Indoor air pollution in Air-Conditioned bus and non-Air-Conditioned bus

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Abstract. The use of buses as mass transportation mode has become a popular option for the people because of the cheap price and flexibility. The bus comfort is one of the keys to improving the quality of transportation service. However, the bus capability to carry many people with various conditions has a potential risk of creating indoor pollution inside the bus. This study aims to examine the level of air pollution inside an air-conditioned bus and a non-air-conditioned bus with a biological agent's approach as the source of pollutants. The analysis conducted in this study is limited to microorganisms as one of the sources of indoor air pollution. Several media are placed in some part of the air-conditioned bus and non-air-conditioned bus. The study shows that there are fungi inside the buses that serve as contaminants and pathogen microbes that can cause air pollution.

1. Introduction
The use of buses as mass transportation mode has become popular among people because of the cheap price and flexibility. The bus has the capability to carry many passengers with various destinations in which there are passenger exchanges in its journey. However, studies which are aimed to analyse air pollution inside the bus are still very limited in number [4]. The problem of indoor air pollution has a potential risk of becoming health problems because people tend to stay indoors. Air Conditioner (AC) is an alternative to replace natural ventilation and can improve people's comfort, but the Air Conditioner that is rarely cleaned can become a good place for the microorganism to grow. That condition can impact air quality and cause various health disorders, which is called Sick Building Syndrome (SBS) or Tight Building Syndrome (TBS) [9].

Research on indoor air pollution with the parameter of biological agents has not been conducted for the bus. However, similar research has been conducted in the motor vehicle examination room in 2015. The study results reveal that the level of indoor air pollution exceeded the threshold, with the number of the pathogen was 508 CFU/m³ [5]. The previous study has become a reference and comparison in researching indoor air pollution with biological agents' parameter inside the bus.

Indoor air pollution is the infiltration of substance, energy or other components. The problem of air quality inside a room is usually influenced by several factors: lack of air ventilation (52%), air pollutant...
inside the room (16%), air pollutant outside the room (10%), microbes (5%), building materials (4%), and other factors (13%) [10]. Indoor air pollution can happen because of humans activity, such as air pollution caused by bacteria, protozoa, and other microbes. Air ventilation problems can be caused by a lack of fresh air inside the room, poor ventilation, and lack of maintenance on the ventilation system. It can also be caused by outdoor aspects such as transportation, gas, and chimney [11].

The process of heating, ventilation and air conditioner can influence the humidity and air quality inside a room. Vapor accumulation in building construction results in humidity and microbe growth. We can notice the sign by examining color changing and a defective surface of the materials, wet stains, humid condition, and fungi’s smell. The humidity can result from rainwater, surface water, groundwater and local water, which are not appropriately drained and cause condensation [7]. The bacteria grow well in a humid place in which the air produced by the AC can cause lower room temperature and result in high humidity. If the temperature is too low and humidity is high, fungus and parasite will grow easily. An air conditioner which is not cleaned correctly becomes the main cause of health problem [10].

2. Methodology
This research aims to analyse the air quality, which is limited by using the parameter of biological agents to examine the bus's air quality. It was conducted using a viable air sample method in which blood jelly media in a cup was used to grow the microorganism in the buses, which were operated in Tegal, Central Java.

Several media were placed on some parts of the bus, which were considered places that humans often visited. This method used a growth media, which was jelly in a cup or jelly strips to grow microorganisms. In this research, the biological parameter used was the existence of microbes and fungi as the indicator of indoor air pollution, which were compared with the standard described in the Minister of Health Decree Republic of Indonesia Number 1204/MenKes/ SK/X/2004 Regarding the Requirements of Environmental Health.

3. Result and discussion
This research was conducted to analyse indoor air quality, focusing on microorganisms, such as microbes and fungi, as the indicator. The result was compared with the standard described in the Minister of Health Decree Republic of Indonesia Number 1204/MenKes/ SK/X/2004 Regarding the Requirements of Environmental Health (indoor 200 CFU/M$^3$)[12]. The finding showed that the number of microbes and fungi in the non-air-conditioned bus was higher than that in the air-conditioned bus. In a non-air-conditioned bus, there were 112 microbes and 36 fungi found. While in the air-conditioned bus, there were 84 microbes and 20 fungus found.

The finding also revealed some microbes found in the non-air-conditioned bus such as Bacillus subtilis, Staphylococcus aureus, and staph epidermidis Klebsiella sp, Streptococcus, and Escherichia coli, which were pathogen and could cause air pollution. Whereas in the air-conditioned bus, similar microbes were found except streptococcus and Escherichia coli. The fungi found in the sample location were Aspergillus fumigatus, Penicillium sp, Mold, Aspergillus niger, which were pathogens and contaminants that could cause air pollution. The number of fungi was almost the same in the non-air-conditioned bus and the air-conditioned bus. The details are described in the following table.

| No | The Point of Location | The Number of Microbe (CFU/m$^3$) | Type of Microbe                  |
|----|-----------------------|-----------------------------------|----------------------------------|
| 1  | 1.1                   | 17                                | Bacillus Subtilis, Staphylococcus aureus, staph epidermidis |
| 2  | 1.2                   | 24                                | Bacillus Subtilis Staphylococcus aureus, staph epidermidis, , klebsiella sp |
| No | The Point of Location | The Number of Microbe (CFU/m$^3$) | Type of Microbe |
|----|-----------------------|----------------------------------|----------------|
| 3  | 4.1                   | 22                               | Bacillus Subtilis, Staphylococcus aureus, staph epidermidis |
| 4  | 4.2                   | 49                               | Bacillus Subtilis, Staphylococcus aureus, staph epidermidis, Klebsiella sp, streptococcus, dan escherichia coli |

