ORIGINAL ARTICLE

Bioaerosol Levels in Indoor Air of Animal House and Hospital Laboratories; A Comparison with Library and Administrative Offices

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ABSTRACT

Introduction: This study reported the concentration of bacterial and fungal bioaerosol at an animal house and hospital laboratories with the aim to compare the concentration levels at library and administrative offices. The bioaerosol levels between mid-shift (afternoon) were also compared to the concentration measured during pre-shift (morning). **Methods:** The NIOSH 0800 method utilising microbiological air sampler collecting airborne bacterial and fungal samples via impaction technique on Nutrient agar (NA) and Sabouraud Dextrouse agar (SDA) as culture medium, respectively. Sampling was done twice daily; before (pre-shift) and during working (mid-shift) hour. **Results:** The highest bacteria and fungi concentration was recorded at the animal house with median concentration of 2477 CFU/m^3 (IQR=121-2477) and 791 CFU/m^3 (IQR = 379-2081), respectively. Higher-risked workplaces such as animal house and hospital laboratories have significantly higher bioaerosol concentrations compared to control workplaces such as library and administrative offices ($p<0.05$). Interestingly, there were significantly higher fungi concentrations during the pre-shift compared to the mid-shift, for both high risk and control workplaces. **Conclusion:** Animal research room had exceeded the recommended bioaerosol level of 500 CFU/m^3, but all the other sites had concentrations below the recommended level. Appropriate control measures should be adhered such as practicing hygiene practices and housekeeping to minimise the bioaerosol exposure among the workers and occupants.

Keywords: Bioaerosol, Animal house, Hospital laboratory, Library, Administrative office

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INTRODUCTION

Bioaerosol can be referred to particles of biological origin or living microbes that are suspended in air. It is one of the sources affecting indoor air quality (IAQ) accounted for 5% of indoor air pollution. Low in temperature, high humidity level and inadequate ventilation are among the factors that are affecting the IAQ whereby could lead to condensation and growth of biocontaminants. Generally, airborne particulates can carry microbes that can be dispersed in the indoor environment and then finally deposited on surfaces to grow or inhaled into the respiratory system. Hence, increase the opportunity in wide spreading of airborne diseases that can affect the humans, animals, and plants (1). As for example is fungal spores, have shown a substantial tolerance to environmental conditions such as heat (2) thus are particularly dangerous to health. The exposure of such biological hazard can lead to several health effects either short term or long term. The symptoms that frequently being related to the bioaerosol exposure and poor IAQ are allergic, rhinitis, asthma, pneumonia, irritation of the eyes, nose, throat and lungs, headaches, fatigue and trouble in concentrating (3).

Work task, human activities and equipment at workplaces are also among the principal contributing factor of airborne microbial contamination accumulation and transmission (4). Because of the different numbers and types of biological agents that may be present due to work task variation, the biological hazards in the workplaces may also diverse. It is anticipated that the level of bioaerosol exposure at animal houses and hospital laboratories may differ from libraries and administrative offices due to different nature of the tasks (4). In the animal house, the source of bioaerosol is usually the laboratory animals, their furs and secretions, litters, beddings, feed and cages. Whereas sources of biohazards in hospital is the harbouring of infectious material biocontaminants originate from patients' sample such as serum, blood, pus, urine, stool, sputum,

saliva, as well as from the contaminated equipment. In addition to that, laboratory procedures may potentially generate bioaerosol that are inhalable into the lungs of the medical laboratory technologists and increase their risk for occupational infections. Whereas, the microbial matter contamination levels in libraries and office buildings might be influenced by numerous sources such as the heating, ventilation and air-conditioning (HVAC) system, humidifiers, water towers, transmission among people through coughing, sneezing and talking. However, there has been of particular concern that the presence of pathogens in hospital libraries may be antimicrobial-resistant (5). Thus contact with these bacteria may therefore increase the risk of infections which resulted to be especially difficult to treat and potentially lethal. Previous review of literatures has provided evidences confirming the presence of bacteria and fungi in library air, books, and surfaces (6). As it has been suspected to be the sources of disease transmission among the public, thus preventative strategies should be implemented to monitor the prevalence of bacteria and fungi in these environments as well as their associated health impacts on workers and the public.

