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The Indoor Air Quality in Laboratory Buildings. A Case Study in Integrated Laboratory of UIN Sunan Ampel Surabaya

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Abstract

Indoor Air Quality (IAQ) is one of the critical issues in sustainable development related to human health as the primary goal. Sustainable development should address potential human exposure to pollutants and health impacts. The laboratory, as educational support in the university, has specific contaminants, but studies on IAQ and thermal comfort in the laboratory have not been studied. IAQ and thermal comfort in a laboratory are essential as they can affect the work and health of the researchers and staffs. The purpose of this study is to analyze indoor air quality in an integrated laboratory of UIN Sunan Ampel Surabaya. This research is a cross-sectional study. Data analysis was done by a quantitative descriptive method. The air quality parameters in the laboratory were temperature, relative humidity, and carbon dioxide (CO2) concentration. All settings compared to the air quality standard. The analysis on carbon dioxide (CO2) concentration, relative humidity (%RH), temperature (˚C) has shown that the indoor air does not exceed the standard according to ASHRAE standard and Health Ministry Regulation with the maximum concentration was 444,3 ppm. The fan installation and increased air filter to controlled humidity are the option to improve the indoor air quality.

Keywords: Indoor Air Quality, Thermal Comfort, Laboratory

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1. Introduction

Sustainable development is a development process that for present and the future, without overexploitation natural source [1]. Sustainability has become a significant consideration for development to improve economic capacity, protecting and restoring the ecological system and improving human welfare [2]. To achieve sustainable development, it should minimize the environmental impact. Sustainable development must be able to overcome the potential for exposure to pollutants and health impacts on humans whether they occur outdoors or indoors.

Pollutants exposure occurs in an indoor environment is more dangerous than the outdoors, because humans spend most of their time indoors [3], and can even pay 90% of their time indoors (EPA, 2009). Indoor air quality needs to maintained for human health. IAQ has referred to the air quality in the room and around the room, primarily related to the health and comfort of room occupants [4]. The research reported by ASHRAE (2011) shows IAQ has a direct impact on worker health, work comfort, and performance. Besides, bad IAQ can cause various short-term and long-term health problems including allergic reactions, respiratory problems, eye irritation, sinusitis, bronchitis and pneumonia (ASHRAE, 2007). Regarding the building, WHO stated around 30% of buildings experienced significant IAQ problems.

In institutional buildings, the laboratory has become a particular microenvironment has specific pollutants and exposures depending on the experiment and the number of people working in it[5]. Laboratory workers will tend to are exposed to various chemical and microbiological substances. While working in the laboratory, the users (staff, instructors, assistants, and students) exposed to pollutants will cause acute and chronic health effects.

Ventilation and the amount of air pollutant sources are the two main factors that influence IAQ in the laboratory. Other factors that may have influence are building characteristics, such as moisture damage, building materials, furniture, and cleaning products. Pollutants accumulation in the indoor environment can prevent with use of ventilation. Ventilation has a function for air circulation and air exchange in the indoor environment. There are two types of ventilation, natural and mechanical ventilation. The air exchange in natural ventilation depends on the difference in pressure, related to air and wind temperatures. Natural ventilation is more economical and has environmental benefits but is not sufficient for the laboratory.

Mechanical ventilation is needed because of the strength of emissions and the potential danger of indoors pollutants. Installing an HVAC system into the laboratory plays a vital role in controlling comfort, indoor air quality, indoor aseptic and thermal conditions suitable for creating an ideal work environment for the users. IAQ and thermal comfort in the laboratory is essential because they can affect the user's work and health.

Integration Laboratory at the UIN Sunan Ampel Surabaya has become a supporting part for educational activities, and it has three floors. Each floor contains six laboratory rooms, comprising laboratory of a computer, language, biology, basic chemical, ecology, environmental engineering, and marine science. Every room in the laboratory has natural and mechanical ventilation in the form of windows, air conditioning and fume hood in the basic chemistry and environmental engineering laboratory. From the background

mentioned, we were interested in researching IAQ in the Integration Laboratory of UIN Sunan Ampel Surabaya.

The Integrated Laboratory in the UIN Sunan Ampel Surabaya has become a supporting part for educational activities, and they locate it in a three-story building. Each floor comprises six laboratory rooms, comprising computer laboratories, language laboratories, biological laboratories, basic chemical laboratories, ecology laboratories, environmental engineering laboratories, and marine science laboratories. Every room in the laboratory has natural and mechanical ventilation in the form of windows, air conditioning and fume hood in the basic chemistry and environmental engineering laboratory. From the background mentioned, we were interested in researching IAQ and thermal comfort in the Integration Laboratory of UIN Sunan Ampel Surabaya.

