Indoor Air Factors Affecting the Growth of Microorganism in an Indonesian Gas Company's Dormitory

Sjahrul M. Nasri[1], Asduki D. Athari[2], Laksita Ri Hastiti[3], Fiori A. Putri[4]

[1]Technical Service Unit for Occupational Health, Safety and Environment, Universitas Indonesia, Indonesia
Integrated Laboratory and Research Center Building (ILRC), 2nd Floor Campus Universitas Indoensia
Depok, West Java 16424, Indonesia

[2,3,4]Department Occupational Health and Safety, Faculty of Public Health, Universitas Indonesia, Indonesia
Building C, 1st Floor Faculty of Public Health Universitas Indonesia, Depok, West Java 16424, Indonesia

ABSTRACT

Introduction: Mold may affect the Indoor Air Quality (IAQ) in workplace dormitories. This study aims to investigate indoor air factors that affect molds growth in a dormitory of an LNG Company in Indonesia. Several indoor air determinant factors, including relative humidity, general temperature, wet temperature, dry temperature, air velocity, illumination, particulate matter, and carbon dioxide concentration were assessed against the growth of microorganism colonies. **Methods:** This study was a cross-sectional study using a 2 (two)-stage Andersen sampler based on NIOSH 0800 Bioaerosol Sampling Method for Indoor Air Quality for viable bioaerosol sampling. Bioaerosol samples were collected from 50 indoor, corridor, and outdoor sampling points. The total colony count for bioaerosols (TCC) was then determined (CFU/m^3). Ten indoor air quality parameters, i.e., relative humidity, general temperature, wet temperature, dry temperature, air velocity, illumination, particulate matter, and carbon dioxide concentration, were measured. **Results:** The average mold colony concentration in the dormitory rooms was higher (703.1 CFU/m^3) than the maximum standard issued by the Ministry of Health of the Republic of Indonesia (< 700 CFU/m^3) while the relative humidity was very high (84.4% RH on average), with a direct relation between the humidity and the mold colony concentration. A significant correlation was also identified between mold colony concentration, wet temperature, and CO_2 concentration. **Conclusion:** Significant correlations between bioaerosols, relative humidity, wet temperature, and indoor CO_2 concentration indicate insufficient ventilation and poor indoor air quality in the dormitory.

Keywords: carbon dioxide, humidity, indoor air, mold, temperature

Corresponding Author:
Sjahrul M. Nasri
Email: sjahrul@ui.ac.id
Telephone: +628128761955

INTRODUCTION

The quality of indoor air is of greater significance to human health due to the longer exposure of indoor air compared to the outdoor air. An average person inhales around 6-10 l/min and needs 15 m^3 of air per day (Dang *et al*., 2020). Indoor air quality is crucial to human health, since most human's activities take place in an indoor environment, such as in offices, dormitories, and houses (Enitan *et al*., 2017). Presently, people spend more than 80% of their time indoors, including in their accommodation. Human activities such as talking, sneezing, coughing, walking, and washing can produce biological dust in the air. Food, houseplants, house dust, clothing, carpets, wood materials, and furniture can also occasionally release various types of microorganisms into indoor air (Dang *et al*., 2020). Concentrations of fungi in indoor environments vary depending on factors like temperature, humidity, materials, number and circulation of people, characteristics of the building, geographical and climatological conditions, heating-cooling, and ventilation systems (Özkan, 2020). Therefore, it is essential to study and evaluate indoor air quality and take appropriate measures to protect the health of the people.

Various genera of microorganism may be identified in indoor air, particularly Staphylococcus, Bacillus, Micrococcus, Cladosporium, Aspergillus, and Penicillium (Degois *et al*., 2021b). Several prior studies have demonstrated that the microbial characterization depends on the indoor air environment and will differ greatly in season, time, ventilation, and location (Fujiyoshi, Tanaka and

Cite this as: Nasri, S. M *et al.* (2022) 'Indoor Air Factors Affecting the Growth of Microorganism in an Indonesian Gas Company's Dormitory', *The Indonesian Journal of Occupational Safety and Health*, 11(3), pp. 445-453.

 doi:10.20473/ijosh.v11i3.2022.445-453
Received August 05, 2022, received in revised form September 27, 2022, Accepted October 30, 2022, Published: December 2022

Maruyama, 2017). A previous study has reported that an indoor air temperature exceeding 25ºC can cause an increase in fungi growth (Zender-Świercz *et al*., 2019). It is also suggested that there is a correlation between the amount of fungi and the indoor air temperature (Stojanović Bjelić, Ilić and Farooqi, 2020). Molds produce millions of spores, and they are loosely attached that even slight air currents will disturb the spores, making them airborne. Molds spores come in small sizes (large spores are 10-20mm, average 1-5mm); hence, it can easily stay airborne and may be inhaled and breathed deep into the airways. Spores are very tolerant to dryness, changes in temperature, UV light, and some chemicals (Giri, 2020).

