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INDOOR AIR QUALITY STUDY OF COASTAL BAILEO BUILDINGS, WEST SERAM, MALUKU

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ABSTRACT

Thermal comfort is one of the most influencing aspects to affect comfort level in the interior. Indoor Air Quality (IAQ) is one part of thermal comfort parametric often suggested in any building assessment for its role to affect health and comfort. IAQ is influenced by physical factors (temperature, air humidity and air velocity) and chemical factors (in the form of substances in the air). Traditional buildings in Indonesia have long since considered IAQ in its passive design approach, one of them is in Baileo. This paper reports an investigation of IAQ in coastal Baileo in West Seram, Maluku. This quantitative research is conducted in method comparative analysis method. This paper discusses the relation between IAQ in Baileo to building formation and materials selection. The measurement done shows that IAQ in coastal Baileo in West Seram has good performance on both physical and chemical factors.

Keywords: Indoor Air Quality; coastal Baileo; West Seram.

INTRODUCTION

Indoor Air Quality (IAQ) is an aspect that greatly affects the room occupants' health and comfort. IAQ is influenced by the 2 main factors, namely physical factors such as air humidity and air velocity, and chemical factors in the form of chemical substances in the air such as HCHO and TVOC. The presence of physical pollutants such as particulates materials (PM) (solid substances in the air) can affect air quality. Particulates (PM) can be classified based on its size, ranging from PM1, PM2.5, PM10 (number represent size in µgram/m^3). Large particulates such as PM10 can cause irritation to the eye while small particulates have a more dangerous effect since the smaller the particle size, the easier it is to enter the respiratory system and even the human blood circulation.

Even though the health level of the room can be learned through observing physical and non-physical factors, the occupants comfort should not be neglected. The convenience of space can be assessed through the level of thermal comfort experienced by its users. There are many aspects that affect the tolerance level of thermal comfort, from the physical that provide stimulation to the senses, up to non-physical aspects such as beliefs, backgrounds and habits.

Traditional building has played an important role in community gathering in its public area since a long time ago. The passive approach of it has been known for its comfort and used for study and implemented in modern design. However, this understanding may come in the subjective pass of knowledge and quantitative data provided minimally to support how comfortable and effective this passive design approach is. This reason affects how the renovation is done to the traditional building that merely just retains its decorative elements.

This research is conducted in Baileo building in Pununggan where the building has just been rebuilt. Baileo is a traditional house from the province of Maluku which is used as a place for any custom or other important activities in the community to date (Handoko, 2007). Baileo building in general is a building with many openings and has a higher floor height of the room. It has different characteristics ranging from the formation, arrangement of the room and the material based on historical origins, locations and materials used (Wattimena, 2013). Even though 2 Baileo in Pununggan used in this research built in a mountainous area, there are differences in the formation of buildings and the surrounding environment in the two Baileo, which allows differences in its IAQ performance. This research aimed to provide measured data and study the comfort of the Baileo building which is still used today, to measure and compare its pollutant content, and to study the comfort level experienced by the users.

Indoor Air Quality Aspect

According to the National Health Medical Research Council, indoor air quality is defined as air inside a building that is occupied by a group of people who have different levels of health, which is accumulated for at least one hour. Greenship Rating Tools for Spaces in Version 1.0 gives priority points for the quality of air in the room in the design of a room in space (GBCI, 2012). There are some factors affecting IAQ. Those are the physical and chemical factors.

The physical factors parameters are temperature, relative humidity, and air movement. Comfort air temperature is between 18°-30°C with relative humidity (RH) range between 40% - 60% (Givoni, 1998). The temperature in Indonesia is classified in 3 levels of comfort (Karyono, 2013): (1) Cool comfortable in range 20.5°-22.8°C (effective temperature), (2) Optimal comfortable temperature between 22°-25°C, (3) Warm comfortable between 25.8°-27.1°C with RH ranging from 62%-85% for the past year (Meteorological and Geophysical Centre Indonesia, 2019). Air exchange is the process of replacing air that contains a lot of CO_2 to fresh air with higher O_2. Human activities in the form of breathing, smoking, and cooking can produce CO_2. Expected air exchange to allow comfort in passive ventilation is 5-0.1 ACH (Air Change Per Hour) for or equal to a minimum of 0.25 m/s (EPA, 2003). Thermal comfort is a parameter that is greatly influenced by human perception.

