Hindawi
Complexity
Volume 2023, Article ID 9345311, 11 pages
https://doi.org/10.1155/2023/9345311

Research Article

Key Elements Affecting the Library's CFU Concentration in Taiwan

Bang-Lee Chang,[1] Han-Kuang Tien,[2] Yong-Jun Lin,[3] and Gary Li-Kai Hsiao [4]

[1]*Department of Architecture and Urban Design, Chinese Culture University, Taipei, Taiwan*
[2]*Department of International Trading, Chinese Culture University, Taipei, Taiwan*
[3]*Center for Weather Climate and Disaster Research, National Taiwan University, Taipei, Taiwan*
[4]*Department of Disaster Management, Taiwan Police College, Taipei, Taiwan*

Correspondence should be addressed to Gary Li-Kai Hsiao; gary670120@yahoo.com.tw

Received 16 August 2022; Revised 9 April 2023; Accepted 18 April 2023; Published 10 May 2023

Academic Editor: Daniele Salvati

Public libraries are popular gathering places, so understanding the factors that contribute to colony-forming unit (CFU) concentrations and how to minimize them is essential. This study aimed to investigate the factors that affect CFU concentrations in a public library, using air sampling (Bioluminescent ATP-assay) and statistical analysis software (SPSS) to collect and analyze data. The findings indicated that the CFU concentration in the library was significantly influenced by the air quality surrounding the building, the number of library visitors, and the hygiene and health of both visitors and employees. Additionally, indoor temperature and humidity were found to be key factors affecting CFU concentration. These findings suggest the need for better ventilation and air filtration systems, as well as regular cleaning and disinfection in public libraries. Furthermore, research is recommended to investigate other potential factors that may impact indoor air quality in public spaces.

1. Introduction

When examining a library, a place with a specific use, the following two aspects should be considered: the safe storage of library books and documents, and the health and comfort of users (citizens). These two aspects are influenced by numerous factors, which frequently interact and restrict each other. For the safe storage of books and documents, researchers should emphasize the following issues: (a) problems such as mildew and rot, discoloration, and quality changes caused by molds, fungi, bacteria, and actinomycetes; (b) problems related to insects (e.g., silverfish, booklice, and drywood termites) that feed on paper materials spontaneously eating or chewing books and documents; and (c) whether the temperature and humidity level causes paper materials to become brittle (which results in the paper breaking) or damp. Regarding user health and comfort, airborne microorganisms and the tiny particles released by microorganisms, fleas, and house dust mites influence people's health, comfort, adaptability, and psychological and subjective perceptions. Library managers frequently encounter dilemmas related to considering both aspects (i.e., the safe storage of library books and documents, and user health and comfort). According to the results of this study, if an appropriate management system can be developed, and the temperature and humidity of indoor environments effectively controlled, then the problems mentioned above can be resolved, thereby doubling the effects achieved and maximizing the results [1–5].

Taiwan is located in a subtropical region that experiences substantial water during rainy seasons and typhoons, forming a warm yet humid climate. A previous study reported that in the past century (between 1897 and 1997), the average temperature and relative humidity in Taiwan were 23°C and 80%, respectively [6–8]. According to statistical data of the last 10 years (between 2002 and 2011) obtained by the Central Weather Bureau, the average temperature and relative humidity in Taiwan ranged from 22°C to 23°C and

77% to 79%, respectively. Furthermore, based on data in relevant literature, particles suspended in the air can damage the human respiratory system. Particle contaminants with a diameter of less than 5.7 μm easily induce various respiratory diseases, such as chronic rhinitis, bronchitis, asthma, and pneumonia. If sulfur dioxide is adsorbed by the surface of suspended particles, the severity of the damage to the human respiratory system is expedited and increased [9–11]. Bioaerosols are types of suspended particle that includes microorganisms suspended in air (e.g., viruses, bacteria, fungi, and mold) and tiny particles (e.g., spores, pollens, and toxins) released by microorganisms [12–14]. These tiny microorganisms and particles enter the human body via the respiratory tract, thereby affecting people's health [15–17].

Studies have indicated that people spend more than 80% of the time in indoor environments [18, 19]. Lance found similar results in 1996, reporting that the general population spends 87.2% of each day in indoor environments, 7.2% of the time commuting or using transport, and the remaining 5.6% engaging in outdoor activities. Juneja Gandhi and Tainio have similar findings to Lance [20, 21].

This study employed several investigatory factors (e.g., differing floor levels, time periods, indoor environment properties, floor area, number of people or users, and library indoor temperature and humidity) and adopted the impactor-type sampler (Buck, Bio-Culture B30120) to extract bioaerosol samples of a library's indoor air. Subsequently, we directly impinged the samples onto a suitable medium to determine the library's internal colony-forming unit (CFU) concentration. Based on the experiment and statistical analysis results, the key factors that influence the CFU concentration are the relative humidity, temperature, and properties of an indoor environment. However, no significant causal relationship was observed between the other factors (i.e., the total number of people inside the library, floor area, time periods, and number of floors) and the CFU concentration.

A number of studies and projects have extensively examined the air quality (including the distribution of bioaerosols) of different building types or uses. In addition, numerous journal publications have presented critical insights and valuable research outcomes. Various research findings, conclusions, and recommendations regarding the enhancement of air quality in different areas have provided outstanding contributions. By reviewing and summarizing the research methods used by international and professional scholars investigating topics related to air quality, we found that international methods for examining IAQ typically involve the following procedures: an exploration and review of previous research, relevant data analysis, experimental collection of air bioaerosol samples, selection of suitable mediums for sample cultivation, and finally, use of microscopes for determining the number of bioaerosols in the culture medium, which is then used to calculate the concentration of bioaerosols in 1 m^3 of air [12, 22–35].

