values, and vice versa (Prayoga, 2019).

B. Metabolic Rate

Based on ANSI/ASHRAE 55-2020, Kelechava (2021) described metabolic rate as activity-dependent. The unit of measurement for metabolic rate is met, which equals 58.2 W/m2. As an example, the metabolic rate of a heavy machine may reach 3 met, whereas the metabolic rate of an office worker may only reach 1.2 met.

7. Climatic Factors in Thermal Comfort

Climatic factors are those that influence thermal comfort based on the state of nature or climate (Prayoga & Kusumawanto, 2019). Listed below are some of the variables included in this study.

A. Location

Every location may have a unique climate. Geographically speaking, Indonesia is situated at a latitude of 7 degrees (Estiningtyas, 2013). It causes high relative air temperatures and humidity across the entire nation. In order to optimize thermal comfort conditions in the climatic zone of Indonesia, physical zone and air velocity must be taken into account (Muniz-Gäal et al., 2020). For example, it may be possible to construct a building that can respond to and adapt to the local climate.

B. Air Temperature

The air temperature in one region may vary significantly from that of another. Several factors, such as the angle of the sunrays, the direction of the wind, the sea current, clouds, and the duration of sun exposure, may account for the variance. There are three categories of air temperature based on the resulting comfort condition.

Table 1. Categories of air temperature based on the resulting comfort condition

Comfort Condition	Air Temperature (℃)	Relative Humidity (%)
Cool and comfortable	20.5 – 22.8	50 - 80
Optimally comfortable	22.8 – 25.8	70 - 80
Slightly comfortable	25.8 – 27.1	60 - 70

Source: SNI T-14-1993-03

The lowest and highest temperatures necessary to achieve thermal comfort in the three categories listed above are 20.5°C and 27.1°C, respectively. Indonesians generally feel comfortable in relative humidity ranging from 40% to 70% (SNI, 1993). Too cold or too hot air tends to decrease a person's productivity rate. To increase it, adjusting the air temperature to one's comfort level is the solution.

D'Amato (2018) stated that the impact of cold temperatures is modulated by additional environmental conditions. For instance, asthmatic patients felt that cold humid air was more bothersome than cold dry air, while those in the control group had fewer respiratory issues. If indoor exposure occurs rapidly and without gradual adaptation to a temperature 2°C to 3°C lower than the external temperature, and especially with a 5°C difference (avoid an indoor temperature below 24°C), there would be a risk of negative effects on the respiratory tract, and the patient risks developing a clinical condition characterized by an exacerbation of the respiratory symptoms of his chronic respiratory disease.

C. Relative Humidity

Estiningtyas (2013) mentioned that relative air humidity is the ratio of water vapor in the air to its maximum capacity. Thermal comfort is significantly affected when air temperature approaches or exceeds the comfort limit and relative humidity is above 70% or below 40%. Room humidity affects heat loss, and high relative humidity can make heat loss harder, causing discomfort. To counteract high humidity, sufficient wind speed is required.

D. Wind Velocity or Air Movement

Lippsmeier (1994) indicated the standard air velocity within a comfortable environment as follows.

- 0.25 m/s: Convenient, with little to no air movement.
- 0.25 m/s - 0.5 m/s: Convenient air movement.
- 1.0 m/s - 1.5 m/s: Airflow sensation ranging from acceptable to uncomfortable.
- Above 1.5 m/s: Inconvenient

Ki-Nam et al. (2013) found that participants seated quietly under a parasol felt local cooling on their exposed legs and arms in high-speed winds, causing thermal discomfort. Subjects of their research experienced thermal comfort when the air velocity was less than 1.2 m/s and felt the best comfort at a 0.41 m/s wind speed.

Methodology

1. Research Methodology

This research used a comparative (quantitative) and qualitative literature study with sources from various references, such as books and research journals of other researchers, to present data on Honai houses and three of Indonesia's other traditional houses that are cited as comparisons.