The chemical factors parameters often measured in any harmful chemical materials found in the air (EPA, 2003). The presence of chemical pollutants may cause discomfort to sickness. Common chemicals found indoors are carbon monoxide (CO), formaldehyde (H_2CO), benzene (C_6H_6), nitrogen dioxide (NO_2), and naphthalene ($C_{10}H_8$). Other indoor air pollutants that have been studied are volatile organic compounds (VOCs) and phthalates. Volatile organic compounds (VOCs) are emitted by many consumer products and decomposing materials. Three of the most worrisome are formaldehyde, benzene, and naphthalene (GreenFacts Scientific Board, 2019).

Physical Polutan

Physical pollutants that are easily found in the form of particulates (EPA, n.d) that can have a negative impact on health are PM1 (particulate size <1 µgram / m3), PM2.5 (particulate size <2.5 µgram / m3), PM10 (particulate size < 1 µgram / m3) where the smaller the particle size will have a greater impact on human health (Tatty, 2009).

Tabel 1. Particulates Size and Health Aspect

Name	TV (µgram/m^3)	Source	Health Effect
PM_{10}	150	Sand Dust	Eye irritation
$PM_{2,5}$	65	Fine Dust	Respiratory tract irritation
PM_1	42.5	Particles from the combustion of fine dust (very small)	

Source: Indonesian Ministry of Health and BMKG

Chemical Polutan

As the increment of chemicals used in buildings nowadays, VOCs (Volatile Organic Compounds) become major and commonly found in buildings either new or old (since the old building may also be renovated). VOCs are organically-occurring hydrocarbons that evaporate at room temperature, meaning they have high photochemical volatility, or photochemical reactivity (Lafond, ND). VOC's major sources are furniture and building/ finishing materials such as paint, flooring, and carpet. However, consumer products and some indoor activities related to heat such as cooking and incense burning mat also be transient sources of VOC. VOCs generated outdoors can be transported indoors and deteriorate indoor air quality. Due to the complexity of the emitted VOC mixtures, TVOC is usually employed as a useful parameter to evaluate VOC emission and IAQ (Jiang *et.al.* 2017).

One of the most common VOC found is formaldehyde or HCHO. Exposure to HCHO can cause irritation of the eyes and upper respiratory tract. HCHO has been classified as a Group 1 human carcinogen by the International Agency for Research on Cancer (Marutzky et al., 2010). Formaldehyde concentrations in dwellings vary according to the age of the building, temperature and relative humidity, the air exchange rate, and the season (WHO guidelines for indoor air quality: selected pollutants, 2010). Its threshold limit value is 0.1 ppm TLV-TWA (Threshold Limit Value - Time Weighted Average (usually 8 hours)) and 0.3 ppm TLV-STEL (Threshold Limit Value - Short Term Exposure Limit (usually 15 minutes)) (Lafond, ND).

METHODOLOGY

This research is conducted in narrative quantitative methods using 3 Baileo in the coastal area as a case study. Data collected on site using observation towards occupants, measurements on selected physical and chemical pollutants, and spreading questionnaires to building occupants. Data collected then processed by comparing them with literature and acceptance standards. Main data collected are temperature, air velocity, humidity, wind direction, the results of physical and chemical pollutants measured in the air, and occupants comfort level. The study was conducted on January 1st to January 25th, 2019.

The study was conducted in 3 Baileo namely Baileo Rumahkay, Baileo Tihulale and Baileo Kamarian on empty and occupied condition. The occupants quantity will illustrate the use of space

during the Saniri Meeting (Meeting of accountability and resolution in one period) conducted by the king and the customary management ranging from 10-12 local occupants. These occupants will serve as permanent respondent to answer the questionnaires. Due to the remote location and unavailability of laboratorium with a distance of less than 2 hours from the researched object, some parametrics of complete IQA test were not done such as biological pollutant and swab test.

