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Achieving Green Airport Standards by Managing Indoor CO and CO_2 Levels at Domestic Terminal of Banyuwangi Airport

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ABSTRACT

Introduction: Green Airport is an airport development concept designed to be healthy. Excess levels of carbon monoxide (CO) and carbon dioxide (CO_2) in the room can cause discomfort in the form of headache, nausea, vomiting, vertigo, and feeling confused and weak. This study aimed to determine the implementation of CO and CO_2 control in rooms to achieve a green airport at Banyuwangi Airport.
Materials and Methods: In this descriptive study, the obtained data were compared with related regulations. The physical and chemical quality of indoor air was measured at 85 points in three main rooms at risk using CO and CO_2 detectors. Control was done through observing and measuring ventilation and detection systems in the entire occupied space.
Results: The measurement results of CO and CO_2 levels have met the specified threshold value below 29 ppm for CO and 5000 ppm for CO_2. Physical quality measurements have not met the requirements for indoor temperature above 27.1°C and humidity above 60%. The assessment of ventilation aspects in the domestic terminal building of Banyuwangi Airport was achieved based on SNI 03-6572-2001 received 29 rooms or 74.3% of the rooms, 10 rooms that do not fit the ventilation system are toilet.
Conclusion: The results of the assessment conducted show that there are still aspects that are not in accordance with the provisions of green buildings.

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Introduction

Green airport is a development concept with green buildings. Green buildings can be interpreted as facilities and infrastructure designed to be healthy and built in the way of resource efficiency using ecological principles [1]. According to the regulation of the Minister of Public Works and Urban Housing Indonesian No. 02/PRT/M/2015 criterion, green building includes indoor air quality planning to improve the health and comfort of space users. One fulfillment of indoor air quality criteria is the control of indoor carbon monoxide (CO) and carbon dioxide (CO_2) levels. Control of CO and CO_2 levels in the room is carried out by providing adequate ventilation and monitoring CO and CO_2 levels, so that they are consistently below the threshold. Green buildings can be interpreted as facilities and infrastructure designed to be healthy and built using resource efficiency procedures and ecological principles [1]. Based on the Minister of PUPR RI No. 02 / PRT / M of 2015, a green building is a building that meets building requirements and has a significant measurable performance in saving energy, water, and other resources through the application of green building principles. Green building aims to create a sustainable green building by meeting the requirements for green building construction, both technical requirements and administrative requirements of green buildings. They are efficient, healthy, safe, comfortable, easy, energy and other resource efficient, and eco-friendly [2].

The air in the room can be more dangerous because humans spend more than 90% of their time indoors [3]. Factors causing air quality problems in the room are pollutants from inside and outside the room, ventilation systems, carrier media, and people's history of diseases [4]. According to the National Institute of Occupational Safety and Health (NIOSH), the magnitude of the contribution to the cause of indoor air pollution is the lack of air ventilation contributing by 52%, followed by the presence of sources of indoor contamination by 17%, sources of outdoor contamination by 11%, microbes contributing 5%, building materials by 3%, and others by 12% [5].