2. Research Indicators

In this research, the authors compared the hearth or fireplace systems, material elements, and construction elements of the Honai houses to those of several of Indonesia’s other types of traditional houses. The author also analyzed the relationship between thermal comfort in these traditional houses and the probability of their occupants developing respiratory tract diseases. Accordingly, the following indicators are utilized in this research:

Table 2. Indicators required for comparing the Honai houses to the other traditional houses

Research Indicators	
Quantitative	**Qualitative**
Average air velocity outside the house	Hearth and ventilatory systems utilized
Average air velocity inside the house	Building material elements
	Building construction elements

Source: Author, 2022

3. Research Variables

Table 3. Research variables applied in this research

Research Variables	
Dependent	**Independent**
Thermal comfort level, including: Air temperature Relative humidity Air velocity	Hearth and ventilatory sistem
Tendency of the occupants of the house to suffer from respiratory tract diseases	Building material elements
	Building construction elements

Source: Author, 2022

4. Research Stages

Before conducting research, the first step to take is preparation. It aimed to determine the condition of the observed loci, develop the context of the research problems, and identify the factors that are contextual to the locus of the observation. The following are the specifics of the preparation phase process.

i. Search for sufficient references for study and analysis.
ii. Conducting interviews concerning the current physical condition.
iii. Identifying the original information collected.

Following that, the step of conducting research commenced. Several previously conducted studies, websites, measurements, as well as follow-up surveys, provided additional information used in this research. Here are the complete processes undertaken to gather the data.

Table 4. Processes undertaken to gather data

Processes	Required Tools	Results
Literature reviews	Internet access	Findings from past studies, information on the current state of the research locus and the comparator loci, etc.
CFD simulations	SketchUp, Autodesk CFD	CFD simulation data focusing on air movements in the research locus and the comparator loci.
Comparing process	-	Comparison data from the synthesized and analyzed data resulted from literature reviews and CFD simulations

Source: Author, 2022

5. Research Limitations

This research had various limitations, including the following:

i. Due to limited access to the research loci, only comparative (quantitative) and literature study (qualitative) methodologies were employed in this research.
ii. The purpose of this research is to prove the hypothesis regarding the physical quality of the Honai houses, which lacks adequate ventilation in terms of air temperature, humidity, and wind speed, which influence the risk of respiratory tract disease among the occupants.
iii. In this study, a comparison was made between the independent variables and the dependent variables in the Honai houses and the three comparator traditional houses that also have fireplace systems inside: the traditional houses in Kampung Naga, Tasikmalaya, West Java; the traditional houses in Kampung Wana, East Lampung, Lampung; and Sa'o House in Kampung Bena, Flores, East Nusa Tenggara.
iv. The independent variables were observed to

determine which traditional house is objectively superior to the Honai houses in terms of thermal comfort and susceptibility to respiratory tract disease.

v. The CFD simulation was conducted to produce supporting data that might strengthen the hypothesis mentioned earlier. As for the simulation objects, this simulation utilizes models of the Honai houses as well as models of the three comparator traditional houses. This simulation mainly focuses on the variables of air movement and speed, as these factors are the most influential on the variables of air humidity and air temperature.

Result and Discussion

1. Existing Conditions of Honai Houses

A. Hearth System in Honai Houses

The Dani tribe has a tradition or habit that is rare in other regions: burning stones. This stone-burning tradition is intended for cooking, warming themselves, and providing the primary nighttime illumination. This tribe has long been accustomed to inhaling firewood smoke from the fireplaces. As long as the door of the house remains open, the occupants can continue to receive sufficient oxygen. When the door is closed, however, the smoke can be harmful for their respiractory tracts.

When the temperature drops, the fireplaces begin to warm the room. Typically, the fire is lit in the late afternoon, after the Dani men have returned home from searching for food and hunting (Suryani et al., 2015).

B. Respiratory Disease Attacking the Occupants of Honai Houses

In this research, air pollutants or smoke from the fireplaces in the Honai houses required constant inhalation by the occupants. Wood-burning smoke in the house is also a risk factor for pneumonia. This can be made worse if the home does not have enough ventilation or if the kitchen is right next to the living room or bedroom (Ministry of Health of the Republic of Indonesia, 2010).

C. Construction Elements of Honai Houses

i. Flooring

The flooring used in Honai houses is made of straw or grass material. Straw or reed material must be dry so that it will not cause relative humidity in the room to become high due to wet material conditions.

ii. Walls

The walls of Honai houses are composed of two layers of rough wooden planks. The utilization of two layers is meant to keep the room warm and reduce the amount of wind entering the house.

iii. Ventilation

Honai houses only contain small, low-slung doors. These houses lack windows and ventilation. So, the smoke from the inner fireplace stays inside, which can be bad for the health of the occupants.

iv. Roof

The typical Honai house has a straw or reed roof with a dome-shaped wooden structure. This material's gaps let water in. Hence, density is crucial. These properties require constant maintenance to ensure that water cannot enter and that the roof is in good condition.