An important aspect to define the environmental quality of air surrounding wide human populations during their daily work activities are effective prevention and control of the dissemination of such infectious agents and allergic components that have led to potential undesirable effects on human beings. For example, workers should use suitable personal protective equipment such as gloves, mask or respirator, laboratory coat and safety shoes when there is a risk of exposures to biological hazard. Previous literature has also reviewed the problem of controlling bioaerosol disease transmission in animal houses, and recommendation on the basis of engineering control design (7). Hence it is important to evaluate the bioaerosol levels in workplaces with high risk of direct exposures to bacterial and fungal contamination compared to control workplaces with a need to identify suitable and adequate control measures to prevent such occurrences of adverse health effects.

However, no specific threshold limit values (TLV) has been established for the environmental concentration of biological agents by the American Conference of Governmental Industrial Hygienists (ACGIH) as there is no existing information in allowing a scientifically acceptable dose–response relationship (8) as cited in previous study (9). On the other hand, a study in Malaysia (10) has referred to the recommended level of 500 colony forming unit (CFU)/m^3 based on the ACGIH (8) and World Health Organisation (WHO).

MATERIALS AND METHODS

Study locations and sampling strategy

This was a comparative cross-sectional study aims to compare the airborne bacterial and fungal exposure levels between workplaces of potentially high risk of bioaerosol exposure and the control workplaces. An initial visit involving a walkthrough survey was carried out at the animal house, hospital laboratories, library and administrative offices in gathering work task information and determining the suitable sampling site. Sample size determination was based on the United States Environmental Protection Agency (USEPA) "Guidance on Choosing a Sampling Design for Environment Data Collection" (11), for the sample calculation of stratified sampling method (n=70 for each pre- and mid-shift). Therefore, three different sampling sites at each location were selected based on the walk through survey's anticipation that the workplaces were potentially having high and low microbial exposure. Table I shows the descriptions of the decided sampling sites at each location for the comparative stage.

Table I: Description of selected sampling sites

No	Location	Description
	Animal House	
1.	Research Room	Housing laboratory animals
2.	Experimental Room	Procedural room
3.	Store Room	Storage of bedding
	Microbiology & Parasitology Laboratory	
1.	Bacteriology Lab.	Involve bacterial samples
2.	Mycology Lab.	Involve fungal samples
3.	Media Room	Media preparation
	Pathology Laboratory	
1.	Routine Lab.	Involve tissue grossing
2.	Special Test Lab.	Immunohistochemistry
3.	Cytopathology Lab.	Involve body fluid, cervical smear and sputum cytology
	Library	
1.	Level 1	Reading area (less occupants, n=1-2)
2.	Level 2	Reading area (moderate occupants, n=5)
3.	Level 3	Reading area (more occupants, n=10-15)
	Administrative offices	
1.	Office #1	More occupants (n=35)
2.	Office #2	Less occupants (n=8)

Bioaerosol monitoring at the animal house was also conducted for a descriptive analysis involving five animal research rooms, procedural room, laboratory room, two store rooms and an office; monitoring was done once at each room in duplicate. Duo SAS sampler (Italy) were used to determine the bacterial and fungal counts at the animal house during this descriptive stage. The flowrate was set between 500 to 1000 litre per minute which can be adjusted to calculate the colony forming unit in cubic metre following the manufacturer's formula, $N = a \times 10^3 (ft)^{-1}$, where N = number of microbial CFU/m^3 in indoor air, a = colonies counted on petri dish (CFU), f = flowrate (litre/minute); t = duration of sampling (minute).

Following the NIOSH method 0800 for bioaerosol sampling, using the impaction technique, a total of 140

airborne samples were collected during the comparative stage from nine high risk sampling sites (three sites of an animal house and six sites of hospital laboratories) and five sampling sites for control workplaces (one library and two offices) utilising microbiological air samplers (Microflow α, Aquaria, Italy). The bioaerosol samples were collected for five consecutive days at each sampling site. On each day, the sampling was conducted twice; in the morning (pre-shift) and in the afternoon (mid-shift). Sampling for morning session was done before the workers started their work, approximately from 7.30 am until 9.00 am, whereas the evening sampling was conducted from 2.30 pm until 4.00 pm. The sampled air during the comparative stage was drawn into the air sampler through plates or aluminium head of Microflow α with 380 holes. The sampling time was set to 8.19 minutes, corresponded to 1000 litres of air drawn and 120 litre/minute for flow rate.