If an air-conditioning system cannot be installed, good ventilation in the storage area should be maintained. Generally, a suitable temperature in the summer is 24.4°C to 27.7°C, and that in the winter is 21.1°C; the optimal relative humidity level in the summer is 40% to 70%, and that in the winter is 20% to 50% [36, 37].

When the temperature exceeds 25°C, most insects grow and reproduce rapidly; however, their reproduction rate declines when the temperature ranges between 15°C and 20°C, with temperatures below 10°C influencing their development. Overall, reducing humidity can lower the probability of insect and pest attacks [38, 39].

Because excessive humidity in one part of a storage area induces the growth of microorganisms or molds, insects and pests that feed on molds (e.g., silverfish and booklice) are attracted to the storage areas and will eat and chew on books or archives [40, 41].

The factors that influence the evaporation of water from the skin are not only related to the surface condition of the skin but also the relative humidity of residential environments [42, 43]. After the outbreak of COVID-19, the world economy, human resources, production of daily necessities, and various business activities have been severely affected. The survival and development of various industries are affected. In order to prevent the rapid spread of the epidemic, the government has adopted various methods to restrict people's freedom of movement and social activities during the epidemic. Gathering numbers and social distancing are strictly limited. Scholars and experts in related public health fields began to explore the transmission variable route of the COVID-19 studies using airborne, droplet, oral foam, or fungi as virus transmission media [44–54].

2. Materials and Methods

For this study, we collected bioaerosol samples from a public library in Taoyuan County. This study employed the impactor-type sampler (Buck, Bio-Culture B30120) to extract an air sample of an appropriate volume via aspiration that was then directly impinged onto a culture medium suitable for bacterial and fungal growth. Cultivation was conducted at a temperature of 30 ± 1°C for a total of 48 ± 2 hours, and the tryptone soy agar (TSA) comprising tryptone, soy peptone NaCl, and agar, was used as the culture medium. The flow rate of the sampler was 100 L/min, and the sampling time was 1 min. Samples were taken in February and April at three time points: 09:00, 12:00, and 15:00. The density of the sampling point depended on the floor area: a collection point was established for every 500 to 1,000 m^2. The relevant experimental equipment and procedures are described as follows:

(a) Impactor-type samplers (reference photographs), as shown in Figure 1.

(b) Experimental procedures: air sampling using plate count agar, incubate microorganisms (e.g., fungi) in the culture medium for 48 hours, and calculate the enumeration (CFU/m^3) of the microorganisms (e.g., fungi or bacteria).

(c) CFU is then calculated using the logarithm (to base 10) of the number of microorganisms on the culture dish.

(d) The CFU concentration was determined by converting the CFU through calculations.

(e) Experimental method: Environmental Inspection Institute, Environmental Protection Agency. Airborne fungal concentration detection method (NIEA E401.15C).

(f) Each venue shall complete the sampling within 2 hours before the end of the business hours of the venue, but the 24-hour business venue can choose any time period for sampling.

(g) At least 2 sampling points should be implemented in each site and should be selected on the personnel movement line, and additional sampling points should be added if necessary (if there are other leaks, traces of microbial growth, and places where personnel complain of discomfort).

(h) The sampling location should be at least 0.5 meters away from indoor hardware structures or display facilities and at least 3 meters away from doorways or elevators.

For this study, we selected a public library established in 1980s in the Taoyuan County City. When conducting the microorganisms CFU concentration experiment, in addition to obtaining approval from management units and reducing user inconvenience, we also considered the representativeness and integrity of sampling. In other words, besides circumventing human factors, the necessity and importance of sampling sites (including floor level) and the number of sampling points were also carefully considered. After assessing all subjective and objective influential factors, we decided to conduct sampling on February 24, 2020, and April 7, 2020, of 84 sampling points, which included areas on the first, fourth, and fifth floors and at seven sites, that is, the technology (IT) department (363 m^2), periodical room (333 m^2), children's reading room (242 m^2), audio-visual classroom (201 m^2), open-shelf reading room (363 m^2), reference room (242 m^2), and the general reading room (242 m^2). Based on the experimental results, preliminary inferences, when the number of bioaerosol colonies outside the site increases, and the number of people entering the site from the outside also increases, the number of bacterial colonies inside the site will increase due to the increase in the number of people. When the people entering the site who already carry bioaerosols, the amount of bioaerosols inside the site will increase with the increase of people entering the site.

More experts and scholars are studying the correlation between bioaerosols and COVID-19. The concentration of bioaerosols is not only related to indoor air quality but also has an important relationship with the spread speed and expansion of the COVID-19 epidemic [57–71].

3. Results and Discussion

3.1. Correlation between the Total Number of People Who Entered the Library and CFU Concentration. According to the experimental data, the total number of people who entered the library and the average CFU concentration on February 24, 2020, was 467 and 104 CFU/m^3, respectively. The total number of people who entered the library and the average CFU concentration on April 7, 2020, was 374 and 211 CFU/m^3, respectively. Based on the general understanding that a higher number of people in the library suggest a higher presence of bioaerosols, the CFU concentration on April 7, 2020, should be higher than that on February 24, 2020. However, the experimental results showed the opposite phenomenon. If the average CFU concentration was regarded as the dependent variable, and the number of people as the investigatory factor, using SPSS statistical software to conduct analysis of the least significant difference (LSD) multiple comparisons, we found that the number of people and average CFU concentration were not significantly correlated ($p > 0.05$). Furthermore, even with the same use purpose (floor area was the same), when adopting user density (people/m^2) to investigate CFU concentration, a significant relationship was not observed ($p > 0.05$).