In addition, some types of bacteria such as Streptococcus, Mycoplasma and Staphylococcus may cause skin-related diseases, as well as respiratory system diseases and allergies. Consequently, it can lead to an increased proportion of people infected by these microorganisms. In a normal indoor air quality, the number of microorganisms must be lower than the number of the outdoor microorganisms (Salihu *et al*., 2018). Another study reported Corynebacterium and Staphyloccocus as the bacteria that represent more than 5% of the bacterial reads in most samples, with a concentration of 45% and 88%, respectively (Degois *et al*., 2021a). A previous study also stated that high humidity and poor cleanliness of the rooms are conditions that support a strong growth of fungi. Moreover, other environmental factors such as vegetation, urbanization, and airborne particulate matter, also affect the growth of mold and bacteria in the indoor air (Dang *et al*., 2020).

The United States Environmental Protection Agency (US EPA) and the World Health Organization (WHO) have recognized Indoor Air Quality (IAQ) as a multi-disciplinary phenomenon and classified pollutants into several categories. The presence of fungi and bacteria in indoor environment will cause serious problems to human's health, leading to respiratory symptoms such as asthma, cough, reduced lung functions, wheezing, allergies, allergic bronchopulmonary aspergillosis (ABPA), and allergic fungal sinusitis (AFS) (Mannan and Al-Ghamdi, 2021). Meanwhile, a different study has reported that mechanical ventilations may also have detrimental health effects, including an increased risk of asthma, dry eyes, and sick building syndrome symptoms (Lim *et al*., 2021). Moreover, a commission report by Royal College of Physicians has estimated that nearly 3 billion people worldwide are daily exposed to poor indoor air quality caused by the use of solid fuels for cooking, heating, and lighting. This report concluded that household air pollution is a major contributor to global figures for morbidity and mortality, with major effects on respiratory system.

In fact, fungal spores are generally recognized as an important cause of respiratory allergies in both the lower and upper respiratory tracts. Allergic reactions usually occur at the site of the allergen deposition. When a higher number of fungal spores is inhaled, they will be deposited in the nasopharynx and are associated with nasal and/or ocular symptoms usually referred to as hay fever (also known as rhinitis). Spores with a size of less than 5mm can penetrate the lower airways, where allergic reactions and asthma may occur (Giri, 2020).

A prior study has shown an increased level of indoor air quality parameters, particularly carbon dioxide (CO_2), which is closely related to the indoor ventilation rate and is associated with the daily risk of eye fatigue, allergic rhinitis, and atopic dermatitis symptoms (Lim *et al*., 2021). This study reported that an increase of CO_2 by 100 ppm is associated with an elevated risk for eye fatigue and cough symptoms in adults. In addition, a high level of indoor relative humidity is associated with a low risk of skin dryness in adults but a high risk of cough and rhinitis symptoms in children (Lim *et al*., 2021).

Recently, both scientists and the public have focused on risks associated with IAQ due to significance changes in the complex compositions of indoor air pollutants (Mannan and Al-Ghamdi, 2021). Indonesia is a country with high humidity, meaning that it has prominent mold growth and increased risks of bioaerosol-related human health issues.

With indoor air quality related issues in mind, the researchers conducted an initial observation in a dormitory building of an Indonesian LNG company. Most workers will 7 to 12 hours in the dormitory everyday. The dormitory started to operate in 2009, and a few months after it was operated, some workers complained about bad smell and presence of fungi in their rooms, including on their clothes, shoes, bags, and other personal items kept in the room after several months of operation. It was predicted that the dormitory room had a high relative humidity that was similar to the outdoor environment, causing increased growth of fungi. Since the dormitory used air conditioners, other factors may also contribute

to the fungal growth, including temperature, air velocity, illumination, particulate matter, and carbon dioxide concentration.

Thus, this study aims to investigate the determinant factors of microorganism colony growth, including relative humidity, general temperature, wet temperature, dry temperature, air velocity, illumination, particulate matter, and carbon dioxide concentration in an Indonesian LNG company's dormitory.