| The number of microbes | 112 |

**AIR-CONDITIONED BUS**

| No | The Point of Location | The Number of Microbe (CFU/m$^3$) | Type of Microbe |
|----|-----------------------|----------------------------------|----------------|
| 1  | 2.1                   | 38                               | Bacillus Subtilis, Staphylococcus aureus, staph epidermidis, klebsiella sp |
| 2  | 2.2                   | 16                               | Bacillus Subtilis, staph epidermidis, , klebsiella sp |
| 3  | 3.1                   | 13                               | Bacillus Subtilis, staph epidermidis |
| 4  | 3.2                   | 17                               | Bacillus Subtilis, Staphylococcus aureus, staph epidermidis |

| The number of microbes | 84 |

| Maximum limit         | 200 |

Based on table 1 above, it can be seen that *Bacillus subtilis* is found both in the air-conditioned bus and in the non-air-conditioned bus. *Bacillus subtilis* is usually found in soil and the human digestive tract. One of the members of *Bacillus* genus, *B. subtilis*, has a stem form and can form hard endospore protection, which enables it to tolerate extreme environmental conditions.

This bacterium is one of the bacteria in enzyme production, secreted and used on an industrial scale by biotechnology companies. *Staphylococcus aureus* is the most dangerous bacterium of all *Staphylococcus*. This bacterium can spread through direct contact with an infected person, using an infected object or inhalation of an infected drop from sneeze or cough. *Staphylococcus aureus* can infect all body organs from the outer skin to the heart, lungs, and bones and cause poisoning since some can create toxins. *Staphylococcus epidermidis* is one of the bacteria from *Staphylococcus* genus that can cause opportunistic infections (attack individuals with weak body immune systems). This bacterium is found in the human's mouth and intestine. Some of them are pathogenic and cause illness in humans, such as pneumonia, meningitis, necrotizing fasciitis, erisipelas, sore throat and endocarditis [7]. *Streptococcus* is only found in the non-air-conditioned bus.

Another result that we can see from the table is the existence of *Escherichia coli* (*E. coli*), which is only found in the non-air-conditioned bus. Generally, this bacterium is found in the human colon. Most of *E. Coli* is not dangerous, but some species such as *E. Coli* type O157:H7 can cause severe food poisoning in humans, causing bloody diarrhea because of exotoxin produced named verotoxin.

Species of *Klebsiella* are known can cause many diseases such as pneumonia, urinary tract infection, septicemia, meningitis, diarrhea and soft tissue infection. Species of *Klebsiella* have also been involved in pathogenesis, ankylosing spondylitis and other spondyloarthropathies. The majority of *Klebsiella* infection is caused by *K. pneumoniae* and followed by *K. oxytoca*. *Klebsiella* infection often happens to very young people, very old people, and those who suffer from basic diseases such as cancer and most infections that involve contamination of invasive medical devices [7].
Table 2. The result of fungus examination.

| No | The Point of Location | The Number of Fungus (CFU/m³) | Type of Fungus |
|----|-----------------------|-------------------------------|----------------|
|    |                       | NON-AIR-CONDITIONED BUS       |                |
| 1  | 1.1                   | 12                            | Aspergillus fumigatus, Penicillium sp, Mold |
| 2  | 1.2                   | 9                             | Aspergillus fumigatus |
| 3  | 4.1                   | 12                            | Aspergillus fumigatus, Penicillium sp, Aspergillus niger |
| 4  | 4.2                   | 3                             | Aspergillus fumigatus, Penicillium sp |
|    |                       | AIR-CONDITIONED BUS           |                |
| 1  | 2.1                   | 6                             | Aspergillus fumigatus, Mold |
| 2  | 2.2                   | 3                             | Aspergillus fumigatus |
| 3  | 3.1                   | 4                             | Aspergillus fumigatus, Aspergillus niger |
| 4  | 3.2                   | 7                             | Aspergillus fumigatus, Penicillium sp |

Based on table 2 above, it can be seen that infection caused by Species of Aspergillus results in significant morbidity and mortality. Most of the infections are related to Aspergillus fumigatus, Aspergillus flavus and Aspergillus terreus. Aspergillus niger is less common to be reported as the cause of invasive diseases. However, it has been related to otomycosis, cutaneous infection, pneumonia, fatal lungs, and long-term steroid for COPD/Cronic Obstructive Pulmonary Disease [1,6,9].

Inspection of COPD patients with invasive lungs aspergillosis (IPA) shows that 3.6% of cases are caused by Aspergillus niger [2]. Another case mentions that Aspergillus niger is associated with 75% of infected patients' death rates [3]. Mold species can grow indoor or outdoor and grow well in a warm and humid environment. While the Penicillium species commonly grow indoor is the Penicillium chrysogenum. Penicillium will produce toxin with medium toxicity, which can cause allergy and infect untreated patients.

4. Conclusion

According to the research conducted in the air-conditioned bus and the non-air-conditioned bus using the parameter of the biological agent as indoor air pollution indicator, it is concluded that in both buses, several microbes such as Bacillus subtilis, Staphylococcus aureus, staph epidermidis, Klebsiella sp, Streptococcus, and Escherichia coli are found. Even though microbes are still under the threshold (normal level), those microbes are considered pathogenic and dangerous for human health.

Microbes in the non-air-conditioned bus are higher in number than those in the air-conditioned bus. There are 112 microbes in the non-air-conditioned bus and 84 microbes in the air-conditioned bus, in which E. coli and Streptococcus are not found in the air-conditioned bus. Aspergillus fumigatus, Penicillium sp, Mold and Aspergillus niger are pathogen fungi found in the buses and considered dangerous for humans' health. There are similar types of fungi found in both buses; however, the number of fungi is higher in the non-air-conditioned bus (36 fungi) than in the air-conditioned bus (20 fungi).

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