In reality, regardless of the location or sites, we recommend adopting the following two aspects for examining the relative relationship between the number of people and employees and CFU concentrations: (a) in a situation where the amount of external bioaerosols and the number of people entering a site are increasing, the probability that the internal CFU concentration will rise is enhanced. (b) However, if the amount of bioaerosols outside a building are not considered, when the people entering a site are bioaerosol carriers, the amount of internal bioaerosols increases with increasing numbers of people entering the site. In other words, the indoor CFU concentration is not only related to the outdoor CFU concentration but also a person's health and hygiene. Assuming that outdoor environments possess excellent air quality and people's health and hygiene are good, then regardless of the number of people and employees who enter a library, the indoor CFU concentration will not change significantly as the number of people increases.

3.2. Relationship between the Number of Floors, Sampling Time, and CFU Concentration. Except in special circumstances, general users/visitors must pass through the first floor to reach other floor levels; thus, under the same external environment, the first floor is the area through which all users/visitors must pass. Thus, employing common sense, the probability that bioaerosols are present on the first floor is higher compared to that on the other floors. However, according to the experimental results of this study and the LSD multiple comparative analyses using SPSS software, CFU concentrations and the number of floors are not directly correlated ($p > 0.05$). In addition, bioaerosols can directly or indirectly enter and remain (or reside) in the library at any time in the morning or at night.

3.3. Relationship between the Floor Area and CFU Concentration. In this study, bioaerosol samples were collected from seven different locations within the

Traditional Plate Counts | Sieve Air Sampler with a High Flow Rate | Bioluminescent ATP-assay

Figure 1: Reference photographs of the impactor-type samplers [55, 56] (Data source: Bioluminescent ATP-assay).

library, including the IT Department, periodical room, children's reading room, audio-visual classroom, open-shelf reading room, reference room, and general reading room. The result of the LSD multiple comparative analyses using SPSS software showed that larger floor areas did not possess higher CFU concentrations. The size of the floor area and the average CFU concentration did not show a significant correlation ($p > 0.05$). This finding can be explained by considering the methods used to sample bioaerosols. Based on this assertion, bioaerosols travel with the movement of airflow, leading to random deposits on culture dishes or in each corner of the floor. Generally, a larger floor area suggests a greater probability of receiving bioaerosols, but an absolute correlation is absent. For example, when the openings of a building directly contact substantial outdoor pollutants, or when the people who enter a site carry bacteria, even if the site area is relatively small, the CFU concentration will be higher than that of sites with a larger floor area.

3.4. Relationship between Site Use and the CFU Concentration. As shown in Table 1, according to the experimental results and SPSS software analysis, the following three sites (in sequential order) possessed the highest CFU concentration in the library: the periodical room, children's reading room, and open-shelf reading room, and the reference room had the lowest CFU concentration. Regarding the average CFU concentration, a significant difference between the reference room and the periodical room, children's reading room, and open-shelf reading room was observed ($p < 0.05$), as shown in Table 2. Based on this phenomenon, library managers should examine sites with a lower IAQ and determine whether the comparatively poorer performance is the result of old air-conditioners and the poor ventilation is caused by excessive furnishings and overly narrow spaces. Based on the site survey, we made the following observations regarding the reference room: the windows were not obstructed by interior decorations or bookshelves; the bookshelves were arranged in parallel with the windows; the room possessed good ventilation and lighting; and no tables or chairs are provided for readers, and thus, people spend less time in this room.

3.5. Relationship between the Temperature or Humidity and CFU Concentration. When bioaerosols were sampled, the indoor temperature and humidity level were 20.2°C to 25°C and 49.2% to 69%, respectively. According to the experimental results and SPSS software analysis (Table 3), when the temperature range was <22.1°C, 22.1°C to 23.7°C, and >23.7°C, the average CFU concentration was 106.3 CFU/m^3, 154.2 CFU/m^3, and 205.2 CFU/m^3, respectively. In this study, as shown in Tables 3 and 4, the study employed the average temperature and humidity on February 24, 2020 (22.1°C; 64.6%), and April 7, 2020 (23.7°C; 56.1%), as the segment point for SPSS statistical analysis. From Table 4, when the temperature segment ranged between 20.2°C and 25°C, the CFU concentration at <22.1°C and >23.7°C exhibited significant differences ($p < 0.05$). Furthermore, based on the statistical data, the CFU concentration at >23.7°C was higher than that at <22.1°C, indicating that the CFU concentration was correlated to the temperature. As the temperature rose, the CFU concentration exhibited as an increasing trend.

Based on Table 5, when the humidity ranged between 49.2% and 69%, the CFU concentration at a <56.1% and 56.1% to 64.6% humidity level demonstrated significance differences ($p < 0.05$). The CFU concentration at < 56.1% and <64.6% also exhibited significant differences ($p < 0.05$). According to statistical data, the CFU concentration at < 56.1% was higher than that at < 64.6%. Subsequently, we assumed that the CFU concentration was the dependent variable and that the humidity was the independent variable. The regression analysis results indicated that the humidity and CFU concentration were significant ($p < 0.05$), as shown in Tables 6–8. Therefore, when the level of humidity ranges between 49.2% and 69%, higher humidity indicates lower CFU concentration. The regression equation can be expressed as follows:

$$y = -0.438x. \tag{1}$$

Table 1: Average number of bioaerosols at various sites.

Descriptive statistics: Average concentration of bacterial colonies							
	Average	Standard deviation	Standard error	Average at 95% confidence level		Minimum	Maximum
				Lower bound	Upper bound		
IT department	101.0000	70.66824	28.85019	26.8382	175.1618	33.00	193.00
Children's reading room	208.3333	63.06082	25.74447	142.1551	274.5116	100.00	280.00
Reference room	70.0000	61.64414	25.16611	5.3084	134.6916	5.00	175.00
Periodical room	215.0000	148.35768	60.56677	59.3082	370.6918	95.00	475.00
Open-shelf reading room	202.5000	159.86713	65.26548	34.7297	370.2703	55.00	510.00
Audio-visual classroom	183.3333	155.77762	63.59595	19.8547	346.8119	20.00	440.00
General reading room	122.5000	48.86205	19.94785	71.2224	173.7776	85.00	210.00
Total	157.5238	116.75474	18.01565	121.1405	193.9071	5.00	510.00

Table 2: Difference in CFU concentrations between the reference room and other sites.