D. Activities of the Occupants of Honai Houses

The Honai houses are inhabited by several Dani men only. In these houses, several activities are carried out after they work from morning to evening. Kafiar (1986) stated that the occupants of Honai houses constructed their houses as:

i. A place to rest

The main place for Dani men to rest after a day of activities.

ii. A facility to educate the youth

Adult men of the Dani tribe have an obligation to teach boys to continue their struggle and passion.

iii. A place to strategize war and hunting

Dani adult men every day always make strategies before hunting or fighting if there is a dispute.

iv. A facility for gathering and deliberation

Every day, adult Dani men always gather together in the house just to relax, gather, and carry out deliberation activities.

2. Thermal Comfort in Honai Houses

A. Air Temperature

The Decree of the Minister of Health No. 829/Menkes/SK/VII/1999 requires air temperatures between 18°C and 30°C for thermal comfort. The Department of Meteorology, Climatology, and Geophysics of Wamena City (2020) and the author (2022) found that the average temperature outside the Honai houses is 16.4ºC, while inside it can reach 20ºC with fireplace heating. Honai houses are considered comfortable at this air temperature.

B. Relative Humidity

The Department of Meteorology, Climatology, and Geophysics of Wamena City (2020) and the author (2022) discovered that the average humidity outside the typical Honai houses is 70%–75% and inside is 75%–85%. The high humidity is caused by the fireplace smoke trapped in the houses. The Decree of the Minister of Health No. 829/Menkes/SK/VII/1999 states that healthy houses can avoid RTIs by keeping humidity below 70%. Thus, the Honai houses are considered unhealthy and substandard.

C. Wind Velocity

Based on the data compiled from the Department of Meteorology, Climatology, and Geophysics of Wamena City (2020) and the author (2022), the average wind speed outside the Honai houses in the night time is 2 m/s, while inside the house it is 0.2 m/s, so that the cold air from outside the house cannot smoothly enter inside and the relatively warm temperature in the house is maintained. In addition to that, the wind rose in Baliem Kamp recorded by Meteoblue (2022), which is valid data for August 31, 2022 to September 7, 2022, indicates that the majority of the wind came from the east (E) and east-southeast (ESE), with a small amount coming from the southeast (SE).

3. Compared Traditional Houses

A. Traditional Houses in Kampung Naga

Traditional Kampung Naga houses generally feature wood for walls and floors, fiber for roofs, and stones for foundations. Just like Honai houses, these houses contain fireplaces. Hawu, a clay stove used as a fireplace in Kampung Naga houses, is usually placed in the kitchen, which has a front door and several chimneys to evacuate fireplace smoke. The existence of these chimneys is what makes these houses different from Honai houses.

Figure 3 Fireplace system in a traditional house in Kampung Naga
Source: Dewi, 2016

According to the National Department of Statistics (2020), the average air temperature in Kampung Naga is 24.87ºC, the average relative humidity is 84.17%, and the average wind speed is 1.63 m/s. In addition, according to the wind rose data from Meteoblue (2022), the majority of Tasikmalaya's winds flow from the south (S) and south-southeast (SSE).

B. Traditional Houses in Kampung Wana

Figure 4. Typical traditional house in Kampung Wana
Source: Rostiyati, 2013

Kampung Wana is a village situated in East Lampung. In this village, there are still typical traditional houses with unique typologies, such as houses on stilts. Rostiyati (2013) stated that the kitchen in these houses has a large area, so it is usually not only used for fireplaces but also for storing supplies and foodstuffs, as well as cooking and farming equipment. The kitchen and the surrounding spaces are connected by a corridor whose roof height is the same as the kitchen.

According to the National Department of Statistics (2020), Kampung Wana's average air temperature is 27.16^{o}C, the average relative humidity is 82.74%, and the average wind velocity is 0.85 m/s. Additionally, based on the wind rose data from Meteoblue (2022), most Bandar Lampung's winds come from the south (S) and south-southwest (SSW), with a tiny percentage from the east-southeast (ESE), south-southeast (SSE), and southeast (SE).

C. Sa'o House in Kampung Bena

Figure 5. Kampung Bena in Flores
Source: Kadafi, 2019

Kampung Bena is an old megalithic village in East Nusa Tenggara, specifically located in Tiworiwu Village, Jerebu'u, Ngada, Flores. In the village, there is a traditional house called Sa'o. The neighborhood's guarded gardens supply all building materials for Sa'o houses.

