Evaluation of air quality and thermal comfort in classroom

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Abstract. Air quality in the classroom can affect the health of students because students spend a lot of time in the classroom for learning activities. In addition to the air quality of healthy buildings, it is also related to thermal comfort. During the learning process, a comfortable learning interaction is needed, to make it easier for teachers to deliver learning materials. Therefore, this study evaluated the classrooms of SDN 10 Banda Aceh and SDN Kajhu Aceh Besar which were used as objects of research studies. This study uses a quantitative approach through measuring air quality parameters, namely CO2 (Carbon Dioxide), HCHO (Formaldehyde), and TVOC (Total Volatile Organic Compound) concentrations, while thermal comfort, namely air temperature, humidity, and wind speed using an air quality detector and hotwire anemometer. The level of air quality is evaluated based on MENKES/SK/2011 while thermal comfort is evaluated based on the Indonesian national standard SNI and adaptive thermal comfort. Based on the results of the research, the air quality in both schools still meets the MENKES/SK/2011 standard, while the level of thermal comfort in both schools is classified as uncomfortable according to SNI and adaptive thermal comfort.

1. Introduction
Indoor air quality greatly affects human health, because almost 90% of human life is indoors. Likewise, the air quality in the classroom can affect the health of students, because students spend a lot of time in the classroom for learning activities. Therefore, it is very important to pay attention to the air quality in the classroom [1]. If we go back to the Ministry of Health regulations [2], then the indoor air quality standard is already regulated in the law. Therefore, researchers feel the need for further research as a form of evaluation with a focus on evaluating air quality in classrooms. This study aims to assess the performance of classroom windows to reduce air pollution in elementary school classrooms in the cities of Banda Aceh and Aceh Besar.

In addition to the air quality of healthy buildings, it is also related to thermal comfort. During the learning process, a comfortable learning interaction is needed, because this can generate interest and attention from students to make it easier for teachers to deliver learning materials. Comfort is largely determined by the conditions in the environment around which the activity is carried out, both in terms of the adequacy of the space for student and teaching staff activities, as well as the adequacy of supporting infrastructure which includes lighting, temperature, and humidity, and the noise of a room [3].
Comfort and feeling comfortable is a person's comprehensive assessment of his environment. Convenience cannot be represented by a single number. Thermal comfort in an environment can affect human feelings so that it can cause a feeling of comfort or discomfort. Comfort and discomfort cannot be measured in numerical units [4].

Thermal comfort standards already exist in SNI 03-6572-2001 [5]. There are three levels of a comfortable temperature for Indonesians in units of °C TE, comfortable cool conditions the temperature ranges from 20.5 °C to 22.8 °C, for optimal comfort it ranges from 22.8 °C to 25.8 °C, while for warm comfort it ranges from 25.8 °C to 27.1 °C.

In the tropics, much must be considered in the design elements to produce thermal comfort, such as shade design, selection of building materials, and others [6]. In addition to thermal comfort in a study conducted by Tri Harso Karyono [7], the human body has an adaptive ability to adapt to the thermal environment. The comfortable temperature in each area also differs according to the average outdoor temperature. Karyono's study on thermal comfort in several regions in Indonesia resulted in the following equation:

\[ PCT = 0.749T_d + 5.953 \]  \hspace{1cm} (1)

PCT is a comfortable temperature prediction. Td is the average outdoor temperature. Two standards can be used to determine thermal comfort in a room. So by using this standard, the level of thermal comfort in both schools can be known.

2. Research method

2.1. Type of research

This type of research is quantitative descriptive research. Air quality research in classrooms is carried out by measuring the concentration of CO2 (Carbon Dioxide), HCHO (Formaldehyde), and TVOC (Total Volatile Organic Compound), while thermal comfort in classrooms is carried out by measuring air temperature, humidity, and wind speed.

2.2. Location and time of research

The research was conducted in two public elementary schools. The first is SDN 10 Banda Aceh and the second is SD Negeri Kajhu Aceh Besar. The research was carried out in each school, precisely in two classrooms where there were student activities. The research implementation at SDN 10 Banda Aceh takes two days, namely March 18, 2021 to March 19, 2021. Likewise, the implementation of research at SD Negeri Kajhu Aceh Besar takes two days, namely Juni 2, 2021 to Juni 3, 2021 starting at 08.00 - 12.00 WIB.