Site (I)	Sites (J)	Average difference (I-J)	Standard error	Significance	95% confidence interval	
					Lower bound	Lower bound
Reference room	IT department	−31.00000	64.36219	0.633	−161.6622	99.6622
	Children's reading room	−138.33333*	64.36219	0.039	−268.9955	−7.6711
	Periodical room	−145.00000*	64.36219	0.031	−275.6622	−14.3378
	Open-shelf reading room	−132.50000*	64.36219	0.047	−263.1622	−1.8378
	Audio-visual classroom	−113.33333	64.36219	0.087	−243.9955	17.3289
	General reading room	−52.50000	64.36219	0.420	−183.1622	78.1622

* = Average difference achieved a .05 significance level.

Table 3: Average CFU concentrations at various temperatures.

Descriptive statistics: Average CFU concentration							
Temperature range	Average	Standard deviation	Standard error	Average at 95% confidence interval		Minimum	Maximum
				Lower bound	Upper bound		
<22.1°C	106.3333	78.63417	22.69973	56.3716	156.2951	20.00	280.00
22.1°C ~ 23.7°C	154.1875	117.01807	29.25452	91.8330	216.5420	5.00	475.00
>23.7°C	205.2143	130.68410	34.92680	129.7595	280.6690	45.00	510.00
Total	157.5238	116.75474	18.01565	121.1405	193.9071	5.00	510.00

Table 4: Significance between the average CFU concentration and various temperatures.

Temperature segment (I)	Temperature segment (J)	Average difference (I-J)	Standard error	Significance	95% confidence interval	
					Lower bound	Upper bound
<22.1°C	22.1°C–23.7°C	−47.85417	43.04164	0.273	−134.9141	39.2058
	>23.7°C	−98.88095*	44.33966	0.032	−188.5664	−9.1955
22.1°C–23.7°C	<22.1°C	47.85417	43.04164	0.273	−39.2058	134.9141
	>23.7°C	−51.02679	41.24744	0.223	−134.4576	32.4040
>23.7°C	<22.1°C	98.88095*	44.33966	0.032	9.1955	188.5664
	22.1°C–23.7°C	51.02679	41.24744	0.223	−32.4040	134.4576

* = Average difference reached *a* 0.05 significance level.

Table 5: Average CFU concentration at various humidity levels.

Descriptive statistics: Average CFU concentration							
Humidity segment	Average	Standard deviation	Standard error	Average at 95% confidence interval		Minimum	Maximum
				Lower bound	Upper bound		
<56.1%	245.8000	132.05538	41.75958	151.3333	340.2667	110.00	510.00
56.1%–64.6%	139.7500	106.47751	23.80910	89.9170	189.5830	5.00	475.00
>64.6%	113.5833	84.81258	24.48328	59.6960	167.4707	20.00	270.00
Total	157.5238	116.75474	18.01565	121.1405	193.9071	5.00	510.00

Table 6: Significance between the average CFU concentration and various humidity levels.

Humidity segment (I)	Humidity segment (J)	Average difference (I-J)	Standard error	Significance	95% confidence interval	
					Lower bound	Upper bound
<56.1%	56.1%–64.6%	106.05000*	41.67107	0.015	21.7623	190.3377
	>64.6%	132.21667*	46.06910	0.007	39.0331	225.4002
56.1%–64.6%	<56.1%	−106.05000*	41.67107	0.015	−190.3377	−21.7623
	>64.6%	26.16667	39.28786	0.509	−53.3005	105.6339
>64.6%	<56.1%	−132.21667*	46.06910	0.007	−225.4002	−39.0331
	56.1%–64.6%	−26.16667	39.28786	0.509	−105.6339	53.3005

* = Average difference reached a .05 significance level.

Table 7: The R^2 of the regression equation for CFU concentrations and the average humidity.

Model	R	R^2	Adjusted R^2	Estimated standard error	Statistical change				
					R^2 change	F change	df_1	df_2	Significance of F change
1	0.438[a]	0.192	0.172	106.25619	0.192	9.502	1	40	0.004

a. Predictor variable: (constant), average humidity

Table 8: Significance between the CFU concentration and average humidity regression equation.

Coefficient[a]						
Model		Nonstandardized coefficient		Standardized coefficient	t	Significance
		B estimate	Standard deviation	Beta distribution		
1	(Constant)	726.835	185.414		3.920	0.000
	Average humidity	−9.432	3.060	−0.438	−3.083	0.004

* = Average difference reached a 0.05 significance level. a. Dependent variable: average CFU concentration

Table 9: The R^2 for the interactions between temperature and humidity and the average CFU concentration.

Model	R	R^2	Adjusted R^2	Estimated standard error	Statistical change				
					R^2 change	F change	df_1	df_2	Significance of F change
1	0.314[a]	0.099	0.076	112.21624	0.099	4.383	1	40	0.043
2	0.451[b]	0.204	0.163	106.82815	0.105	5.137	1	39	0.029
3	0.457[c]	0.209	0.146	107.86517	0.005	0.254	1	38	0.617

a. Predictor variable: (Constant), average temperature. b. Predictor variable: (Constant), average temperature, average humidity. c. Predictor variable: (Constant), average temperature, average humidity, and product of temperature and humidity multiplication.

Table 10: The significance between the interactions of temperature and humidity and the average CFU concentration.