Most houses in Kampung Bena are made of wood, while modern materials such as concrete, bricks, zinc, and steel frames are disallowed. These modern materials are only used to preserve the village from erosion and not to build houses (Kadafi, 2019). Sa'o's conical roof is made of wood, bamboo, and reeds. Reed roofs are supposed to keep the house warm in the winter and cool in the summer.

From 2019 to 2021, the average air temperature in East Flores, Gewayantana, is 28.27^{o}C, the average relative humidity is 74.13%, and the average wind speed is 3.03 m/s, as reported by the National Department of Statistics (2021). The wind rose data from Meteoblue (2022) indicates that most of the winds originate from the south (S), with a small part of them coming from the south–southwest (SSW) and north (N).

4. CFD Simulations and the Comparison of the Simulation Results

To prove that the ventilation of a building is a factor that greatly influences the emergence of RTIs among the occupants and the thermal comfort in the building, CFD (Computational Fluid Dynamics) simulations were performed using a software called Autodesk CFD. The Honai house model and the three other traditional house models were used as the subjects in these simulations.

In the simulations using the Honai house model, the parameter was determined as a wind speed of 4 m/s, which is the average wind speed in the Baliem Valley, whose data was obtained from Meteoblue (2022). The wind blows from the direction of the house's door, assuming the house faces east. There are also other parameters, namely the condition of the door as the main inlet or the largest aperture of the house to be open or closed. The following is the result of the wind simulation on the existing Honai house model.

Figure 6. Top view of the wind simulation in the existing Honai house model with the door open
Source: Author, 2022

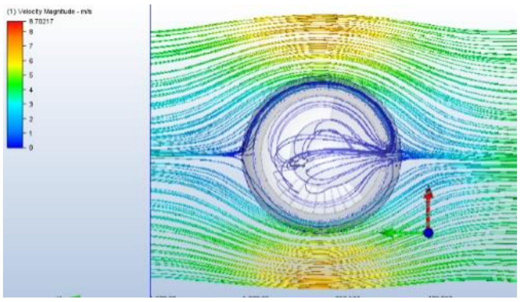


Figure 7. Side view of the wind simulation in the existing Honai house model with the door open
Source: Author, 2022

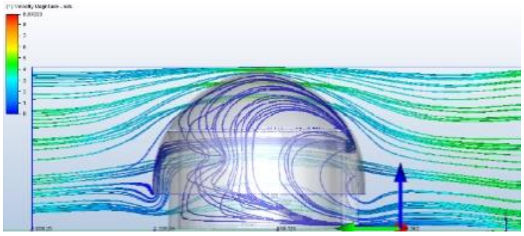


Figure 8. Top view of the wind simulation in the existing Honai house model with the door closed
Source: Author, 2022

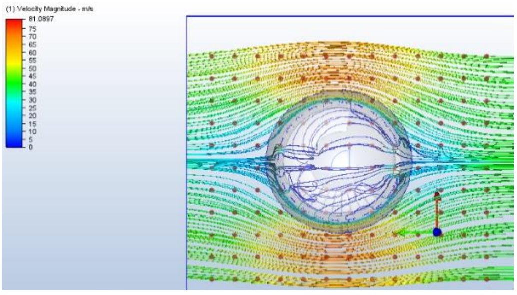
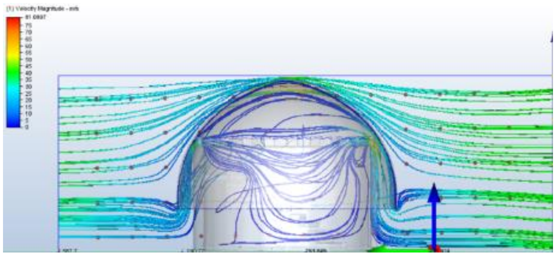


Figure 9. Side view of the wind simulation in the existing Honai house model with the door closed
Source: Author, 2022



Figures 6 and 7 illustrate that the wind entering the house through the door is trapped inside at a minimum speed and comes out slowly through the small gaps between the top-end of the wooden wall and the thatched roof. The wind will carry the fireplace smoke away, but it will be slow and impeded. Thus, the house's occupants inhale smoke, which may lead to respiratory diseases.

The same Honai house model was simulated with the door closed, yielding Figures 8 and 9. From the two figures, the wind can only blow through the little gaps between the top of the walls and the roof.

The main issue is that the air in the fireplace smoke-filled room is trapped and takes a long time to escape through minor holes on the other side of the house. Thus, indoor air quality is riskier with the Honai house model closed than open. With a low wind speed and a high air temperature from the fireplace, the relative humidity inside the house may rise, causing RTI.