2. Methode and Material

The Research was conducted in three laboratories in the Integrated Laboratory building, which are environmental engineering Laboratory, Ecology Laboratory, and biology laboratory. We used the quantitative descriptive method to analyze data. The measured air quality parameters in the laboratory comprise CO_2 concentration, and the thermal comfort variable includes temperature and humidity, those were taken during natural ventilation and mechanical ventilation functions in one hour on one day. The indoor air quality was measured when there were no activities in the laboratory. CO_2 concentration was measured by Lutron CO_2 Meter type GCH-2018, with the specifications in table 1 and the research design of this research was describe in Figure 1. The data result was analyzed according to ASHRAE standard and Health Ministry Regulation.

Table 1: Instrumen Specification.

Parameters	Specification	
CO2	Range	0-4000 ppm
	Accuracy	±5% +40 ppm
RH	Range	10%-95%
	Accuracy	≥70% RH: ± (3% reading+1%RH), <70% RH: ± 3%RH.
Temperature	Range	0-50˚C
	Accuracy	±0,8˚C

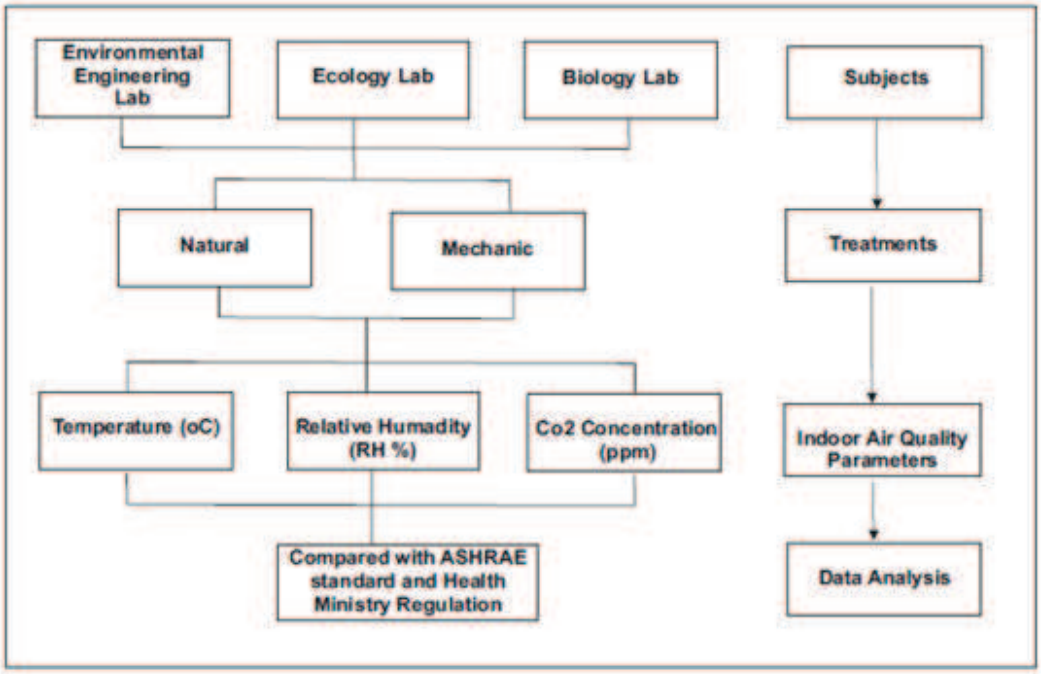

Figure 1: The Research Design.

3. Result and Discussion

Indoor air temperature quality standards according to regulating the Minister of Health No. 1405 of 2002 about health requirements for office and industrial work environment were between 18°C-28°C. Based on the measurement, it experienced during natural ventilation conditions, the ecology laboratory and the biological laboratory temperature had to exceed the standard. While in the mechanical ventilation conditions only biology laboratory are exceeding the standard (table 2). Air temperature in the laboratory must be in optimum conditions. The comfort range is a variable that depends on local geography and climate [6]. Lippsmeier states the comfort limits for tropical conditions range from 19°C-26°C [7]. For the temperature in the room to be in compliance with the standard, necessary to make.

The highest relative humidity (RH) in natural ventilation occurred in the environmental engineering laboratory (62.4%) and the lowest in the biological laboratory (56.6%). While with using mechanical ventilation, the It found highest in the environmental engineering laboratory (59%) and the lowest was in the biological laboratory (see table 3).

Relativity humidity (RH) is determined by several factors including temperature, air conditioning, human activity and water content in the laboratory air, the geographic location of the building, and a humidifier [8].In tropical countries such as Indonesia, throughout the year have high outside temperatures (30°C) with high moisture (90% RH)

Table 2: Laboratories Temperature.