Models		Nonstandardized coefficient		Standardized coefficient	t	Significance	Collinearity statistics	
		B estimate	Standard deviation	Beta distribution			Tolerance	VIF
1	(Constant)	−472.942	301.625		−1.568	0.125		
	Average temperature	27.534	13.151	0.314	2.094	0.043	1.000	1.000
2	(Constant)	1361.262	858.722		1.585	0.121		
	Average temperature	−17.883	23.629	−0.204	−0.757	0.454	0.281	3.562
	Average humidity	−13.159	5.806	−0.611	−2.266	0.029	0.281	3.562
3	(Constant)	1146.503	966.218		1.187	0.243		
	Average temperature	−12.787	25.914	−0.146	−0.493	0.625	0.238	4.203
	Average humidity	−11.690	6.548	−0.543	−1.785	0.082	0.225	4.444
	Product of temperature and humidity multiplication	−11.349	22.532	−0.081	−0.504	0.617	0.802	1.248

a. Dependent variable: average number of bioaerosols

However, examining the effects that both the temperature and humidity factors have on CFU concentrations, no significant relationship was observed ($p > 0.05$), as shown in Tables 9 and 10. In summary, the factors influencing CFU concentrations in a library are indoor humidity, indoor temperature, and the site usage.

4. Conclusion

This study selected a certain public library in Taoyuan County as the research subject and employed tools such as an impinger for air sampling (Bioluminescent ATP-assay) and statistical analysis software (SPSS) to investigate the correlation among various factors and the CFU concentration in the library. According to the results, the CFU concentrations at each site or location in the library were less than 500 CFU/m^3. Furthermore, the statistical analysis data showed that no significant correlation was observed between the indoor CFU concentration and factors such as number of people who enter the library, the number of floors, sampling time, and floor area. The CFU concentration in the library was related to the air quality around the building, the number of people who entered and exited the library, and the hygiene and health of library employees. The key factors influencing the CFU concentration in the library included the indoor humidity and indoor temperature.

In this study, based on literature reviews and statistical analyses, we found that CFU concentrations, the survival and reproduction of molds (or bacteria) or insects that live on molds or bacteria, the conditions (dampness and brittleness) of paper-based books and documents, and the psychological reactions and work efficiency of employees are related to the internal library temperature and humidity. The temperature and humidity are the key factors that influence each of the above factors. When the environmental temperature increased, the CFU concentration exhibited an increasing trend, which declined with increasing environmental humidity. However, the correlation between temperature and humidity and the CFU concentration was not significant ($p > 0.05$). The bioaerosol concentration is related to the indoor air quality and the transmission route of COVID-19, respectively. In this study, impact equipment was used to collect bioaerosols. During the experiment, various factors affecting the concentration of bioaerosols were explored with appropriate test procedures and research methods. According to the research results, the bioaerosol concentration has no significant correlation with the library floor location, room function, number of people in the activity place, room floor area, and amount people of unit area. The key factors affecting the bioaerosol concentration inside the library are indoor temperature and humidity. Other influencing factors are the air quality outside the library and the health status (hygienic conditions) of the people entering the library.

The climate in Taiwan is warm and humid, which is conducive to the growth of bioaerosols. Therefore, if the administrator wants to control the concentration of bioaerosols in the library, a more suitable method is to control the temperature and humidity in the library. As stated in the previous paper, in the process of reducing the concentration of bioaerosols by controlling the temperature and humidity in the library, in addition to considering the impact of temperature and humidity on the growth of mold or bacteria, preservation of books and documents, maintenance of hardware equipment, and the health status of employees who work in the library for a long time consider the comfort and health of people who enter the library in different seasons.

Separate setting and management of storage space and personnel activity place is the most suitable method to solve the problem. In Taiwan, libraries of different types and sizes should have their own temperature and humidity suitable for the operation and management of the library; optimum temperature and humidity for each space used in the library. The temperature and humidity can be beneficial to books, documents (including hardware equipment), and personnel activities at the same time. Regarding the temperature, humidity, bioaerosol concentration, and COVID-19 transmission speed, the mutual influence and correlation, it is necessary to go through multiple sampling and experiments. Only after further research can we find the optimal temperature and humidity that can prevent the spread of COVID-19 and is suitable for the library.

Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

Acknowledgments

The authors would like to thank the public library established in 1923 (during the Japanese occupation period) in the Taoyuan County City. The authors would also like to thank Cooper Consultancy (https://ccil.com.tw) for editing and proofreading the manuscript.

References

[1] P. Querner, J. Beenk, and R. Linke, "The analysis of red lead endsheets in rare books from the fung ping Shan library at the university of Hong Kong," *Heritage*, vol. 5, no. 3, pp. 2408–2421, 2022.

[2] S. Roy, K. Mosteller, M. Mosteller et al., "Citizen science chlorine surveillance during the Flint, Michigan federal water emergency," *Water Research*, vol. 201, Article ID 117304, 2021.

[3] L. T. H. Tan, W. Y. Tee, T. M. Khan, L. C. Ming, and V. Letchumanan, "Legionella pneumophila — the causative agent of Legionnaires' disease," *Progress In Microbes and Molecular Biology*, vol. 4, no. 1, 2021.

[4] V. Stejskal, T. Vendl, R. Aulicky, and C. Athanassiou, "Synthetic and natural insecticides: gas, liquid, gel and solid formulations for stored-product and food-industry pest control," *Insects*, vol. 12, no. 7, p. 590, 2021.