Experimental Apparatus

In this paper, the VSON type WP6910 Indoor Air Quality Monitor was used to measure PM $_1$, $PM_{2.5}$, PM_{10}, TVOC, and HCHO. The IAQ monitor used 1 metre apart throughout the interior with 75 cm height. Air temperature and humidity were measured using Lab Series HTC - 1 digital thermometer and hygrometer. As per air velocity was measured with Gm816 digital wind speed anemometer.

Site Selection

The Baileo building is a place for carrying out traditional activities, portraying the character and community trust and symbols of the existence of customary law in a village. The Baileo building is used as a place to carry out traditional activities such as Saniri Negeri meetings. The existing Baileo building adapted to the formation of the Baileo building that had been owned by the community in Rumahkay, Tihulale, and Kamarian before with some changes agreed at the custom meeting.

The Baileo studied are located in coastal areas surrounded by plantation and close to highways due to development done by the government and to ease the access for locals. Architectural anatomy of these 3 Baileo are similar. They have higher floors ranging from 30-100 cm. The roofs of Baileo are sloping roofs with the shape of the gable and hip roof with relatively high slope. The formation of high slope allows the sunheat to be cooled down before entering

Figure 1. Baileo Rumahkay (marked as 1)

Figure 2. Baileo Tihulale (marked as 1)

Figure 3. Baileo Kamarian (marked as 1)

Tabel 2. Baileo Architectural Specification

	Baileo Rumahkay	**Baileo Tihulale**	**Baileo Kamarian**
Perimeters	Near asphalt street with restricted green area and cemented fence as border.	Almost directly adjacent to the residential high street	Surrounded by large green area without fence and close with settlement and church (building which highly valued by residents)
Temperature	Outdoor temperature: 33°C Indoor temperature: 30.2°C (empty), 31°C (occupied) Felt like: 35°C	Outdoor temperature: 34°C Indoor temperature: 30.2°C (empty), 30.2°C (occupied) Felt like: 35°C	Outdoor temperature: 32°C Indoor temperature: 30.2°C (empty), 31°C (occupied) Felt like: 35°C
Air Velocity	.2 m/s -0.5 m/s	0.8 m/s -2.2 m/s	0.8 m/s -2.2 m/s
Humidity	55%	55%	55%
Room humidity	62%	58%	57%
Wind direction	South East	South East	South East
Floor (measured from surrounding land)	An increase of 30 cm and 70 cm with cement structure. Interior floor covered by cement.	An increase of 90 cm with a coral structure. Interior floor covered by river stone.	An increase of 100 cm with cement structure. Interior floor covered by sand.
Wall and partition	High exterior wall (275 cm) and interior partition (160 cm) in area of pengurus Saniri made from cement.	Partition with 90 cm height made from gaba-gaba (sago leaf stalk) and Ulin wood.	Partition with 90 cm height made from Gupassa wood with a little cavity.
Roof	Gable roof, no maturama. Made from gaba-gaba and Merbau wood.	Hip roof, with maturama. Made from gaba-gaba.	Mix gable and hip roof, with maturama. Made from gaba-gaba and Gupassa wood as structure.
Room arrangement			

the room beneath. The roof is also equipped with Maturama (openings on the rooftop) to dilute the hot air and reduce humidity. For the wall system, all Baileo are using semi closed walls with differences in opening sizing.

RESULTS AND DISCUSSION

Physical Pollutant

The particulate level (PM_1, $PM_{2.5}$, and PM_{10}) examined in 3 Baileos are far below the threshold value determined by the Indonesian Ministry of Health and BMKG. Based on observations on the number of particulates, it was found that the particulate in Baileo Rumahkay was higher than in Baileo Tihulale and Baileo Kamarian. There is a decrease in particulate levels of about 0.01-0.02 µgram/m^3 in the room from empty to occupied. However, this increment is not significant.