1. CFD Simulations on the Model of Traditional Houses of Kampung Naga

In this set of simulations, the parameter was determined as a wind speed of 1.63 m/s, whose data was obtained from the average calculation of the data belonging to the National Department of Statistics of Indonesia, with the following conditions.

Table 5. The conditions of the Kampung Naga Traditional House model to be simulated

Condition	Description
I	The wind blows from the side of the house that features big apertures
II	The wind blows from the side of the house that lacks of apertures

Source: Author, 2022

The following are the floor plan and section of the Kampung Naga Traditional House model used in this simulation, followed by the simulation results.

Figure 10. Floor plan and section of the Kampung Naga Traditional House model
Source: Author, 2022

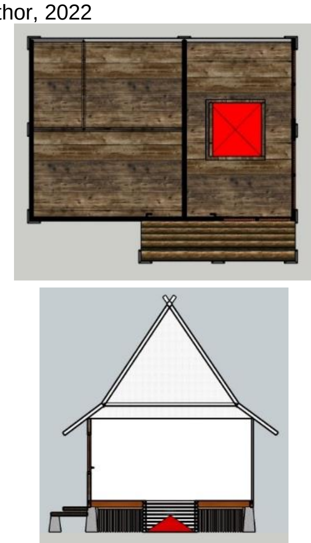


Figure 11. Top view of the wind simulation in the Kampung Naga traditional house model with the condition I
Source: Author, 2022

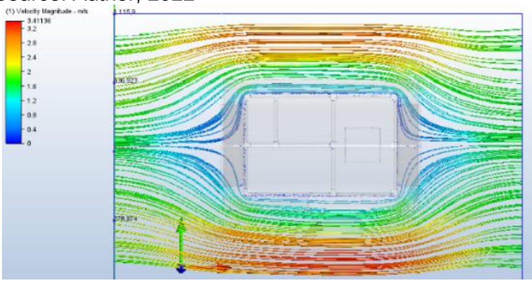


Figure 12. Front view of the wind simulation in the Kampung Naga traditional house model with the condition I
Source: Author, 2022

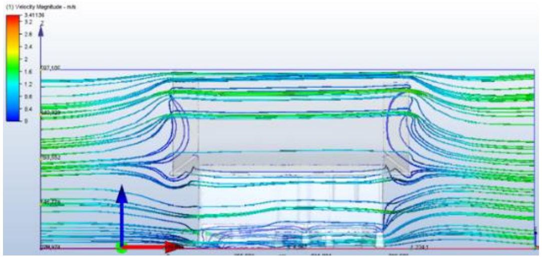
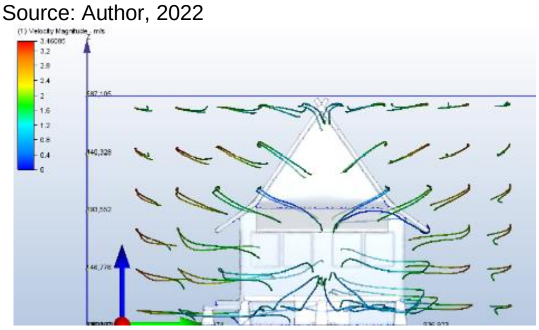


Figure 13. Side view of the wind simulation in the Kampung Naga traditional house model with the condition I
Source: Author, 2022



Based on the simulation results above, it can be stated that with condition I, the smoke from the fireplace can be smoothly carried away by the wind at a speed ranging from 1.2 m/s to 2.0 m/s to the outside of the house, so as not to cause air pollution inside the house.

Figure 14. Top view of the wind simulation in the Kampung Naga traditional house model with the condition II
Source: Author, 2022

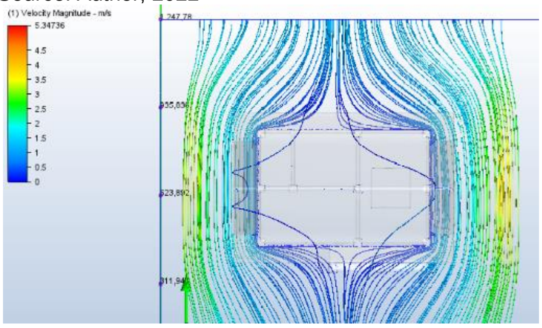


Figure 15. Rear view of the wind simulation in the Kampung Naga traditional house model with the condition II
Source: Author, 2022