Bioaerosol sampling and analysis

Two types of sampling media were used to collect the bioaerosol samples, nutrient agar (NA) (Oxoid, CM0041, England) for bacterial culture and Sabouraud Dextrouse agar (SDA) (Oxoid, CM0003, England) for fungal cultures. Prior to each sampling, 70% alcohol was used to disinfect the inside of the microbiological air sampler and the gloves were worn to prevent cross contamination. The microbiological air sampler was placed at the centre of the room and at the height of 1.0-1.5 meter, representing the breathing zone. Then, sampling media petri plate was placed inside the air sampler and the sampler was turned on for each sampling period (morning and evening) at each location; NA for collection of bacterial isolation followed by SDA for fungal isolation. Plates were removed from the air sampler and well labelled, then transported to the laboratory for incubation. The samples were carefully sealed with parafilm to avoid from being exposed to the air in preventing any contamination. Then, the samples were incubated in an incubator at 37°C (overnight) for bacteria culture and at 30°C (48 hours) for fungal culture. Control media samples were prepared on each sampling day. The control media samples were brought to the sampling location and were treated similar with other sampling media however without the air sampler being switched on. The control samples were then incubated together with other samples. The control media sample is important to monitor for any contamination that might be presented in the prepared agar medium.

After the incubation period, the bacterial and fungal colonies formed were counted representing the colony forming units (CFU) using a colony counter (Funkei Gerber, Germany). The calculation for concentration of CFU (CFU/m^3), was done at exact time to prevent the overgrowth of bacteria and fungi. The number of colonies enumerated on the agar plates after incubation (CFU) was adjusted by referring to the correction table provided by the manufacturer, expressed in CFU/m^3. Below is the formula for the calculation utilising Microflow α (Italy):

Number of CFU/m^3 = (Pr x 10^3) / V

Where,

Pr = Corrected number of colonies from tables (CFU)

V = Chosen sampling volume on Microflow α (litre)

The chosen sampling volume of sampled air (V) is 1000 litres and the number of holes on Microflow α sampling head (N) is 90.

Data analysis

The Statistical Package for the Social Science (SPSS) version 24 was used for data analysis. The results were analysed descriptively and presented in median and interquartile range to the non-normality of data obtained. Comparison on the levels of microbial and fungal contaminations between workplaces was conducted using Kruskal Wallis test. Whereas Wilcoxon Signed-Rank test was used to compare the bioaerosol levels between pre- and mid-shift.

RESULTS

Airborne bacteria and fungi concentration levels

Table II presents the bacteria and fungi concentration levels at respective sampling locations in the animal house. The highest airborne bacteria level was measured at research room E, 64 CFU/m^3, where the research animals were kept in an enclosed room and air-conditioned. The concentration of fungi in research room C and store room #1 that stored the unused bedding were both too numerous to count (TNTC). The highest fungi concentration found was in laboratory room (93 CFU/m^3).

Table III presents both the bacteria and fungi concentration levels for pre-shift and mid-shift at respective sampling locations. The highest airborne bacteria and fungi level were measured during mid-shift at research room (median bacteria: 2477 CFU/m^3, IQR: 121-2477, median fungi: 791 CFU/m^3, IQR:

Table II: Concentration of airborne bacteria and fungi (CFU/m^3) at animal house for descriptive stage

	Bioaerosol Concentration (CFU/m^3)	
Location	**Bacteria**	**Fungi**
Research Room A	10	72
Research Room B	37	1
Research Room C	63	TNTC
Research Room D	50	6
Research Room E	64	46
Laboratory Room	44	93
Procedural Room	36	4
Store Room #1	18	TNTC
Store Room #2	10	45
Office Room #1	32	2
Office Room #2	41	32

Table III: Median concentration of airborne bacteria and fungi (CFU/m³) at different sampling locations