Location	Ventilation type	Temperature (˚C)				Standard
		1	2	3	Average	
Environmental	Natural	25,8	29	28,9	27,9	18˚C-28˚C (According to the Decree of the Minister of Health No. 1405 / MENKES / SK / XI / 2002)
Engineering Lab	Mechanic	24,9	27	27	26,3	
Biology Lab	Natural	30,4	31,4	30	30,6	
	Mechanic	28,1	29,6	29,2	28,9	
Ecology Lab	Natural	29	31	31	30	
	Mechanic	25	25,8	26,3	25,7	
Source: Analyzed result, 2018						

Table 3: Relative humidity measurement result.

Location	Ventilation type	Relative Humidity (RH) %				Standard
		1	2	3	Average	
Environmental	Natural	61,4	63	62,8	62,4	40%-60% (According to the Decree of the Minister of Health No. 1405 / MENKES / SK / XI / 2002)
Engineering Lab	Mechanic	56,2	60	61	59	
Biology Lab	Natural	58,6	57,4	54 49,6	56,6	
	Mechanic	47,9	45,2		47,5	
Ecology Lab	Natural	58,2	57,8	57,4 55,5	57,8	
	Mechanic	51,3	51		52,6	
Source: analyzed result, 2018						

[9]. Low RH can cause Sick Building Syndrome symptoms such as eye irritation, throat irritation, and coughing. Besides that, the poor RH susceptibility to infectious diseases, and asthma [3]. RH is still one factor that influences the survival of microorganisms. Some types of viruses live at extreme humidity levels. Bacteria such as legionella survive in a limited range of humidity is around 55% -65% and can survive in the form of aerosols (bioaerosol). Further, the survival of microorganisms and house dust found on the surface will increase at RH above 60% and can cause respiratory problems [10].

The results of CO2 measurements when natural ventilation conditions have shown the highest CO2 concentration in the ecology laboratory (379 ppm) and the lowest in the environmental engineering laboratory. While the average CO2 measurement results when the condition of active mechanical ventilation shows the highest average

concentrations found in biological laboratories and the lowest in environmental engineering laboratories (see table 4). All CO2 levels under natural ventilation conditions and mechanical ventilation conditions have met the standard of <1000 ppm [11]

Table 4: CO2 Measurement Result.

Location	Ventilation type	CO2 (ppm)				Standard
		1	2	3	Average	
Environmental	Natural	337	249	150	245,3	40%-60% (Ministry of Health) 22˚C -26˚C ASHRAE
Engineering Lab	Mechanic	316	254	182	254	
Biology Lab	Natural	384	446	227	352,3	
	Mechanic	444	505	384	444,3	
Ecology Lab	Natural	286	431	420	379	
	Mechanic	382	437	439	419	
Source: analyzed result, 2018						

CO2 levels were an indicator to determine whether the ventilation. It uses the system in the indoors area. CO2 It must keep levels in a room below 1,000 ppm. If CO2 levels exceed this limit, it will show that the amount of fresh air flowed through the ventilation system is insufficient [12]. Meanwhile, according to OSHA, the allowable CO2 threshold value is 500 ppm. CO2 does not cause harmful health effects when in concentrations above 550 ppm, but if it is in levels above 800 ppm, CO2 can show a lack of fresh air and poor air mixing of air in the building user area It can see a relationship between variables in table 5.

Table 5: The relationship between variables.

Location	Ventilation type	Measurement variables		
		Temperature (˚C)	Relative Humidity (%)	CO_2 Concentration (ppm)
Enviromental engineering Lab	Natural	27,9	62,4	245,3
	Mechanic	26,3	59	254
Biology Lab	Natural	30,6	56,6	352,3
	Mechanic	28,9	47,5	444,3
Ecology Lab	Natural	30	57,8	379
	Mechanic	25,7	52,6	419
Source: analyzed result, 2018				

The temperature for natural ventilation was higher than mechanical It tested ventilation with the air conditioning on the three laboratories. Natural ventilation with opening window allows the outdoor air to enter the interior of the laboratory. Outdoor

air temperature according to Surabaya Temperate was 27-30,2°C [13]. This outdoor temperature affected the inside temperature on the laboratory in the result of natural condition the temperature was higher than with air conditioning. Carbon dioxide (CO_2) is one of the many impurities in the indoor air. It is a normal constituent of exhaled breath and the most significant contaminant produced by the human body [14]. Carbon dioxide (CO_2) concentration on three laboratories was lower than 500 ppm. About half of the carbon dioxide studies suggest that the risk of sick building syndrome symptoms continued to decrease with decreasing carbon dioxide concentrations below 800 ppm [15], Limit values for Carbon dioxide on Finnish Class was 750 ppm. This Indoor air quality meets the requirements of particular groups (elderly, allergic persons, respiratory disease sufferers[16] Carbon dioxide limit values were 950–1300 according to ASHRAE recommends a change of the building's ventilation system [17]. According to these standards, Carbon dioxide (CO_2) concentration on three laboratories was below the standards.