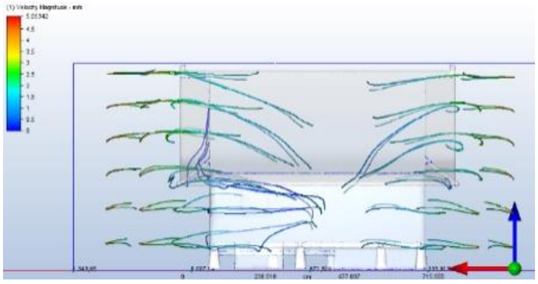
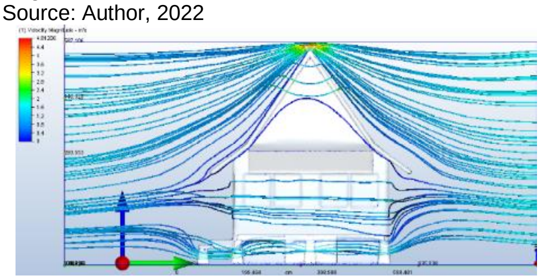


Figure 16. Side view of the wind simulation in the Kampung Naga traditional house model with the condition II
Source: Author, 2022



Based on the simulation results above, it can be stated that with condition II, the smoke generated from the fireplace can be carried by the wind at speeds ranging between 1.2 m/s and 1.6 m/s to the outside of the house, so it does not cause air pollution in the house. inside the house.

2. CFD Simulations on the Model of Traditional Houses of Kampung Wana

In this set of simulations, the parameter was determined in the form of a wind speed of 0.85 m/s, in which the data on the average wind speed is obtained from the average calculation of the data belonging to the National

Department of Statistics of Indonesia, with the similar conditions as shown in Table 5.

The following are the floor plan and section of the Kampung Wana traditional house model used in this simulation, as well as the simulation results.

Figure 17. Floor plan and longitudinal section of the Kampung Wana traditional house model
Source: Author, 2022

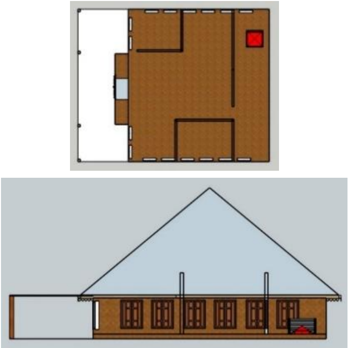


Figure 18. Cross section of the Kampung Wana traditional house model
Source: Author, 2022

Figure 19. Top view of the wind simulation in the Kampung Wana traditional house model with the condition I
Source: Author, 2022

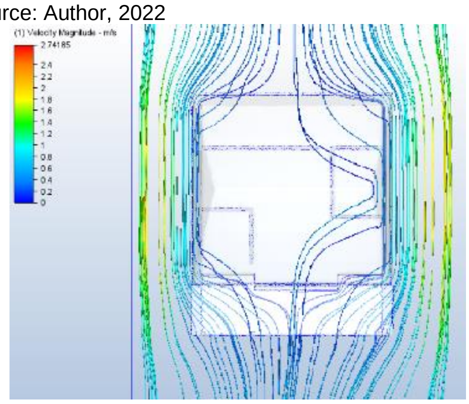


Figure 20. Front view of the wind simulation in the Kampung Wana traditional house model with the condition I
Source: Author, 2022

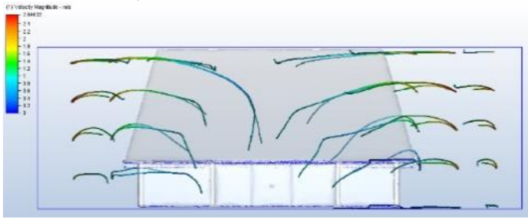
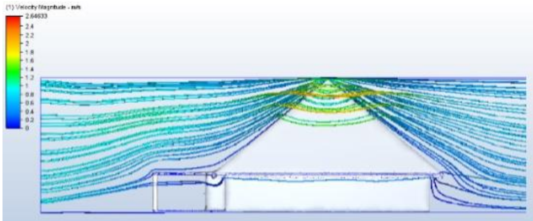


Figure 21. Side view of the wind simulation in the Kampung Wana traditional house model with the condition I
Source: Author, 2022



Based on the simulation results above, it can be stated that under condition I, the smoke generated from the fireplace can be smoothly carried out by the wind at a speed ranging between 0.2 m/s and 0.8 m/s in the active area of the house and by the wind at a speed ranging between 1.0 m/s and 2.0 m/s in the roof area.