METHODS

This was a cross-sectional study conducted from May to June 2014 to determine the relationship between number of mold colonies, and several IAQ parameters (relative humidity, general temperature, wet temperature, dry temperature, air velocity, illumination, particulate matter, and carbon dioxide concentration). Bioaerosol samples were collected from the employees' bedrooms, as well as the corridor and outdoor environment of the residential facilities.

Total population was included in the study, consisting of the 293 rooms of the dormitory. Samples were selected based on the proportional sampling approach, resulting in 46 bioaerosol samples plus four samples, each representing (4) other locations outside the Dormitory rooms. Thus, a total of 50 samples or sampling locations were included in the study.

Bioaerosol sampling was performed carried out using the NIOSH 0800 standard for Bioaerosol Sampling (Indoor Air Quality) (NIOSH NMAM, 1998) with a biostage sampler (Andersen two stage cascade impactor). The US Center for Disease Control and Prevention (CDC) NIOSH constructed the details of sampling and characterization of bioaerosol through the NIOSH Manual of Analytical Methods (NMAM) 0800 that describes methods to collect culturable airborne fungi and bacteria in buildings using an Andersen cascade impactor (Lindsley *et al*., 2017). Previous research by Zavieh et. al., used the NIOSH method 0800–0999 to evaluate the bacterial bio-aerosols in the indoor air concentration of gyms (Zavieh *et al*., 2021). In this mtehod, a Hi-flow active air-sampling pump is used to trap the air from the room through a flexible hose (minimum flow rate of 28.3 L/min). The trapped air is passed to the sampling media, which is placed on the 2 (two stage) bio stage sampler. The duration of air sampling time for bioaerosol sampling in this study was 3-10 minutes. Sampling was done aseptically while using proper personal protective equipment to avoid contamination to the sampling media. After sampling, the sample on a petri dish with DG18 (dichloran glycerol agar) media was covered with a sterile lid and applied to parafilm so that no air could enter and contaminate the sample. Blank bioaerosol samples were taken to ensure quality assurance, and for identification of mold species. The samples were then placed in the cool box where the temperature was maintained between 0-10^{O}C. The samples were sent to the designated laboratory as soon as possible. During bioaerosol sampling, a grab sampling of IAQ parameters, i.e., relative humidity, temperature, air velocity rate, illumination, dry temperature, wet temperature, particulate matter (PM_{10}) and CO_2 concentration, were also carried out simultaneously using a direct reading equipment. Data produced from the direct reading equipment was downloaded to the computer after the measurement was completed.

An integrated air velocity meter was used to measure the air movement speed, room temperature, and humidity. Indoor Air Quality Monitor was used for measuring several IAQ parameters, including relative humidity, dew point, temperature, and carbon dioxide (CO_2) levels. Anemometer was used to measure the speed of air movement or the rate of ventilation (air velocity) while the lux meter was used to measure the level of illumination. A digital camera and a checklist were used during observations or inspections at the research site.

Air samples for mold contamination were sent to two KAN (National Accreditation Committee) accredited laboratories consisting of a laboratory based in East Jakarta for mold colony analysis and a biology laboratory for identification of mold species. Data were collected and univariate and bivariate analyses were conducted using the SPSS version 16.0. In addition, site observation was conducted to observe any evidence of fungi growth or mold on furniture and building materials, the presence of musty odor, potential sources of mold, and other IAQ pollutants, as well as room conditions that reflect the behavior of residents and other important IAQ parameters which related to data analysis.

RESULTS

Most of the data obtained from room air quality parameters measurements are results of reading on the measurement instrument with a direct reading system. Only the parameter of new number of mold colonies was obtained after analysis of samples in

the laboratory. Univariate results for the independent variables in this study are provided in Table 1.

From Table 1, it is apparent that the results of air sample analysis for the number of mold colonies showed that the average value of mold colonies at all sampling locations was 703.1 CFU/m^3. The relative humidity levels at almost all sampling locations exceeded the standard level, ranging from 68.8 to 90.8%, with more than half had a humidity level of above 80% Relative Humidity (RH). On the other hand, the room temperature, or the general temperature, was categorized into two groups of 18-23^{O}C (n=31, 62%) and 23-30^{O}C (n=19, 38%), while the air temperature ranged between 22.0-28.2^{O}C, the average air temperature in Dormitory A of 23.5^{O}C, Dormitory B of 22.8^{O}C, the corridors of 27^{O}C, and an outdoor temperature of 28.2^{O}C.