CO and CO_2 gases are odourless, colourless, and tasteless at low levels, which can cause health problems and even death if exposed to high concentrations. Excessive levels of CO and CO_2 in space can cause discomfort in the form of headaches, nausea, vomiting, vertigo, confusion, and weakness [5]. The source of CO and CO_2 at airports comes from the residual combustion of avtur by jet engines, motor vehicle emissions, and human activity. Activities in the airport building include passenger traffic, passenger service, provision (heating/cooking), food, and smoking [6]. The location of the apron area adjacent to the terminal building has the potential to cause the entry of CO gas emissions from outdoor aircraft into the building. In addition, the density of passengers also contributes to increase CO_2 in space. The content of CO and CO_2 in space is greatly influenced by building materials and airport building height [7]. Exposure to CO will cause platelets and blood vessel model cells to drain free radical material in the form of nitric oxide (NO), which will cause chronic artery damage. Cross-sectional studies have shown that Atherosclerosis heart disease is more closely associated with Carboxyhemoglobin (COHB) than smoking. It can be concluded that COHB can be used as a biological marker in smokers and less functioning as an atherogenesis agent [8]. CO enters the body through the lungs, directly absorbing and combining with hemoglobin (Hb). COHB can reach the highest levels in the coronary arteries and brain, and the levels are low in peripheral arteries. CO gas exits the body through the lungs, and COHB has a half-life of 5 to 6 hours. CO gas can cause respiratory problems. High levels of COHB contained in arterial blood vessels can damage blood vessels, which is mediated by the release of NO from blood vessel endothelial cells and resulting in oxidative damage to the perivascular tissue [8]. Indoor CO generally has reasonable levels, but if it is too high it can cause dizziness and headaches. CO_2 will interfere with the cellular respiratory process. Symptoms arising from chronic CO_2 exposure are vague and difficult to predict, and if present are nonspecific. To avoid health problems and comfort, CO_2 levels in buildings are attempted to be less than 600 ppm. The National Institute for Occupational Safety and Health (NIOSH) states that CO_2 levels in spaces exceeding 1000 ppm should seek adequate ventilation, while the Occupational Safety and Health Administration (OSHA) determines that the maximum CO_2 levels allowed in the workplace are 5000 ppm [5].

Banyuwangi Airport is an airport that is claimed to be the first airport to use the concept of a green airport. The results of preliminary studies that researchers have conducted showed that green building at Banyuwangi Airport is only applicable in the domestic terminal building. The building uses a few air conditioning devices; the interior design of the building was designed with minimal partitions, while the grid-shaped walls were

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expected to make air circulation run smoothly. Based on the study by Hutomo (2019), temperature conditions at Banyuwangi Airport tend to be warm and a little hot, causing uncomfortable conditions. Room conditions can be comfortable with temperatures between 25°C to 32°C. Uncomfortable conditions can be caused because in some rooms there is an inappropriate room temperature, humidity and air flow limits, so that air can circulate. It is difficult to enter the building, since the entrance holes are small in some rooms [9]. Therefore, this study aims to determine the achievement and application of indoor CO and CO_2 control efforts to create a green airport at Banyuwangi Airport as well as an assessment of the application of green airport-based buildings at Banyuwangi Airport.

Materials and Methods

This study used a descriptive research method. The unit of analysis in this study was the domestic terminal building of Banyuwangi Airport. The study variables include the physical and chemical quality of indoor air and efforts to control indoor CO and CO_2. The physical and chemical quality of indoor air consisted of temperature, humidity, CO levels, and CO_2 levels, while CO and CO_2 control efforts were ventilation systems, detection devices, and warning alarms. The ventilation system used in the airport area included natural and mechanical ventilation. Natural ventilation is meant by using natural windows that allow air to enter and exit from outside to the airport space, thus allowing exposure to CO and CO_2 from aircraft on the runway into the airport space.

Measurements of CO and CO_2 levels were carried out in the check-in room, waiting room, and arrival room, which were specially chosen considering that these rooms are places close to the airplane apron and many residents are active in these areas. Purposive sampling is based on a consideration made by the researcher himself, and according to the characteristics or properties of the sampling point's location. Determination of CO and CO_2 level measurement was performed based on SNI 7230:2009 with 85 sampling points in the selected room. CO and CO_2 levels were measured during peak flight hours at 11.30-14.00 WIB on Sundays and Mondays as a representation of weekdays and holidays [10]. CO and CO_2 sampling was carried out in dry season to minimize bias due to rain. Measurement of the area and location of ventilation was done using a measuring device in the form of a rolling meter. CO and CO_2 exposure measurement was carried out at several points, and the tool was exposed at a height of 1-1.5 meters from the floor to get the appropriate results of exposure to humans.