Location	n	Median Concentration of Bacteria (IQR) (CFU/m³)		Median Concentration of Fungi (IQR) (CFU/m³)	
		Pre-shift	Mid-shift	Pre-shift	Mid-shift
Animal House					
Research Room	5	196 (91-2477)	2477 (121-2477)	783 (448-2477)	791 (379-2081)
Experimental Room	5	87 (47-159)	27 (14-101)	28 (13-51)	15 (6-18)
Store Room	5	47 (35-131)	30 (19-62)	112 (56-256)	19 (10-28)
Microbiology & Parasitology Laboratory					
Bacteriology Lab.	5	3 (1-18)	5 (3-6)	2 (1-8)	9 (6-18)
Mycology Lab.	5	50 (45-95)	8 (7-18)	24 (18-28)	26 (16-35)
Media Room	5	23 (11-59)	10 (6-15)	22 (8-36)	10 (6-37)
Pathology Laboratory					
Routine Lab.	5	44 (24-65)	7 (5-39)	17 (13-52)	23 (14-47)
Special Test Lab.	5	26 (19-41)	7 (6-37)	11 (7-19)	26 (9-38)
Cytopathology Lab.	5	31 (12-38)	5 (4-44)	11 (7-23)	49 (20-77)
Library					
All 3 levels	15	15 (7-24)	19 (7-26)	19 (14-23)	12 (7-25)
Administrative Office					
Office #1	5	26 (20-30)	7 (4-8)	49 (32-101)	26 (22-35)
Office #2	5	11 (10-31)	4 (2-19)	31 (15-69)	22 (13-44)

379-2081). This was where the research animals (rabbit) were located. Out of all the workplaces, bacteriology laboratory reported the lowest exposure for both bacteria and fungi during pre-shift.

Comparison of bioaerosol levels between animal house, hospital laboratories and control workplaces

Table IV shows the comparison of bacteria and fungi concentration levels between animal house, hospital laboratories and the control workplaces. During pre-shift, there were significant differences between the workplaces for both bacteria and fungi airborne levels (p=0.001), respectively. Whereas during mid-shift, animal house showed a significantly higher airborne fungi level compared to other workplaces, p=0.001.

Table IV. Comparison of bioaerosol levels between animal facility, hospital laboratories and control workplaces

Bioaerosol	Location	n	Pre-shift		Mid-shift	
			Median Concentration (IQR) (CFU/m³)	p value	Median Concentration (IQR) (CFU/m³)	p value
Bacteria	Animal house	15	112 (28-590)	0.001*	19 (15-413)	0.670
	Hospital laboratories	30	13 (7-24)		23 (10-39)	
	Control workplaces	25	18 (13-49)		23 (13-27)	
Fungi	Animal house	15	96 (47-49)	0.001*	42 (27-199)	0.001*
	Hospital laboratories	30	29 (14-50)		7 (5-11)	
	Control workplaces	25	19 (14-28)		8 (4-13)	

Statistical test - Kruskal Wallis test, *p is significant when <0.05

Comparison of bioaerosol levels between pre-shift and mid-shift

Further statistical analysis was performed between the distribution of airborne bacteria and fungi during pre-shift (morning) and mid-shift (afternoon) by separating between two different categories of exposure; high risk workplace such as animal house and hospital laboratories versus control workplaces such as library and administrative offices. Table V shows that there were no significant differences in the level of airborne bacteria between pre-shift and mid-shift for both workplace categories, respectively (p>0.05). Whereas, there were significantly higher airborne fungi levels during pre-shift compared to mid-shift, for both high risk and control workplaces (p=0.001).

DISCUSSION

Table V: Comparison of airborne bacteria and fungi concentrations between pre-shift and mid-shift

Variables	n	Median Concentration (IQR) (CFU/m³)	p value
Bacteria			
High risk workplaces (animal house and laboratories)			
Pre-shift	45	22 (9-51)	0.986
Mid-shift	45	22 (11-45)	
Control workplaces (library and offices)			
Pre-shift	25	18 (13-49)	0.178
Mid-shift	25	22 (13-27)	
Fungi			
High risk workplaces (animal house and laboratories)			
Pre-shift	45	44 (23-76)	0.001*
Mid-shift	45	10 (6-42)	
Control workplaces (library and offices)			
Pre-shift	25	19 (14-28)	0.001*
Mid-shift	25	8 (4-13)	

Statistical test -Wilcoxon Signed- Rank test, *p is significant when <0.05

This study has shown that the bioaerosol exposure levels were significantly higher in animal house as compared to hospital laboratories and the control workplaces; library and administrative offices. The animal research room had exceeded the ACGIH and WHO recommended bioaerosol level of 500 CFU/m³ (10), but all the other sites had concentrations below the recommended level. Our findings reported that the highest median bacterial and fungal concentration level in the animal house was in the research room as compared to the experimental (operating) and store room. The research room was the place where research animals, rabbits were kept. The higher bacteria level concentration may be resulted from the animal's excretions and their bedding which might become the source for bacteria.