Table 1. Bioaerosols and IAQ Parameters by Sampling Location

Location	Average Value of Measurement Results Based on Sampling Locations									
	Relative Humidity	General Temp	Dry Temp	Wet Temp	Air Vel.	Illumination 1 Open window	Illumination 2 Closed window	Particulate Matter (PM_{10})	CO_2	Total Mold Colony
	(%RH)	(^{o}C)	(^{o}C)	(^{o}C)	(m/s)	(Lux)	(Lux)	(mg/m3)	(ppm)	(CFU/m^3)
Dormitory A-Floor 1	75.0	23.8	24.3	21.5	0.08	204.0	78.0	0.016	332.0	730.0
Dormitory A-Floor 2	84.1	23.5	24.4	22.1	0.09	419.0	134.8	0.008	325.5	873.3
Dormitory A-Floor 3	72.3	23.3	24.3	20.6	0.03	500.0	98.0	0.009	300.7	441.7
Dormitory A-Floor 4	87.6	23.3	24.4	22.1	0.10	332.4	107.0	0.006	342.8	893.2
Dormitory A-Floor 5	77.9	23.2	24.0	21.0	0.13	536.2	114.2	0.005	328.4	763.8
Dormitory A-Floor 6	68.8	23.9	25.6	20.9	0.07	452.5	100.5	0.005	277.5	475.5
Average Dorm. A:	77.6	23.5	24.5	21.4	0.08	407.4	105.4	0.008	317.8	696.2
Dormitory B-Floor 1	77.2	22.3	23.5	21.0	0.15	318.8	138.1	0.012	359.3	681.7
Dormitory B-Floor 2	82.3	22.3	23.5	20.6	0.13	210.3	102.0	0.006	330.7	734.0
Dormitory B-Floor 3	77.2	23.0	25.5	21.7	0.06	210.4	148.0	0.008	306.0	681.0
Dormitory B-Floor 4	78.3	22.0	22.7	19.8	0.11	476.4	87.8	0.010	381.0	762.8
Dormitory B-Floor 5	80.6	23.7	24.6	21.7	0.07	527.0	419.0	0.008	319.0	851.0
Dormitory B-Floor 6	75.0	23.4	24.8	21.2	0.14	363.0	140.5	0.004	289.0	549.3
Average Dorm.B:	78.4	22.8	24.1	21.0	0.11	379.1	172.6	0.008	330.8	710.0
Average Dorm	78.0	23.1	24.3	21.2	0.10	393.2	139.0	0.008	324.3	703.1
Corridor	90.8	27.0	27.5	26.0	0.13	508.0	43.5	0.010	224.0	972.0
Average Corridor	90.8	27.0	27.5	26.0	0.13	508.0	43.5	0.010	224.0	972.0
Outdoor	89.1	28.2	28.8	26.6	0.18	499.0	N/A	0.005	185.0	855.0
Average Outdoor	89.1	28.2	28.8	26.6	0.18	499.0	0.0	0.005	185.0	855.0

The wet temperature parameters were also divided into two groups with the same temperature range as the general temperature. A wet temperature of 18-23^{O}C was identified in 10 rooms (20%), while the wet temperature of 23-30^{O}C was found in the majority of the sampling locations (n=40, 80%). As for the range, the lowest wet temperature was 17.9^{O}C while the highest wet temperature was 26.6^{O}C., with the highest average wet temperature was found in the outdoor locations (28.8^{O}C) while the highest was seen in Dormitory B with 21.0^{O}C. The dry temperature was also categorized into two groups, with 10 rooms (20%) were found to have a dry temperatures of 18-23^{O}C, while a dry temperature of 23-30^{O}C was seen in the majority of of the sampling locations (n=40, 80%). The lowest dry temperature was 21.2^{O}C, while the highest was 29.2^{O}C. On average, the lowest dry temperature was 24.1^{O}C (Dormitory B), while the highest was 28.8^{O}C (outdoor).

Ventilation rates or air velocities in meters per second (m/d) was measured in the range between 0.01 m/d and 0.25 m/d and. Based on Table 1, the highest average air velocity was 0.18 m/d in outdoor locations and the lowest was 0.08 m/d in Dormitory A. For room lighting or illumination, measurements are made using two scenarios: with the window curtain open (light source in the room with sunlight from outside) and the window curtain closed (light source only comes from the room lights). The light intensity with the window opened ranged between 148-874 lux with the highest being in the corridor with 508.0 lux and the lowest in Dormitory A with 379.1 lux. Meanwhile, the light intensity with the window closed ranged between 38-774 lux, with Dormitory B having the highest intensity with 172.6 lux. In term of dust with a diameter below 10 microns (10μm) or particulate matter-10 (PM_{10}), the highest concentration was 0.027 while the lowest was 0.003 mg /m^3. On average, the highest average concentration of dust was 0.010 mg/m^3 in the corridor while the lowest was identified in the outdoor location with 0.005 mg/m3. For the carbon dioxide (CO_2) level, no room or location of sample collection had a CO_2 level of above 500 ppm, with a range of 115 to 447 ppm, with the average level in all locations was between 185-324.3 ppm.