Carbon dioxide (CO_2) concentration with air conditioning measurement was higher than with natural ventilation in three laboratories. It was found that Carbon dioxide (CO_2) exposure derived from air conditioning on a laboratory. Raatikainen [18] stated that The IAQ parameters like carbon monoxide and carbon dioxide from building materials and furniture exist in indoor air derived from operating air conditioning systems in buildings [18]

It closely related temperature and relative humidity. The decreasing temperature will decrease the relative humidity. It was found that Relative moisture in three laboratories has a minimum value of 47,5% and the maximum amount was 62,4%. The new act is supported by Finnish Asumisterveysohje 2003 in which the guideline value for indoor temperature is 21°C and, for relative humidity, the guideline is 20-60% during the heating season [18]. The indoor environment is a complex system, with its elements connected and affecting each other. For example, when increasing the ventilation rate by opening the window to allow outdoor air to enter the inside building, some fraction of the pollutants generated indoors is removed, for example, CO2 or combustion products produced during laboratory activities. However, increased ventilation can promote the increase of inside temperature leading to swelling of relative humidity.

Increased ventilation can increase the in gress of pollutants and particles from outside attending to elevated concentrations indoors when the indoor environments are close to busy roadside [19]. Integrated Laboratory was It located laboratory in Jl. Ahmad Yani 117 Surabaya City is close to busy roadsides. It may cause gaseous exposure when the laboratory uses natural ventilation.

The differences between the parameter value on three laboratories were determined by its properties and activities in a laboratory. The features on Environmental Engineering Laboratory were Analytical Electronic Balance, Desiccator, Fume Hood, Muffle Furnace, Oven, Stirring Hot Plate, Horizontal Water Sampler, Vertical Water Sampler, Coagulant and Flocculants Equipment, and Gas Analyzer. Meanwhile, activities on the Environmental Engineering Laboratory are Environmental Chemistry Research, Analysis of Environmental Pollution, and Analysis of Wastewater and Solid Waste. The student was doing the experiment courses every day according to the schedule. Maximum capacity on Environmental Engineering Laboratory was 30 students with four laboratory assistant. Usage of Fume Hood, Muffle Furnace, and Oven will emit the gaseous and particulate pollutant. The properties on Biology Laboratory were Analytical Electronic Balance, Binocular Microscope, Oven, pH meter, and spectrophotometer.

Meanwhile, activities on Biology Laboratory include General Biology, Cell Biology, Animal and Plant Physiology, Biotechnology, Ocean Biology, and environmental toxicology. The student was doing the experiment courses every day according to the schedule. Maximum capacity on Biology Laboratory was 25 students with three laboratory assistant. Usage of this equipment especially oven will emit the gaseous and particulate pollutant. Also, the properties on Ecology Laboratory were Analytical Electronic Balance, Binocular Microscope, Stereo Microscope, Oven, pH meter, and Refrigerator. Activities on Ecology Laboratory are ecology research, animal and plant morphology, bioremediation, soil ecology, and bioconversion. Carrying capacity on Ecology Laboratory was 20 students with two laboratory assistant. Usage of this equipment especially oven and refrigerator will emit the gaseous and particulate pollutant.

In general combustion or burning is a chemical reaction in which a fuel combines with oxygen. When there is insufficient oxygen, burns incompletely and produces by-products of combustion there are Carbon monoxide, Polynuclear aromatic hydrocarbons (PAHs), Formaldehyde, Sulfur dioxide, Nitrogen dioxides, and Particulates [20] There are a lot of combustion appliances including space heaters, ovens, furnaces, gas water heaters, and fireplaces. The combustion of stove and furnace result in pollutants such as CO, CO_2, NOx, Sox, HC, and PM [21]. Although these activities were not considered during the study, historical usage of laboratory equipment may emit the residue.

From the result above, we found that natural ventilation will increase the indoor temperature leading to strengthening of relative humidity and lowering the carbon dioxide concentration. Therefore, how to primary improve air quality in high relative humidity can be achieved by increasing the air temperature inside the room. However, the increase in temperature may affect the relative humidity of the air that is very low

to cause discomfort. The fan installation and increased air filter to controlled humidity with the option to the indoor air quality improvement for providing appropriate good environment was another way to control indoor air quality [22]

4. Conclusion

This study highlighted the indoor air quality in the Integrated Laboratory of UIN Sunan Ampel Surabaya. The analysis on carbon dioxide (CO_2) concentration, relative humidity (%RH), temperature (˚C) has shown that the indoor air does not exceed the standard according to ASHRAE standard and Health Ministry Regulation with the maximum concentration was 444,3 ppm. The fan installation and increased air filter to controlled humidity with the option to the indoor air quality improvement for providing appropriate good environment was another way to control indoor air quality.

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