Figure 22. Top view of the wind simulation in the Kampung Wana traditional house model with the condition II
Source: Author, 2022

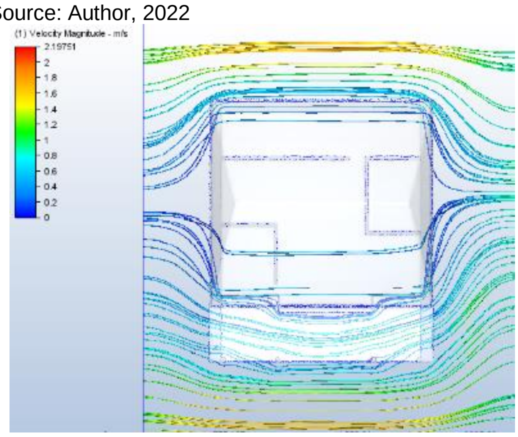


Figure 23. Front view of the wind simulation in the Kampung Wana traditional house model with the condition II
Source: Author, 2022

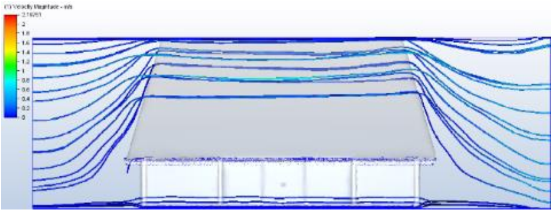
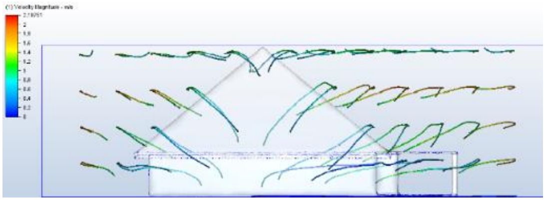


Figure 24. Side view of the wind simulation in the Kampung Wana traditional house model with the condition II
Source: Author, 2022



Based on the simulation results above, it can be stated that with condition II, the wind can still enter the house quite smoothly through the openings on one side of the building and out through the openings on the other side. Thus, the smoke from the fireplace can be carried by the wind at a speed ranging from 0.2 m/s to 0.8 m/s to the outside of the house, so it does not cause air pollution inside the house.

3. CFD Simulations on the Model of Sa'o Traditional House

In this set of simulations, the parameter was determined in the form of a wind speed of 0.85 m/s, in which the data on the average wind speed is obtained from the average calculation of the data belonging to the National Department of Statistics of Indonesia, with the similar conditions as shown in Table 5.

The following are the floor plan and section of the Kampung Wana traditional house model used in these simulations, followed by the simulation results

Figure 25. Floor plan and section of the Sa'o House model
Source: Author, 2022

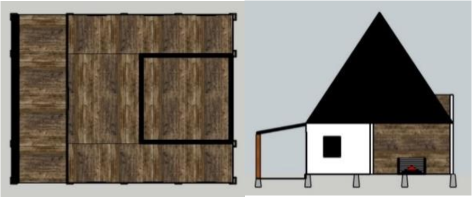


Figure 26. Top view of the wind simulation in the Sa'o House model with the condition I
Source: Author, 2022

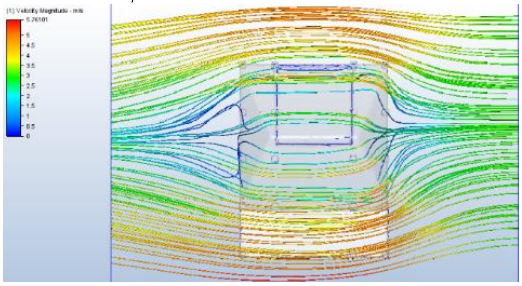


Figure 27. Front view of the wind simulation in the Sa'o House model with the condition I
Source: Author, 2022

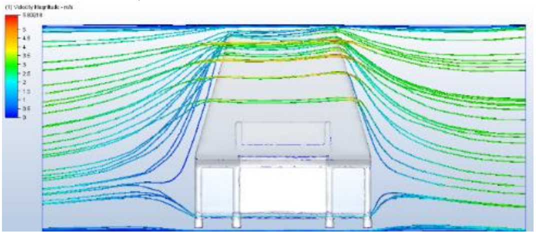
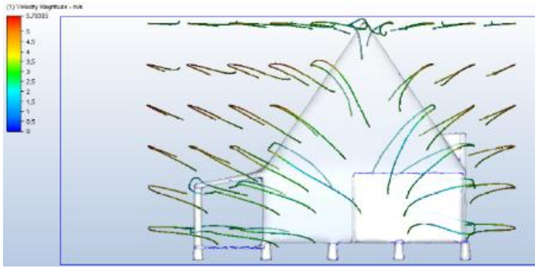