Mold samples were sent to the laboratory to assess the number of the mold colonies and their type. The mold species identified in the samples are listed in Table 2 with their percentage based on the frequency of discovery.

There were nine (9) species of fungi identified from the samples collected indoor, in the corridor and outside of the dormitory building. The outside air carried 4 species, while 8 species and 2 species were identified in the indoor and corridor air. Three

Table 2. Mold Species Identified in Rooms, Outside Locations, and Corridors of Dormitories

Location	Name of Mold Species	Percentage
Outdoor	Mycelia sterilia	50%
	Aspergillus niger	30%
	Curvularia lunata	10%
	Penicillium chrysogenum	10%
Indoor (bedroom)	Penicillium citrinum	31%
	Mycelia sterilia	25%
	Aspergillus niger	13%
	Alternaria alternate	6%
Indoor (bedroom)	Curvularia lunata	6%
	Fusarium acuminatum	6%
	Aspergillus terreus	6%
	Aspergillus nidulans	6%
Corridor	Aspergillus niger	50%
	Mycelia sterilia	50%

Table 3. Correlation Between Bioaerosols and IAQ parameters in an Indonesian LNG Dormitory

Variable	R	R2	Line equation	P-value
Humidity (RH)	0.867	0.752	=(-1217.662) + 24.671*RH	0.00001
General Temperature	0.186	0.034	=(-159.855)+39.060*Temp	0.271
Dry Temperature	0.149	0.022	=174.997+23.152*Dry Temperature	0.302
Wet Temperature	0.592	0.35	=(-766.283)+71.012*Wet Temperature	0.00001
Air Velocity	0.136	0.019	=652.836 + 555.078*Laju_Ventilasi	0.367
Illmuination-1 (Open window)	0.027	0.001	=731.521- 0.039*Illumination-1	0.861
Illumination-2 (Closed window)	0.06	0.004	=696.417 + 0.140*Illumination-2	0.691
PM_{10}	0.056	0.003	=690.493+ 5.212*PM_{10}	0.136
CO_2	0.409	0.167	=-145.003 + 2.578*CO_2	0.005

of the four (4) species found in the outdoor air were also found indoor. In other words, 44% of the mold species found in indoor air were also found in the outdoor air. Penicillium citrinum, Mycelia sterilia, and Aspergillus niger were the top three species in terms of frequency in the indoor air. Meanwhile, in the outdoor air and corridors, Mycelia sterilia and Aspergillus niger were the most commonly found species.

Bivariate analysis was carried out to see the relationship between independent variables and confounding variables. Meanwhile, for the dependent variables, the statistical test used was the correlation test for two numerical variables.

Based on the statistical test results, some variables significantly correlated with the number of mold colonies in the dormitory. These were relative humidity, wet temperature, and CO_2 (p-value= lower than 0.05). On the other hand, general temperature, dry temperature, air velocity, illuminations (both in closed windows and open windows), and PM10 were not correlated with the number of mold colonies.

DISCUSSION

This study suggested that the highest average level of mold colony was found in the corridor (972 CFU/m^3) while the lowest was found in Dormitory A (696.2 CFU/m^3) with an average of 843.4 CFU/m^3 for the total area of the dormitory. This value is above the recommended maximum level as stated by the Indonesia Ministry of Health (2011) (maximum 700 CFU/m^3).

The results of this study show that the poor quality of air in the rooms in the dormitory building is liked to the mold contamination and that he fungal growth in this vicinity is affected by high relative humidity, the high concentration of carbon dioxide, and wet temperature. Inside the dormitory room, the dominant colony is the Penicillium citrinum while at the dormitory's corridor, the most frequent microorganism colony identified was Aspergillus niger and Mycelia sterilia.