This study finding at the research rooms of animal house replicates the findings of previous studies involving companion animal clinics (3), poultry houses (12, 13)

and livestock barns (14). For example, the total bacterial count at the animal clinics was higher (290 ± 114 CFU/m^3) compared to total fungi counts (182 ± 148 CFU/m^3) (3). A previous study involving poultry farmers reported the concentration of bacterial and fungal aerosol in poultry houses ranged from 2.5 x 10^2 to 2.9 x 10^6 CFU/m^3 for bacteria, and 1.8 x 10^2 to 1.8 x 10^5 CFU/m^3 for fungi (12). They found that the bioaerosol concentration increased between sampling stages based on the chicken production cycle, hence increase the risk of bioaerosol exposure that was associated with the farmers' routine activities in handling the poultry. This would explain that different work tasks perform at each study locations (animal house, hospital laboratories, library and administrative offices) give different environmental bioerosol exposure. Whereas a study in Lithuania reported that the highest concentration of bacteria was measured in poultry houses followed by pig house, insulated cowshed and uninsulated cowshed; the differences were statistically significant (14). The insulated cowshed had significantly higher (2.3 times) average amount of bacteria counts compared to uninsulated cowsheds, most probably due to poor ventilation system. Moreover, in this study, the animal house was not using air-conditioning system and has fan-driven ventilation especially at the research room. This might contribute to higher bioaerosols concentration level at the animal house. The good ventilation with good maintenance of HVAC system will decrease the growth of bioaerosols (15). However, such factor cannot be established in this current study as the ventilation was not measured and was solely hypothesised based on the walk through survey.

The concentrations of bacteria and fungi in the hospital laboratories in this study were about 20-fold lower than the previously reported in Thailand hospital laboratories (16) of which they reported the highest mean of bacteria level measured was 304.4 ± 264.2 CFU/m^3 and the highest fungal counts was 500.8 ± 64.2 CFU/m^3. Whereas, in this study, among the hospital laboratories, mycology laboratory had the highest median concentration of bacteria and fungi followed by routine laboratory. It is might be because of the grossing of the human tissue task that being carried out at the routine laboratory. The work task such as tissue grossing were done inside the grossing cabinet where the bioaerosol being absorbed out to reduce the exposure level among the staff. At the hospital laboratories, the work activities in microbiology laboratory involves the isolation and culture, wire loops and pipetting that may produce airborne microorganisms (17). Moreover, the temperature and humidity at such laboratories were monitored and recorded to ensure it does not exceed certain limit so to not affecting the specimens and also the process. Similar to our discovery, a previous study also suggested that high count of bacteria may indicate overcrowding or poor ventilation (16). Hence, in order to control the environmental conditions and preventing the harbouring of biological agents, recommendations were made to install air-conditioning systems in buildings to improve ventilation. Nevertheless, it has been reported that the humidifier components of these systems themselves are becoming the favourable source of microbial growth, increasing the risk of fungi and bacteria contaminated aerosol dispersion that affects human health (18).

The concentration levels of bacteria in the evening between animal house and control workplaces had no significant different. The books in the library can proliferate the microbial growth due to the existence of organic and cellulosic matter (19). While other factors that may become the sources of microorganism at the control workplaces are human activities, such as sneezing, talking, coughing and walking. Given that the highest median concentration for both bacteria and fungi at library in this study was 19 CFU/m^3 respectively. This finding was contradicted to a study reported the concentrations of airborne bacteria and fungi collected in university libraries by settling technique ranged between 367–2595 CFU/m^3 (4). Another study at archives and libraries reported higher level of microbial contamination in the air ranged from 490 to 5600 CFU/m^3, specifically higher concentrations of airborne fungi compared to others (5300 CFU/m^3, $p<0.05$) (20). With respect to the level in offices, it has been previously reported that bacterial contamination in carpeted office floors ranged from 44 - 450 CFU/m^3 and in synthetic office floors, it ranged from 122 - 794 CFU/m^3 (21). The low bioaerosol burden in this current study might be contributed by the structural design and the low number of occupants per area (4). However such conclusion cannot be drawn and generalised because the information gathered was descriptive in nature and was not statistically analysed. Moreover, for offices, the highest median concentration of bacteria and fungi was at Office #1 (26 CFU/m^3 and 49 CFU/m^3 respectively) of which by observation, was larger in size compared to the Office #2, and Office #1 had more occupants with estimated average number of staff was 15 staff. The most significant source of airborne bacteria is the presence of humans hence increased human activities (22). Obviously, by avoiding overcrowding and designing good ventilation systems can improve a healthier quality of indoor air in the building (4). Moreover, number of occupants and their movements are one important factor contributing to higher airborne bacterial levels than in their absence (21, 23). Fungal concentration at library was slightly higher compared to sampling site from pathology, microbiology and parasitology laboratory. It may be because of the students indirectly releasing the fungal spores into the air from infected books by removing them from racks and opening the pages, or in the event where the library workers dusting the racks and books (19). In some specific cases, the total mean concentration of fungi was reported to be slightly decreased or the values were maintained as