Figure 28. Side view of the wind simulation in the Sa'o House model with the condition I
Source: Author, 2022



Based on the simulation results above, it can be stated that, with condition I, the smoke from the fireplace can be smoothly carried by the wind at speeds between 3.0 m/s and 4.5 m/s outside the house, so the smoke does not cause air pollution inside the house. Although the wind coming in is relatively strong, it only circulates in the roof area so that it will not affect the comfort of the occupants inside.

Figure 29. Top view of the wind simulation in the Sa'o House model with the condition II
Source: Author, 2022

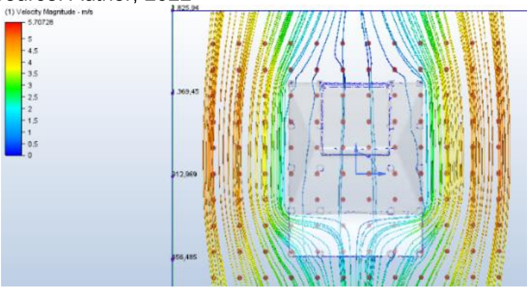


Figure 30. Rear view of the wind simulation in the Sa'o House model with the condition II
Source: Author, 2022

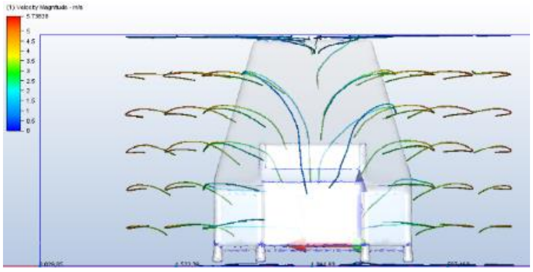
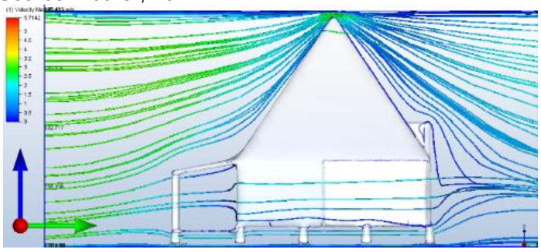


Figure 31. Side view of the wind simulation in the Sa'o House model with the condition II
Source: Author, 2022



Based on the simulation results above, condition II allows the wind to carry fireplace smoke at 1.0 m/s to 2.0 m/s outside the home, reducing air pollution inside. The Sa'o house's air circulation conditions differ from Honai houses' despite its tiny apertures. When the door is closed, Honai houses receive little breeze, even none at all.

Conclusion

Based on the research that the author completely conducted, it can be concluded into several points as follows.

1. The speed of the wind blowing into the Honai houses impact the occupants' health and thermal comfort since it carries fireplace smoke outside. Most Honai houses have no air ventilation to take the smoke outside, so the breeze is restricted within. Due to the smoke, the interior of the house becomes warmer and more humid, and the occupants automatically inhale the smoke. Fungi, germs, and viruses in the house's dampness potentially infect the occupants' respiratory systems.
2. Honai, Naga, Wana, and Sa'o houses are situated in regions that have relatively cold climatic conditions, so most of the people have fireplaces in their homes. Among all these traditional houses, Honai houses are the only ones that have the most closed interiors without any ventilation or apertures, causing smoke from the fireplaces to be blocked in the houses and inhaled by the occupants. So, it can be stated as the main cause of the high percentage of cases of respiratory tract disease in Papua.
3. Unlike Honai houses, the comparator traditional houses have sufficient ventilation systems so that the winds can enter smoothly into the houses and carry the fireplace smoke to the outside of the houses. This is evident from the results of the CFD simulations using the related traditional house models as the subjects. With the wind and smoke being carried out of the house, the intensity of smoke potentially inhaled by the occupants of the house is small, the humidity of the air inside the house is lower, and the potential for respiratory tract disease in the occupants is also lower.
4. The author would like to suggest that the occupants of the existing Honai houses provide an adequate area of openings between the top-end of the wooden wall and the thatched roof for the fireplace smoke to exit easily. Therefore, the number of RTI sufferers in Papua might decrease.

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