[5] A. Pereira, A. R. Silva, and L. F. Melo, "Legionella and biofilms—integrated surveillance to bridge science and real-field demands," *Microorganisms*, vol. 9, no. 6, p. 1212, 2021.
[6] L. S. P. Nguyen, G. R. Sheu, S. C. Chang, and N. H. Lin, "Effects of temperature and relative humidity on the partitioning of atmospheric oxidized mercury at a high-altitude mountain background site in Taiwan," *Atmospheric Environment*, vol. 261, Article ID 118572, 2021.
[7] C. Y. Lin, S. B. Su, C. J. Peng, and K. T. Chen, "The incidence of mumps in Taiwan and its association with the meteorological parameters: an observational study," *Medicine*, vol. 100, no. 37, 2021.
[8] L. W. Lai, "Poor visibility in winter due to synergistic effect related to fine particulate matter and relative humidity in the taipei metropolis, taiwan," *Atmosphere*, vol. 13, no. 2, p. 270, 2022.
[9] J. Chatkin, L. Correa, and U. Santos, "External environmental pollution as a risk factor for asthma," *Clinical Reviews in Allergy and Immunology*, vol. 62, pp. 72–89, 2021.
[10] I. C. Stanley, V. O. N. Njoku, C. Arinze, I. F. Chizoruo, and E. N. Blessing, "A Review: effects of air, water and land dumpsite on human health and analytical methods for determination of pollutants," *Analytical Methods in Environmental Chemistry Journal*, vol. 4, no. 3, pp. 80–106, 2021.
[11] H. Saleem, S. J. Zaidi, A. F. Ismail, and P. S. Goh, "Advances of nanomaterials for air pollution remediation and their impacts on the environment," *Chemosphere*, vol. 287, Article ID 132083, 2022.
[12] A. R. Gollakota, S. Gautam, M. Santosh et al., "Bioaerosols: characterization, pathways, sampling strategies, and challenges to geo-environment and health," *Gondwana Research*, vol. 99, pp. 178–203, 2021.
[13] P. Kumar, M. Kausar, A. B. Singh, and R. Singh, "Biological contaminants in the indoor air environment and their impacts on human health," *Air Quality, Atmosphere and Health*, vol. 14, no. 11, pp. 1723–1736, 2021.
[14] N. F. Al-Rubaey, H. Hussain, N. Ibraheem, M. M. Radhi, N. K. K. Hindi, and R. K. Al-Jubori, "A review of airborne contaminated microorganisms associated with human diseases," *Medical Journal of Babylon*, vol. 19, no. 2, pp. 115–122, 2022.
[15] A. Lenart-Boroń, A. Bajor, M. Tischner, K. Kulik, and J. Kabacińska, "Particulate matter concentrations and fungal aerosol in horse stables as potential causal agents in recurrent airway disease in horses and human asthma and allergies," *Applied Sciences*, vol. 12, no. 18, p. 9375, 2022.
[16] S. Dharmaraj, V. Ashokkumar, S. Hariharan et al., "The COVID-19 pandemic face mask waste: a blooming threat to the marine environment," *Chemosphere*, vol. 272, Article ID 129601, 2021.
[17] A. L. Moreno-Ríos, L. Tejeda-Benitez, and C. F. Bustillo Lecompte, "Sources, characteristics, toxicity, and control of ultrafine particles: an overview," *Geoscience Frontiers*, vol. 13, no. 1, pp. 1–15, 2022.
[18] P. Fermo, B. Artíñano, G. De Gennaro et al., "Improving indoor air quality through an air purifier able to reduce aerosol particulate matter (PM) and volatile organic compounds (VOCs): experimental results," *Environmental Research*, vol. 197, Article ID 111131, 2021.
[19] M. G. Adam, P. T. Tran, and R. Balasubramanian, "Air quality changes in cities during the COVID-19 lockdown: a critical review," *Atmospheric Research*, vol. 264, Article ID 105823, 2021.
[20] T. Juneja Gandhi, P. R. Garg, K. Kurian et al., "Outdoor physical activity in an air polluted environment and its effect on the cardiovascular system—a systematic review," *International Journal of Environmental Research and Public Health*, vol. 19, no. 17, Article ID 10547, 2022.
[21] M. Tainio, Z. Jovanovic Andersen, M. J. Nieuwenhuijsen et al., "Air pollution, physical activity and health: a mapping review of the evidence," *Environment International*, vol. 147, Article ID 105954, 2021.
[22] C. Du, B. Li, W. Yu et al., "Characteristics of annual mold variations and association with childhood allergic symptoms/diseases via combining surveys and home visit measurements," *Indoor Air*, vol. 32, no. 9, 2022.
[23] T. M. Mata, A. A. Martins, C. S. Calheiros et al., "Indoor air quality: a review of cleaning technologies," *Environments*, vol. 9, no. 9, p. 118, 2022.
[24] Y. Zhang, T. Yan, F. Wang, X. Xu, W. Jiang, and Z. Huang, "Experimental evaluation on microwave radiation disinfection efficacy of the bacterial aerosols attached to a SiC composite filter," *Building and Environment*, vol. 226, Article ID 109721, 2022.
[25] H. Singh, R. K. Maurya, P. Sharma, P. Kapoor, and T. Mittal, "Aerosol generating procedural risks and concomitant mitigation strategies in orthodontics amid COVID-19 pandemic–An updated evidence-based review," *International Orthodontics*, vol. 19, no. 3, pp. 329–345, 2021.
[26] S. Manibusan and G. Mainelis, "Passive bioaerosol samplers: a complementary tool for bioaerosol research. A review," *Journal of Aerosol Science*, vol. 163, Article ID 105992, 2022.
[27] S. S. Nunayon, M. Wang, H. H. Zhang, and A. C. Lai, "Evaluating the efficacy of a rotating upper-room UVC-LED irradiation device in inactivating aerosolized Escherichia coli under different disinfection ranges, air mixing, and irradiation conditions," *Journal of Hazardous Materials*, vol. 440, Article ID 129791, 2022.
[28] Z. Liu, M. Wu, H. Cao et al., "Impact of the visitor walking speed and glass barriers on airflow and Bioaerosol particles distribution in the typical open tomb," *Building and Environment*, vol. 225, Article ID 109649, 2022.
[29] D. De Ferreyro Monticelli, S. Bhandari, A. Eykelbosh, S. B. Henderson, A. Giang, and N. Zimmerman, "Cannabis cultivation facilities: a review of their air quality impacts from the occupational to community scale," *Environmental Science and Technology*, vol. 56, no. 5, pp. 2880–2896, 2022.
[30] T. M. Mata, G. M. Oliveira, H. Monteiro, G. V. Silva, N. S. Caetano, and A. A. Martins, "Indoor air quality improvement using nature-based solutions: design proposals to greener cities," *International Journal of Environmental Research and Public Health*, vol. 18, no. 16, p. 8472, 2021.
[31] C. Viegas, B. Gomes, M. Dias, E. Carolino, and L. Aranha Caetano, "Aspergillus section Fumigati in firefighter headquarters," *Microorganisms*, vol. 9, no. 10, p. 2112, 2021.
[32] S. S. Nunayon, H. H. Zhang, V. Chan, R. Y. Kong, and A. C. Lai, "Study of synergistic disinfection by UVC and positive/negative air ions for aerosolized Escherichia coli, Salmonella typhimurium, and Staphylococcus epidermidis in ventilation duct flow," *Indoor Air*, vol. 32, no. 1, 2022.
[33] C. Viegas, M. Dias, and S. Viegas, "Electrostatic dust cloth: a useful passive sampling method when assessing exposure to fungi demonstrated in studies developed in Portugal (2018–2021)," *Pathogens*, vol. 11, no. 3, p. 345, 2022.
[34] M. E. Nordberg, M. Täubel, S. Heikkinen et al., "Toxicological transcriptome of human airway constructs after exposure to indoor air particulate matter: in search of relevant pathways of