Higher particulate found in Baileo Rumahkay was affected by its physical adjacencies. Rumahkay is very near to asphalt high street with relatively lower

Tabel 3. Baileo Architectural Specification

Baileo	Indicator	PM_1 (µgram/m^3)		$PM_{2.5}$ (µgram/m^3)		PM_{10} (µgram/m^3)	
		Empty room	Occupied	Empty room	Occupied	Empty room	Occupied
Rumahkay	Highest	0.08	0.08	0.11	1.0	0.12	0.11
	Frequently	0.06	0.06	0.1	0.09	0.1	0.1
	Lowest	0.05	0.03	0.08	0.05	0.09	0.09
Tihulale	Highest	0.03	0.05	0.05	0.07	0.05	0.08
	Frequently	0.03	0.03	0.05	0.05	0.05	0.03
	Lowest	0.03	0.02	0.03	0.03	0.03	0.03
Kamarian	Highest	0.07	0.07	0.1	0.1	0.11	0.09
	Frequently	0.07	0.07	0.1	0.1	0.11	0.04
	Lowest	0.07	0.04	0.1	0.07	0.11	0.03

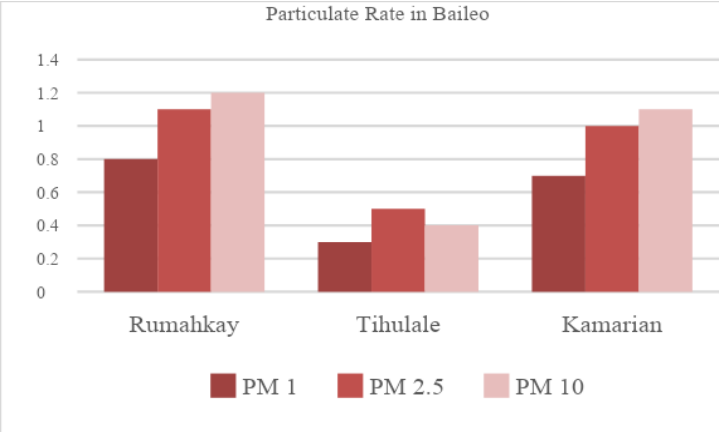


Figure 4. Particulate Comparison between Baileos

air velocity compared to the other 2 Baileos. As well as its floor is risen lower compared to the other 2 Baileos, allowing higher chance of dust and sand from outside to enter the interior. However, the existing particulate in Rumahkay was slightly different than in Kamarian even Kamarian suggests the highest floor rise. However the interior of Baileo Kamarian is using sand as its main floorings that suggest the existing PM_{10} to exist even without entry from the dust outside. The best performance was found in Baileo Tihulale. The raised floor and main door that is not facing the main street helps to reduce the possibility of any particulates entry. The material of the floor is using river stone and that does not easily keep dust.

Chemical Pollutant

Based on measurements done in the research sites, there are no chemical pollutants found in forms of TVOC nor HCHO. The levels of chemicals in the air resulting in an acidic scent is zero. The inexistence of these substances is highly related to material and finishing selection. All 3 Baileos are using natural material such as varieties of woods, gaba-gaba (sago leaf stalk), stone, sand, and small amounts of cement as foundation only. The material selected applied with no further finishing and place accordingly as it is. Apart from that, the openings of all 3 Baileos are relatively big (over 40% of each wall) with sufficient air velocity to keep the indoor well naturally ventilated.

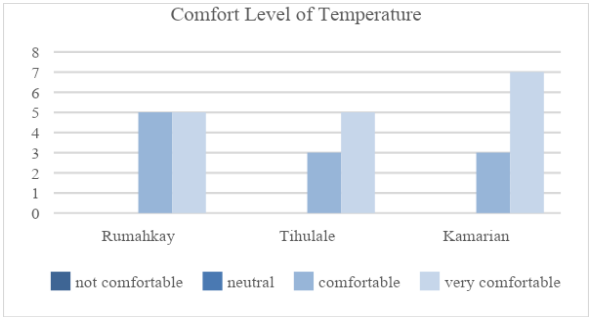
Figure 5. The Atmosphere of Baileo Rumahkay, Tihulale, and Kamarian (from top to bottom)