Based on the measurement data of mold colonies, it was found that the average number of mold colonies in all samples analyzed was 731 CFU/m^3, with the highest being 972 CFU/m^3 and the lowest being 185 CFU/m^3. Specifically for the air inside the bedrooms, both Dormitory A and Dormitory B have a mold colony of 714.7 CFU/m^3. The expert team on biological factors recommends a an indoor mold concentration for living and public quarters of 5.0 x 103 CFU/m^3 (Dudzinska, 2011). Meanwhile, the maximum threshold for microorganism contamination, including mold, according to the Ministry of Health of the Republic of Indonesia Health Ministry is 700 CFU/m^3 (Regulation of the Minister of Health of the Repubilc of Indonesia, 2011). In the outdoor setting of the dormitory, a high concentration of mold is also found, with the average number of mold colonies in the outside area of the building of 855 CFU/m^3 and of 972 CFU/m^3 in the corridors. The high number of mold colonies outside the room has the potential to be a source of contamination.

There are at least nine (9) species of mold or fungi identified in the study site. Of the eight species found in the room, five are only found indoors and three (3) are also found outside the room. Sterilia mycelia is the predominant in all sampling locations, along with Aspergillus niger. For the Penicillium group, the Penicillium chrysogenum species is found in outside air, but not in the indoor air. In contrast, Penicillium citrinum is only found in the room. Culvularia lunata species is discovered in both outside and indoor air. Cladosporium is mostly known as an outdoor-originated mold species, while Aspergillus and Penicillium are easily found in the contaminated indoor environment (Mentese *et al*., 2020). Some species of Penicillium can also be found in indoor environments and are allergenic in nature and can trigger several conditions such as hypersensitivity pneumonia, allergic alveolitis, keratitis, otomycosis, and penicilliosis.

A recent study by Giri (2020) stated that Aspergillus, Penicillium, and other fungi can grow indoor without any obvious moisture problems. In addition, these fungi can be detected at a higher level indoors, compared to outdoors. Other fungus species, such as Acremonium, Alternaria, Aspergillus spp., A. niger, A. flavus, A. versicolor, Aureobasidium, Botrytis, Cladosporium, Exophiala, Fusarium, Penicillium, Paecilomyces, Scopulariopsis, Stachybotrys, Trichoderma, and Torula contribute to deterioration of construction materials made of concrete and stone (Giri, 2020).

The indoor mold concentration is higher in homes where visible mold growth or dampness occurred. The main sources of indoor air pollutants are building construction materials and decoration materials, such as carpet, pressed wood, floor coverings, and wall paint (Mentese *et al*., 2020). However, indoor fungi can be a mixture of fungi from outdoor and indoor sources. A previous

study also presented that Aspergillus Niger as one of the dominant fungi in the indoor environment (Leite Júnior *et al*., 2018). Studies also showed the presence of 160 cfu/m3 Mycelia sterilia in sleeping rooms (Zautner, Frickmann and Podbielski, 2021) and 14% in indoor air (Saadati *et al*., 2022).

Fusarium spp is found in both indoor and outdoor air. According to EPA, this is a potentially toxigenic fungus that may lead to various unexpected health effects may occur. However, there is no single literature that suggested certain fungus species as far riskier than other fungi. The fungi found in this study are all hydrophilic fungi, which explain its relationship with humidity. A high concentration of mold spores will cause health concerns to people in the form of allergic reactions or mycotoxin poisoning, causing fungal infection (mycosis). Specifically for Aspergillus niger, this species can infect and grow in human's lungs (Spicer, 2015).

Based on the statistical analysis results, there are three parameters of indoor air quality that have a significant relationship with the number of mold colonies: relative humidity, wet temperature, and carbon dioxide (CO_2) gas level. Microbial growth, including fungal growth, is commonly observed in an environment with high relative humidity, particularly if the RH is greater than 90%, 98%, 70%, 84%, and 80%. The U.S. Environmental Protection Agency recommends to maintain the indoor relative humidity to below 60%, ideally between 30% to 50%. Low humidity may also discourage pests (such as cockroaches) and dust mites.

A previous study demonstrated that several pathogenic strains are able to grow at 37°C, including Trichoderma (T. citrinoviride, T. longibrachiatum), Aspergillus (A. flavus, Aspergillus sp. section Nigri), Rhizopus (R. oryzae) and Paecilomyces sp (Vornanen-Winqvist *et al*., 2020). A previous studies reported a linear relationship between the RH-level and the growth of Penicillium sp. (Vornanen-Winqvist *et al*., 2020) and Aspergillus sp. Moreover, poor cleanliness of the rooms will increase the growth of fungi (Dang *et al*., 2020). In this study, the concentration of fungi in the morning is found to be higher than in the afternoon due to the morning temperature that is suitable for fungal growth (~30ºC). Therefore, the growth of fungi is not only directly controlled by RH but also by the wet temperature. The presence of fungi and bacteria aerosols indoors is linked to several factors such as the activities of the occupants, temperature, relative humidity, and inadequate ventilation (Chegini *et al*., 2020).