moisture damage-associated health effects," *Environment International*, vol. 158, Article ID 106997, 2022.

[35] N. J. R. Kraakman, J. González-Martín, C. Pérez, R. Lebrero, and R. Muñoz, "Recent advances in biological systems for improving indoor air quality," *Reviews in Environmental Science and Biotechnology*, vol. 20, no. 2, pp. 363–387, 2021.

[36] W. P. Sung, T. Y. Chen, and C. H. Liu, "Strategy for improving the indoor environment of office spaces in subtropical cities," *Buildings*, vol. 12, no. 4, p. 412, 2022.

[37] W. Zheng, J. Hu, Z. Wang et al., "COVID-19 impact on operation and energy consumption of heating, ventilation and air-conditioning (HVAC) systems," *Advances in Applied Energy*, vol. 3, Article ID 100040, 2021.

[38] A. T. Nottingham, J. J. Scott, K. Saltonstall et al., "Microbial diversity declines in warmed tropical soil and respiration rise exceed predictions as communities adapt," *Nature Microbiology*, vol. 7, no. 10, pp. 1650–1660, 2022.

[39] T. Gao, Q. Xu, Y. Liu, J. Zhao, and J. Shi, "Predicting the potential geographic distribution of Sirex nitobei in China under climate change using maximum entropy model," *Forests*, vol. 12, no. 2, p. 151, 2021.

[40] Y. A. Yigezu, M. A. Moustafa, M. M. Mohiy et al., "Food losses and wastage along the wheat value chain in Egypt and their implications on food and energy security, natural resources, and the environment," *Sustainability*, vol. 13, no. 18, Article ID 10011, 2021.

[41] R. Nicastro and P. Carillo, "Food loss and waste prevention strategies from farm to fork," *Sustainability*, vol. 13, no. 10, p. 5443, 2021.

[42] Y. Jin, F. Wang, S. R. Payne, and R. B. Weller, "A comparison of the effect of indoor thermal and humidity condition on young and older adults' comfort and skin condition in winter," *Indoor and Built Environment*, vol. 31, no. 3, pp. 759–776, 2022.

[43] X. Meng, L. Meng, Y. Gao, and H. Li, "A comprehensive review on the spray cooling system employed to improve the summer thermal environment: application efficiency, impact factors, and performance improvement," *Building and Environment*, vol. 217, Article ID 109065, 2022.

[44] H.-J. Tang, C.-C. Lai, and C.-M. Chao, "The collateral effect of COVID-19 on the epidemiology of airborne/droplet-transmitted notifiable infectious diseases in taiwan," *Antibiotics*, vol. 11, no. 4, p. 478, 2022.

[45] V. K. Bains and R. Bains, "Is oral hygiene as important as hand hygiene during COVID-19 pandemic?" *Asian Journal of Oral Health and Allied Sciences*, vol. 10, no. 5, 2020.

[46] T. S. Higgins, A. W. Wu, E. A. Illing et al., "Intranasal antiviral drug delivery and coronavirus disease 2019 (COVID-19): a state of the art review," *Otolaryngology-Head and Neck Surgery*, vol. 163, no. 4, pp. 682–694, 2020.

[47] A. Baran, M. C. Adigüzel, and H. Aydin, "Calidad microbiológica de ensaladas de verduras listas para comer servidas en restaurantes de carne durante la pandemia de COVID-19 en Turquia," *Revista Científica de la Facultad de Ciencias Veterinarias*, vol. 32, pp. 1–11, 2022.

[48] R. C. K. Law, J. H. K. Lai, D. J. Edwards, and H. C. Hou, "COVID-19: research directions for non-clinical aerosol-generating facilities in the built environment," *Buildings*, vol. 11, no. 7, p. 282, 2021.

[49] A. McCarthy, L. Saldana, D. N. Ackerman et al., "Ultra-absorptive nanofiber swabs for improved collection and test sensitivity of SARS-CoV-2 and other biological specimens," *Nano Letters*, vol. 21, no. 3, pp. 1508–1516, 2021.