there was increase in occupancy, hence it may indicate that presence of most fungal species were usually not human-borne (23). Moreover, the factor of old building that made up from wood and plaster can easily grow fungi (15).

Correlation between the conditions of microclimatic and numbers of airborne microorganisms has been previously established (20). The environmental factors such as dampness enhances the indoor microbial growth and its multiplication (23). Variations in indoor humidity and temperature have significant effects on microbial diffusion and growth (9). At the range of relative humidity between 60% to 90%, fungi can grow and produce spores that are easily dispersed by air circulation yet for their development they require lower relative humidity than bacteria. Whereas bacteria contamination could increase over the humidity levels of 100% (18, 24), as more water is needed for their growth. However, in this study, the temperature and humidity were not measured hence no correlation can be established in this study.

Results for bacteria exposures showed no significant different between the pre-shift and mid-shift sessions for both high risk and control workplaces, respectively. This might be explained by the air–conditioning system. The air conditioner was being off when the work time is over resulted in those bacteria were settled down and remained in the workplace. On the next morning, when the air conditioner was switched on, the level of bacteria increased due to disturbance effects of dust upon sudden air circulation. Similar to the findings in a previous study reported that they found high contamination after ventilation system was installed which could be explained by the initiation of air movement when the ventilators were activated (18). Higher ventilation rate generates increased air movement and turbulence in which can remove spores from the surfaces of objects and from the walls and floor of the room, hence explains the increase in their level. Whereas it could also be contributed by bacteria underwent a real amplification due to few air changes or the microorganisms accumulation in the air system during air conditioning in the offices (9). Similarly, the concentration levels of bacteria were also increase in the current study during evening, as the offices were busy with human activities and presence of staff and students. However, this finding is in contrast to findings by Soto et al. (2009) where higher level of bacteria and fungi were reported in the afternoon (1.00 pm) compared to the morning session (8.00 am) (23). It is contradicted to this current study where we found the levels of fungal exposures were significantly higher during pre-shift than mid-shift for both high risk and control workplaces. The source of fungi may come from the animal's bedding. Animals faeces and their bedding can stimulate the growth of bacteria and occasionally release spores of fungal into the air (25). During the night towards the morning, the bedding might accumulate the faeces and urine of the animals, then being changed in the evening; hence the increased in levels during pre-shift. Moreover, the research room at animal house were closed area without adequate ventilation thus can grow the bacteria.

CONCLUSION

In conclusion, the bioaerosol exposure showed significantly great variations across study locations. The mid-shift fungal bioaerosol exposure was significantly lower than the pre-shift levels for both high risk and control workplaces. Higher exposure levels of bioaerosol at high risk workplaces compared to non-exposed might be due to different work tasks as example, jobs involved with animals may contribute to increase levels of bioaerosol. Hence, appropriate control measures should be adhered at high exposure workplaces such as hygiene practices and housekeeping to minimise the exposure eventually reduces risk of adverse health effects among workers.

This study only focuses on microbial and fungal air counts screening at different locations comparing their concentration levels, between high risk workplaces and low risk workplaces, due to time and source limitations. Future research should include the prospect of isolation and identification of bacteria and fungi and measuring other climatic parameters such as air ventilation, temperature and humidity as well as assessing the health effects and symptoms among the workers.

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