An elevated CO_2 has been demonstrated to have a highly variable impact on fungal growth as it depends on the environment. Fungal mycelium needs a high concentration of CO_2 to grow (Pavlík *et al*., 2020). For instance, the number of Aspergillus is constant while the number of Penicillium decreases when the carbon dioxide level is elevated (Tang, Kuehn and Simcik, 2015). Another study reported the correlation between high CO_2 production, fungal growth, and mycotoxin accumulation (Garcia-Cela *et al*., 2020). Another prior research also suggested that the presence of mold is associated with dusts on indoor surfaces, such as those accumulated on carpets and furnishings and from indoor plants, that can be resuspended into the indoor air through activities such as walking or cleaning (Chegini *et al*., 2020). This study also mentioned that the indoor airborne bacteria and mold can be contaminated by outdoor airborne bacteria through natural ventilation and indoor generative sources.

Mold fungi have a higher tendency to grow in dry atmosphere and high temperature (Spicer, 2015). It can be affected by a dark and poorly aerated indoor environment. An indoor environment can also be contaminated by bacteria growing in water reservoirs or moist environments (Mata *et al*., 2022). A study conducted by Araujo and Cabral (2010) also demonstrated that the optimum temperature for growth and sporulation is usually around 25-30°C, while the minimum moisture content of building materials which will allow fungal growth is approximately 76%.

CONCLUSION

Microorganism contamination in the company's dormitory under study is high. A significant correlation between bioaerosols and relative humidity, wet temperature, and carbon dioxide level demonstrated in this study suggested that these variables can be considered as the determinant factors of microorganism growth in the indoor environment of dormitory facilities.

ACKNOWLEDGEMENTS

The researchers would like to thank the Management of Company for their trust to the authors and team to conduct the Indoor Air Quality

measurements for research purpose and to provide recommendations to the company.

REFERENCES

Araujo, R. and Cabral, J. P. (2010) '*Fungal Air Quality in Medical Protected Environments*', in Kumar, A. (ed.) Air Quality. London: IntechOpen, pp. 357–382.

Chegini, F. M. *et al*. (2020) 'Indoor and Outdoor Airborne Bacterial and Fungal Air Quality in Kindergartens: Seasonal Distribution, Genera, Levels, and Factors Influencing their Concentration', *Building and Environment*, 175, p. 106690.

Dang, D. Y. N. *et al*. (2020) 'Microbiological contamination of indoor air in university classrooms(Case study: University of Science - Vietnam National University,Ho Chi Minh city)', *Vietnam Journal of Science, Technology and Engineering*, 62(4), pp. 30–35.

Degois, J. *et al*. (2021a) 'Indoor Air Quality Assessment in Dwellings with Different Ventilation Strategies in Nunavik and Impacts on Bacterial and Fungal Microbiota', *Indoor Air: International Journal of Indoor Environment and Health*, 31(6), pp. 2213–2225.

Degois, J. *et al*. (2021b) 'Indoor Air Quality Assessment in Dwellings with Different Ventilation Strategies in Nunavik and Impacts on Bacterial and Fungal Microbiota', *Indoor Air: International Journal of Indoor Environment and Health*, 31(6), pp. 2213–2225.

Dudzinska, M.R. (2011) *Management of Indoor Air Quality*. London: CRC Press.

Enitan, S.S. *et al*. (2017) 'Microbiological Assessment of Indoor Air Quality of Some Selected Private Primary Schools in Ilishan- Remo, Ogun state, Nigeria', *International Journal of Medical and Health Research*, 3(6), pp. 8–19.

Fujiyoshi, S., Tanaka, D. and Maruyama, F. (2017) 'Transmission of Airborne Bacteria Across Built Environments and its Measurement Standards: A Review', *Frontiers in Microbiology*, 8(Nov), pp. 1-17.

Garcia-Cela, E. *et al*. (2020) 'Carbon Dioxide Production as an Indicator of Aspergillus Flavus Colonisation and Aflatoxins/Cyclopiazonic Acid Contamination in Shelled Peanuts Stored Under Different Interacting Abiotic Factors', *Fungal Biology. British Mycological Society*, 124(1), pp. 1–7.

Giri, S. K. (2020) 'Prevalence Of Air-Borne Fungi in Indoor Environment of Dental Clinic', *International Research Journal of Modernization in Engineering, Technology and Science*, 2(8), pp. 1161–1169.