Data were obtained through observation and measurement at the domestic terminal building of Banyuwangi Airport. Observations were made to obtain data on the condition of ventilation, detection devices, and warning alarms in buildings. Measurements were made to determine the location and size of ventilation in the building and determine the temperature, humidity, CO levels, and CO_2 levels. Temperature, humidity, CO, and CO_2 levels were measured using CO and CO_2 tools-detector by electrochemical, pre-equipped thermohygrometer. The data were then analyzed descriptively by tabulation and compared with related regulations, namely the Minister of PUPR RI No. 02 / PRT / M Year 2015, SNI 03-6572-2001, SNI 19-0232-2005.

Ethical issue

Ethical issues (including plagiarism, informed consent, misconduct, data fabrication and/or falsification, double publication and/or submission, redundancy, etc.) have been completely observed by the authors.

Results

Physical and chemical quality of indoor air

CO and CO_2 control efforts aimed to achieve healthy and comfortable environmental conditions for room residents, especially in the aspects of physical air quality in the form of temperature and humidity and air chemical quality in the form of CO and CO_2 levels. CO and CO_2 levels were measured momentarily for 30 minutes at 30 different points in each room, namely the check-in room, lounge, and arrival hall.

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Based on Table 1, the measurement of CO levels showed a result of 0 ppm in the entire chamber or no CO gas found in the entire space. Measurements of CO_2 levels in the check-in, waiting, and arrival halls on Sunday were 386, 814, and 384, respectively, while on Monday, sequentially, they were 388, 839, and 386 ppm. Measurement of CO_2 levels in the domestic terminal building of Banyuwangi Airport showed the highest levels in the waiting room and did not show a significant difference between working days and holidays.

Indoor air CO and CO_2 control

Indoor air CO and CO_2 control comprised ventilation systems, CO and CO_2 monitoring devices, and warning alarms. Control aspects were assessed by observing and measuring components in control efforts. Measurements were made to determine the location and size of ventilation, while observations were made to determine the condition of ventilation systems, detection devices, and warning alarms. Ventilation assessment was carried out on the entire space occupied or used for passenger and worker activities in the domestic terminal building of Banyuwangi Airport. CO and CO_2 monitors and warning alarms were examined in three main rooms at risk of increased CO and CO_2 levels including check-in, waiting, and arrival halls. Control of CO and CO_2 in indoor air at Banyuwangi Airport based on Circular Director General Cipta Karya No. 86/2016 earned 2.23 points from the total points that can be obtained of 9 to 24.7% of points achieved.

Table 1: Results of physical quality and chemistry of indoor air

Parameters	Check-in room		Lounge		Arrival hall		NAB (Threshold value)
	Sunday	Monday	Sunday	Monday	Sunday	Monday	
CO (ppm)	0	0	0	0	0	0	29*
CO_2 (ppm)	386	388	814	839	384	386	5000*
Temperature (°C)	29.3	30.3	27.3	27.5	29.1	30.1	27,1**
Humidity (RH%)	75	67	69	65	73	66	60**

Information
*SNI 19-0232-2005
**SNI 03-6572-2001

Table 2 shows that the assessment of ventilation aspects in the domestic terminal building of Banyuwangi Airport was achieved based on SNI 03-6572-2001 received 29 rooms or 74.3% of the rooms, 10 rooms that do not fit the ventilation system are toilet. The suitability of ventilation included having natural ventilation of more than 10% of the floor area of the room, natural ventilation facing open areas or adjacent spaces that are not sanitary compartments, the location of natural ventilation less than 3.6 meters above the floor, having mechanical ventilation that lights up always when occupied if natural ventilation is not met. Moreover, closed spaces should have mechanical ventilation to remove dirty air at least 2/3 of the volume of room air with a maximum height of 0.6 meters above the floor, and the air rate outside mechanical ventilation for the transportation area space has to be at least 0.21 m^3/min/person.