[50] P. C. Guest, *Identification of Biomarkers, New Treatments, and Vaccines for COVID-19*, vol. 1327, Springer, Berlin, Germany, 2021.

[51] V. B. Hsue, K. Itamura, A. W. Wu et al., "Topical oral and intranasal antiviral agents for coronavirus disease 2019 (COVID-19)," in *Identification of Biomarkers, New Treatments, and Vaccines for COVID-19. Advances in Experimental Medicine and Biology*, P. C. Guest, Ed., vol. 1327, Springer, Cham, Switzerland, 2021.

[52] P. R. Armijo, N. W. Markin, S. Nguyen et al., "3D printing of face shields to meet the immediate need for PPE in an anesthesiology department during the COVID-19 pandemic," *American Journal of Infection Control*, vol. 49, no. 3, pp. 302–308, 2021.

[53] P. W. Olupot, E. Menya, J. Jjagwe et al., "Development and appraisal of handwash-wastewater treatment system for water recycling as a resilient response to COVID-19," *Journal of Environmental Chemical Engineering*, vol. 9, no. 5, Article ID 106113, 2021.

[54] O. De Giglio, G. Diella, M. Lopuzzo et al., "Management of microbiological contamination of the water network of a newly built hospital pavilion," *Pathogens*, vol. 10, no. 1, p. 75, 2021.

[55] R. Staniszewski, D. Cais-Sokolińska, Ł. K. Kaczyński, and P. Bielska, "Use of bioluminescence for monitoring Brown coal mine waters from deep and surface drainage," *Energies*, vol. 14, no. 12, p. 3558, 2021.

[56] A. Lopreside, M. M. Calabretta, L. Montali et al., "Bioluminescence goes portable: recent advances in whole-cell and cell-free bioluminescence biosensors," *Luminescence*, vol. 36, no. 2, pp. 278–293, 2021.

[57] O. De Giglio, G. Diella, M. Lopuzzo et al., "Impact of lockdown on the microbiological status of the hospital water network during COVID-19 pandemic," *Environmental Research*, vol. 191, Article ID 110231, 2020.

[58] M. Nomani, M. Varahram, P. Tabarsi et al., "Decreased neutrophil-mediated bacterial killing in COVID-19 patients," *Scandinavian Journal of Immunology*, vol. 94, no. 3, 2021.

[59] S. Vardoulakis, D. A. E. Oyarce, and E. Donner, "Transmission of COVID-19 and other infectious diseases in public washrooms: a systematic review," *Science of the Total Environment*, vol. 803, pp. 0048–9697, 2022.

[60] M. Ippolito, G. Misseri, G. Catalisano et al., "Ventilator-Associated pneumonia in patients with COVID-19: a systematic review and meta-analysis," *Antibiotics*, vol. 10, no. 5, p. 545, 2021.

[61] A. Emami, F. Javanmardi, A. Keshavarzi, and N. Pirbonyeh, "Hidden threat lurking behind the alcohol sanitizers in COVID-19 outbreak," *Dermatologic Therapy*, vol. 33, no. 4, 2020.

[62] M. Kucia, J. Ratajczak, K. Bujko et al., "An evidence that SARS-Cov-2/COVID-19 spike protein (SP) damages hematopoietic stem/progenitor cells in the mechanism of pyroptosis in Nlrp3 inflammasome-dependent manner," *Leukemia*, vol. 35, no. 10, pp. 3026–3029, 2021.

[63] P. J. Lillie, A. Samson, A. Li et al., "Novel coronavirus disease (Covid-19): the first two patients in the UK with person to person transmission," *Journal of Infection*, vol. 80, no. 5, pp. P578–P606, 2020.

[64] J. Liang, C. S. Swanson, L. Wang, and Q. He, "Impact of building closures during the COVID-19 pandemic on Legionella infection risks," *American Journal of Infection Control*, vol. 49, no. 12, pp. P1564–P1566, 2021.

[65] A. D. Elisanti, E. Ardianto, N. Ida, and E. Hendriatno, “Efektifitas paparan sinar uv dan alkohol 70% terhadap total bakteri pada uang kertas yang beredar di masa pandemi covid-19,” *Jurnal Riset Kefarmasian Indonesia*, vol. 2, no. 2, pp. 113–121, 2020.
[66] M. V. Trinidad, M. L. Antonio, C. B. Carlos et al., “Assessment of hand hygiene strategies on skin barrier function during COVID-19 pandemic: a randomized clinical trial,” *Contact Dermatitis*, vol. 86, no. 4, pp. 0105–1873, 2020.
[67] T. Irfan, “Legionella surveillance in stagnant water systems during COVID-19 lockdown in Istanbul,” *Malaysian Journal of Microbiology*, vol. 17, no. 6, pp. 720–724, 2021.
[68] G. C. Marianne, D. Elise, D. Evelyne, and P. Michèle, “Impact of recommissioning flushing on Legionella pneumophila in a large building during the COVID-19 pandemic,” *Frontiers in Water*, vol. 4, pp. 2624–9375, 2022.
[69] O. De Giglio, F. Triggiano, F. Apollonio et al., “Potential use of untreated wastewater for assessing COVID-19 trends in southern Italy,” *International Journal of Environmental Research and Public Health*, vol. 18, no. 19, Article ID 10278, 2021.
[70] A. Brunello, M. Civilini, S. De Martin et al., “Machine learning-assisted environmental surveillance of Legionella: a retrospective observational study in Friuli-Venezia Giulia region of Italy in the period 2002–2019,” *Informatics in Medicine Unlocked*, vol. 28, Article ID 100803, 2022.
[71] W. J. Rhoads, M. Sindelar, C. Margot, N. Graf, and F. Hammes, “Variable Legionella response to building occupancy patterns and precautionary flushing,” *Microorganisms*, vol. 10, no. 3, p. 555, 2022.