Leite Júnior, D. P. *et al*. (2018) 'Indoor Air Mycological Survey and Occupational Exposure in Libraries in Mato Grosso-Central Region—Brazil', *Advances in Microbiology*, 08(04), pp. 324–353.

Lim, A. Y. *et al*. (2021) 'Effects of Mechanical Ventilation on Indoor Air Quality and Occupant Health Status in Energy-Efficient Homes: A Longitudinal Field Study', *Science of the Total Environment*, 785, pp. 1-6.

Lindsley, W. G. *et al*. (2017) 'NIOSH Manual of Analytical Methods: Sampling and Characterization of Bioaerosols'. 5th Edition. Washington DC: Department of Health and Human Services.

Mannan, M. and Al-Ghamdi, S. G. (2021) 'Indoor Air Quality in Buildings: A Comprehensive Review on the Factors Influencing Air Pollution in Residential and Commercial Structure', *International Journal of Environmental Research and Public Health*, 18(6), pp. 1–24..

Mata, T. M. *et al*. (2022) 'Indoor Air Quality in Elderly Centers : Pollutants Emission and Health Effects', *Environments*, (2), pp. 1–25.

Mentese, S. *et al*. (2020) 'A Long-term Multi-Parametric Monitoring Study: Indoor Air Quality (IAQ) and the Sources of the Pollutants, Prevalence of Sick Building Syndrome (SBS) Symptoms, and Respiratory Health Indicators', *Atmospheric Pollution Research. Turkish National Committee for Air Pollution Research and Control*, 11(12), pp. 2270–2281.

NIOSH NMAM. (1998) 'Bioaerosol Sampling (Indoor Air) Culturable Organisms: Bacteria, Fungi, Thermophilic Actinomycetes', NMAM 0800 Methods, (1), p. 800.

Özkan, V. K. (2020) 'Fungal Bioaerosols in Indoor Air Environments of Health Services Vocational School in Marmaris, Turkey', *Mantar Dergisi: The Journal of Fungus*, 11(1), pp. 50–56.

Pavlík, M. *et al*. (2020) 'Evaluation of the Carbon Dioxide Production by Fungi Under Different Growing Conditions', *Current Microbiology*, 77(9), pp. 2374–2384.

Regulation of the Minister of Health Of the Republic of Indonesia. (2011). Regulation of the Minister of Health of the Republic of Indonesia No 1077/

Menkes/PER/2011 on Guideline for Healthy Indoor Air.

Saadati, Z. *et al*. (2022) 'Investigation of Indoor and Outdoor Fungal Bioaerosols and Environmental Factors in Indoor Air Quality of Nursery Schools', *International Journal of Molecular and Clinical Microbiology*, 12(1), pp. 1596–1604.

Sa'id, A.S. and Salihu, A.A., 2017 'Microbiological Quality of Indoor Air in Some Selected Buildings at Modibbo Adamawa University of Technology, Yola', *Journal of Microbiology*, 3(1), pp.1-5.

Spicer, N. (2015) 'Global Health Global Health', *JAMA: Journal of the American Medical Association*, 42(3), pp. 89–99.

Stojanović Bjelić, L., Ilić, P. and Farooqi, Z. U. R. (2020) 'Indoor Microbiological air Pollution in the Hospital', *Quality of Life (Banja Luka) - APEIRON*, 18(1–2), pp. 5–10.

Tang, W., Kuehn, T. H. and Simcik, M. F. (2015) 'Effects of Temperature, Humidity and Air Flow on Fungal Growth Rate on Loaded Ventilation Filters', *Journal of Occupational and Environmental Hygiene*, 12(8), pp. 525–537.

Vornanen-Winqvist, C. *et al*. (2020) 'Exposure to Indoor Air Contaminants in School Buildings with and without Reported Indoor Air Quality Problems', *Environment International*, 141(October), p. 105781.

Zautner, A. E., Frickmann, H. and Podbielski, A. (2021) 'Risk assessment for Molds in the Vicinity of a Child Requiring Peritoneal Dialysis Living in a Rural Northern German Area', *Microorganisms*, 9(11), pp. 1–12.

Zavieh, F. S. *et al*. (2021) 'Assessment of Types of Bacterial Bio-Aerosols and Concentrations in the Indoor Air of Gyms', *Environmental Geochemistry and Health*, 43(5), pp. 2165–2173.

Zender-Świercz, E. *et al*. (2019) 'The Microbiology Contaminants and Microclimate Parameters in the Nursery Building', *International Journal of Environmental Science and Technology*. , 16(11), pp. 6699–6704.