2.3. Research instruments

A research instrument is a tool used to measure the observed natural and social phenomena. The following are the instruments used based on the problems to be studied.

| No | Object of research          | Data                                                                 | Method/technique |
|----|-----------------------------|----------------------------------------------------------------------|------------------|
| 1. | Air Quality Aspect          | 1. Concentration of CO2(Carbon Dioxide)                              | Measurement      |
|    |                             | 2. Concentration of HCHO(Formaldehyde)                              |                  |
|    |                             | 3. Concentration of TVOC(Total Volatile Organic Compound)            |                  |
| 2. | Thermal Comfort Aspect      | 1. Air Temperature (°C)                                             | Measurement      |
|    |                             | 2. Air Humidity (%)                                                 |                  |
|    |                             | 3. Air Speed (m/s)                                                  |                  |
The following are tools used in field measurements. Air Quality Detector is a tool to measure air temperature, humidity, CO₂ (Carbon Dioxide) concentration, HCHO (Formaldehyde) concentration, and TVOC (Total Volatile Organic Compound) concentration in classrooms. Then the Hot Wire Anemometer is a tool to measure air velocity in classrooms.

![Air Quality Detector](a) ![Hot Wire Anemometer](b)

**Figure 1.** Measuring instrument. (a) Air Quality Detector; (b) Hot Wire Anemometer.

2.4. Data analysis techniques

Air quality data analysis conducted in this study used quantitative analysis. The data obtained were then compared with the standard used as a reference in the study. While the data from the measurement of thermal comfort were analyzed using psychometric charts [8] and monogram charts [9] to obtain the effective temperature value.

The measurement data were analyzed using psychometric charts to obtain the wet-bulb temperature (WBT) value. The WBT value is obtained from the dry-bulb temperature (DBT) and air humidity (Rh) values which are connected in a psychometric graph. After the WBT value is obtained, a monogram graph is used to obtain the effective temperature value by connecting the DBT, WBT, and Wind Speed values. Furthermore, the effective temperature value that has been obtained is compared with the value of SNI 03-6572-2001 to see the level of thermal comfort.

Adaptive thermal comfort is obtained from the Tri Harso Karyono equation [7]. The average air temperature data is obtained from the Aceh BMKG, then entered into the formula to get a comfortable temperature value. Then the measurement results will be entered into a graph to see a comparison of the comfort level of each class.

3. Results and discussion

3.1. Data description

3.1.1. Situation analysis

This measurement was carried out in public elementary school classrooms. There are two schools selected, the first is SDN 10 Banda Aceh which is located on Jln. Tgk Imum Lueng Bata. Komplek Perumahan Cinta Kasih, Panteriek, Kec. Lueng Bata, Kota Banda Aceh Prov. Aceh. This school is equipped with 12 study rooms, 1 laboratory, and 1 library. Then the second one is SD Negeri Kajhu Aceh Besar which is located in Kajhu Village, Kajhu, Kec. Baitussalam, Kab. Aceh Besar Prov. Aceh. This school is equipped with 12 study rooms and 1 library.
3.1.2. Measurement location

![Location Diagram](image1)

Figure 2. Measurement Location. (a) SDN 10 Banda Aceh; (b) SDN Kajhu Aceh Besar.

Measurements were carried out in four classes, two classes at SDN 10 Banda Aceh and two classes at SDN Kajhu Aceh Besar.

3.1.3. Measuring points

Data in the field will be obtained from measurements of air temperature, humidity, air velocity, CO2 (Carbon Dioxide) concentration, HCHO (Formaldehyde) concentration, and TVOC (Total Volatile Organic Compound) concentration with the height position of the tool parallel to the student's breathing in a sitting position around 105 cm.