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Table 2: Ventilation aspect assessment of banyuwangi airport

Room	Number of spaces	Compliance with SNI 03-6572-2001	Ventilation Points
Check-in	1	Appropriate	1
Lobby lounge	1	Appropriate	1
Wait	1	Appropriate	1
Wait for VIP	1	Appropriate	1
Departure Mushola	2	Appropriate	2
Mushola arrival	2	Appropriate	2
Departure Toilet	6	Not compliant	0
Arrival toilet	4	Not compliant	0
Tenant	9	Appropriate	9
Office on duty	1	Appropriate	1
Information	1	Appropriate	1
Arrival	1	Appropriate	1
Airlines	4	Appropriate	4
Floop airlines	4	Appropriate	4
CTF	1	Appropriate	1
Sum	39		29
Total points		2,23	

According to Table 3, Banyuwangi Airport does not yet have a system to detect CO and CO_2 levels in risky spaces, so a total point of 0 point was obtained from a maximum of 6 points. The assessment of monitoring devices in each room included the presence and suitability of monitoring devices based on the Minister of PUPR RI No. 02 / PRT / M 2015.

Table 3: Aspect assessment of CO and CO_2 monitors, as well as warning alarms

Room	Number of spaces	Compliance with PUPR RI Regulation No. 02/PRT/M of 2015	CO and CO_2 monitor tool points	Warning alarm points
Check-in	1	Not Compliant	0	0
Wait	1	Not Compliant	0	0
Coming	1	Not Compliant	0	0
Sum	3		0	0
Total points			0	

Discussion

Physical and chemical quality of indoor air

According to SNI 19-0232-2005, CO_2 levels in the domestic terminal building of Banyu Wangi Airport still meet the predetermined threshold value of 5000 ppm. Temperature and humidity measurements were carried out as supporting data for CO and CO_2 levels in space. The temperature in the check-in, waiting, and arrival halls on Sundays was 29.3, 27.3, and 29.1°C, while on Mondays, they was 30.3, 27.5, and 30.1°C, respectively. The humidity in the check-in, waiting, and arrival halls on Sundays was 75%, 69%, and 73%, respectively, while on Mondays, it was 67%, 65%, and 66 %. Following SNI 03-6572-2001, the results of temperature and humidity measurements in the three rooms exceed quality standards [11,12].

CO and CO_2 levels at Banyuwangi Airport were at low concentrations which could be caused by the source, and the rate of pollution gas emissions was not too high. The results of the study by Purwanta showed that the larger the airport, the higher the flight activity, and the emissions produced would be higher as well. When indoor CO and CO_2 measurements were carried out at Banyuwangi Airport, there were only two Airbus A320 aircraft with a passenger capacity of 130-200 people landing at Banyuwangi airport[13].

The location of CO and CO_2 emission sources in

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open areas also causes low levels of CO and CO_2 that can enter space. The dispersion speed of a gas is directly influenced by meteorological factors such as wind speed and direction, air turbulence, and atmospheric stability [14]. Based on the study conducted by Kaleka et al. , the lower density of CO than air allows it to be quickly carried away by wind blowing that points west or runway direction, followed by a decrease in the concentration of CO in ambient air because it is dispersed in the air [15].

Another factor that contributes to low levels of CO and CO_2 in space is adequate indoor ventilation. In their research, natural ventilation allows airflow into the room, and the incoming airflow slightly reduces the room temperature and humidity. Inadequate airflow can cause other physical environmental conditions to become worse, such as increased temperature and humidity, which can support indoor air pollution [16]. In line with the study by Talarosha, natural ventilation in the form of windows and doors and permanent ventilation of 9% has a good performance in maintaining air quality in the space (mean CO_2 concentration below 1000 ppm) [17].

The waiting room had a higher CO_2 level compared to other rooms, since the room is a closed space. According to research conducted by Hasibuan et al., in a closed room without an exhaust fan, the process of air exchange from inside the room to outside does not occur ; it causes the air in the room to be trapped along with increasing CO_2 levels in the room [18]. Based on the research by Kurniawan, mechanical ventilation is very influential on air quality in buildings, which is influenced by pressure differences between one room opening and another space, and as a result pollutants remain below the threshold [19].