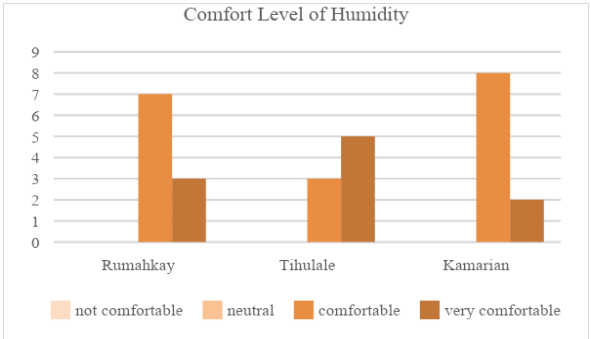
Comfort Level

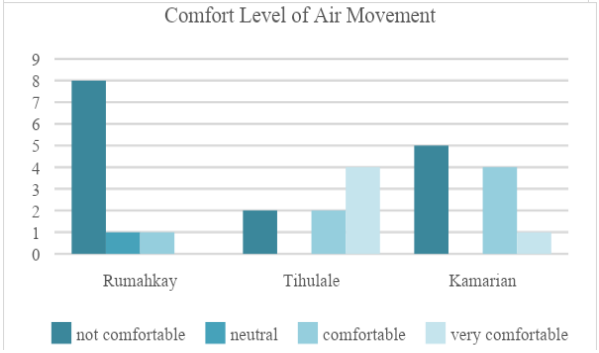
There are 10-12 permanent respondents used in this research to be the benchmark of thermal comfort sensation. Thermal comfort is highly related to

physical and personal factors. Physical factors such as air velocity, air temperature, relative humidity, and radiant temperature. Personal or non physical factors are relative to personal experience, metabolism rate, and psychological factors relate to mood. Therefore, according to physical factors, the air velocity for Baileo Rumahkay is sufficient for 0.2 m/s -0.5 m/s, and for the other 2 it is slightly under. Ideal Air exchange is 5-0.1 ACH (Air Change Per Hour) for or equal to a minimum of 0.25 m/s. The ambient temperature can be categorized as hot or over what is presumed as warm comfortable between 25.8 ºC - 27.1ºC. The ambient temperature existed on average 34°C outdoors, 30.2°C indoor, and felt like 35°C with RH at a high threshold 55-62%.

However, the occupants find that the rooms are comfortable. Based on the response given, the majority of respondents tend to be happy with the temperature, humidity, and the scent inside Baileo. Even though the majority of the participants in Baileo Rumahkay and Kamarian are not happy with the airflow inside Baileo. The occupants find existing particulates as normal and not disturbing.







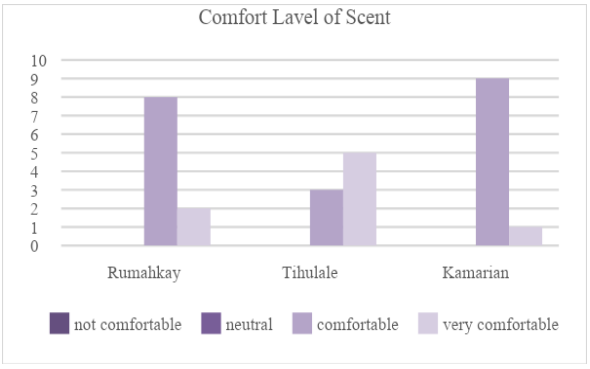


Figure 6. The Occupants Respond to Thermal Comfort Components at Baileo Rumahkay, Tihulale, and Kamarian (from top to bottom)

CONCLUSION

Indoor Air Quality is an important aspect in the design of a building because it affects the health and comfort of the room occupants. IAQ in the coastal Baileo in West Seram needs to be considered because the Baileo building has a traditional value and is still used by the people of Maluku today. IAQ in coastal Baileo are below the Threshold Value (TV). Low levels of pollutants occur due to good air exchange and the use of natural materials. Good air exchange is achieved from the formation of open wall systems and relatively non-massive building blocks. The interior material also takes effect because of their characteristic as an isolator and gives the cold impression despite the colours. Interior finishing with oil based thinner increases the chemical content compared to water based finishing. The comfort of the room user can be identified based on existing standards, however, the comfort level of each person can be different because it is highly influenced by social, cultural and habitual factors that shape a person's perception of perceived comfort.

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