![Measurement Point](image2)

Figure 3. Measurement Point in Classroom

3.2. Measurement results

3.2.1. Air quality measurement (AV, HCHO, TVOC, CO2)

Based on Figure 4, it is known the values of wind speed, HCHO, TVOC, and CO2 in each class. If there is air in the classroom that enters the room, then the concentration values of HCHO, TVOC, and CO2 will decrease. This can be seen when the wind speed in the classroom increases, the concentration of HCHO, TVOC, and CO2 will decrease. Vice versa, if there is no air entering the classroom or the wind speed in the classroom decreases, then the concentration values of CO2, HCHO, and TVOC will increase. Therefore, air exchange using natural ventilation is needed to dilute air pollutants in the classroom.
3.2.2. Air quality measurement (air temperature and air humidity)

Based on Figure 6, it is known the value of air temperature and humidity in each class. The average air temperature in class 4 and class 6 is not too different. However, for air humidity class 6 has a higher average value than class 4.

In addition, if the air temperature in the classroom increases, the humidity in the classroom will decrease, and vice versa. If the air temperature in the classroom is low or decreases, the humidity in the classroom will increase. Therefore, air exchange using natural ventilation is needed to reduce the air temperature in the classroom so that the humidity in the classroom will also decrease.
Based on Figure 7, it is known the value of air temperature and humidity in each class. The average air temperature in class 3 and class 4 is not too different. However, class 3 air humidity has a higher average value than class 4.

In addition, if the air temperature in the classroom increases, the humidity in the classroom will decrease, and vice versa. If the air temperature in the classroom is low or decreases, the humidity in the classroom will increase.

3.2.3. Indonesian National Standard thermal comfort

Based on Figure 8, it can be seen the level of thermal comfort in each class in the effective temperature based on SNI 03-6572-2001. Class 4 on the first day gives a comfortable warm sensation at 08.00-08.30 while grade 6 at 08.10-08.40. The hours of 09.00-12.00 are included in the uncomfortable category according to SNI 03-6572-2001. On the second day of class 4, there is a warm comfortable sensation at 08.00-09.00, while grade 6 is at 08.10-08.40 but for 09.00-12.00 it is included in the uncomfortable category according to SNI 03-6572-2001.
Based on Figure 9, it is known that the level of thermal comfort in each class in the effective temperature is based on SNI 03-6572-2001. Class 3 on the first day provides a comfortable warm sensation at 08.00-08.30 while class 4 is at 08.10-08.40. Class 3 on the second day has a warm and comfortable sensation at 08.00-09.00 while grade 4 is at 08.10-08.40. For 09.00-12.00, the average is included in the uncomfortable category according to SNI 03-6572-2001.

### 3.2.4. Adaptive thermal comfort

#### Table 2. Comfortable temperature range for Banda Aceh and Aceh Besar.

| Location   | Category                              | Max °C | Min °C | Avg °C |
|------------|---------------------------------------|--------|--------|--------|
| Banda Aceh | Td(Average outdoor temperature)       | 33     | 29     | 31     |
|            | Tco(Comfortable temperature)          | 30.5   | 27.6   | 29.1   |
| Aceh Besar | Td(Average outdoor temperature)       | 31     | 19     | 25     |
|            | Tco(Comfortable temperature)          | 29.1   | 20.1   | 24.6   |
The following is a comparison between the air temperature in the SDN 10 Banda Aceh classroom and in the SDN Kajhu Aceh Besar with the average outdoor temperature and comfortable temperature. Based on graph 10, it is known that the level of thermal comfort in each class is based on adaptive thermal comfort. The average air temperature at SDN 10 Banda Aceh at 09.00 and below is below the maximum comfort line and is included in the comfortable temperature. Meanwhile, at 09.00 and above, it is above the maximum comfort line so that it does not include comfortable temperatures.

![Graph](image)

**Figure 10.** Air Temperature comparison. (a) SDN 10 Banda Aceh; (b) SDN Kajhu Aceh Besar.

### 4. Conclusion

Based on the analysis and research results, it can be concluded that the air quality in both schools still meets the MENKES/SK/2011 standard, while the thermal comfort level in both schools is classified as uncomfortable based on SNI 03-6572-2001 and adaptive thermal comfort.

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