The room temperature at Banyuwangi Airport exceeded 27.1°C, and the humidity in the room exceeded the required limit above 60%[9]. Passengers often complain about uncomfortable conditions, especially when the weather is not windy. The indoor temperature becomes high, since during the day, the air temperature outside the room is very high, while the temperature in the room is relatively low. Therefore, air flows from high pressure to low pressure, and the cold air in the room will go outside, and it can be faster if the area of the opening increases[20]. Changes in air temperature in the room can be influenced by natural and artificial ventilation factors (mechanical) and building structural materials. The addition of airflow in naturally ventilated spaces using mechanical ventilation such as fans is needed to lower the temperature and humidity in the room. In contrast, rooms with air conditioning require optimizing the unit performance to lower the temperature and humidity in the space.

Indoor air CO and CO_2 control

Appropriate ventilation was available in 29 rooms out of 39 inhabited rooms. Rooms that did not meet the ventilation requirements were toilets, as many as ten rooms, since natural ventilation did not meet the requirements. The provision of ventilation at Banyuwangi Airport in most spaces met the requirements for adequate ventilation, both natural and mechanical. Kusumawardani et al. reported that the area of natural ventilation inlets in the JFC building Center Jember City uses SNI-03-6572-2001 standard for public buildings at least 10% of the floor area and natural ventilation with openings of at least 10% of the room area [11,21,22].

Indoor CO and CO_2 detection systems are essential for applications in spaces at risk of CO and CO_2 accumulation. The notification system allows users to act promptly to improve indoor air quality through ventilation or turning off pollutant source equipment [23]. The monitor should not be installed in an air-dead room (i.e., near the ceiling), near a window or near a door where there is a lot of air movement, and should not be exposed to extreme temperatures or humidity. Excessive heat or cold will affect performance, and extreme humidity will affect activation time [24].

The assessment of CO and CO_2 control efforts in space at Banyuwangi Airport received 2.23 points from the total points. The overall value of points was from the ventilation aspect, while the aspect of monitoring devices and warning alarms obtained 0 points each. Latuconsina stated that Rusunawa Pesakih Jakarta obtained 4 points for the category of health and comfort in space, for implementing natural ventilation 2 points, and for smoking ban obtained 2 points [25]. Meanwhile, research at Sugar Factory Tjoekir Jombang showed that the suitability of the physical environment with Green Building approach only met 5% of conformity data due to the absence of CO_2 monitoring [26].

Assessment criterion of Green Building By Circular Letter of the Directorate Jenderal General of Copyright Republik Indonesia Number 86 Years 2016, is a maximum total point of 205 points from all aspects of assessment [27]. To achieve the minimum criterion for green building, the required point was at least 70% of the overall point or 143.5 point. Therefore, this study cannot represent achievements of Green Building at the domestic terminal building of Banyuwangi Airport, since the assessment was limited to only CO and CO_2 control aspects. CO and CO_2 control assessments can improve health efforts and comfort in space as one of the conditions to achieve a Green Building at the domestic terminal building of Banyuwangi Airport.

Conclusion

CO and CO_2 levels of indoor air at Banyuwangi Airport follow SNI 19-0232-2005, below 29 ppm for CO and below 5000 ppm for CO_2. Indoor temperature and humidity at Banyuwangi Airport did not meet the standards in SNI 03-6572-2001, namely, room temperature exceeding 27.1 °C and humidity exceeding 60% RH. Control of indoor CO and CO_2 at Banyuwangi Airport based on SE Director General of Cipta Karya Number 86 of 2016 received 2.23 points out of the total points that could be 9 or 24.7% points. Rooms with appropriate ventilation based on SNI 03-6572-2001 were 29 or 74.3% of the total 39 rooms that were measured. The detection system for CO and CO_2 air levels in space was unsuitable based on SE Director General of Cipta Karya No. 86 of 2016, since there was no detection system in risky spaces. Mechanical ventilation can be used to reduce temperature and humidity in the space. Installing mechanical ventilation in the form of exhaust fans in the toilet is needed to increase airflow and remove dirty air from the room. It is necessary to install a CO and CO_2 detection system in the form of monitors and alarms connected to the ventilation system in rooms at risk of CO and CO_2 accumulation, namely in the check-in room, waiting room, and arrival hall, to minimize exposure to CO and CO_2 gases.

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Conflict of interest

The authors declare that there is no conflict of interest.

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