

Exposure Level of Airborne Bacteria in the University Laboratories in Seoul, Korea

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(Received August 26, 2009/Revised September 12, 2009/Accepted October 1, 2009)

ABSTRACT

This study evaluated the bacterial concentrations and affecting factors at the laboratories of a university in Seoul, Korea. Thirty-three samples of total airborne bacteria (TAB) and eighteen samples of gram negative bacteria (GNB) were collected from both microbiology laboratories (7) and chemistry laboratories (6). GM (GSD) of TAB and GNB concentrations were 194 (2.52) cfu/m³, 24 (4.1) cfu/m³, respectively. TAB concentrations in the chemical laboratories (GM (GSD): 193 (2.0) cfu/m³) were not significantly different from those in microbial laboratories (GM (GSD): 202 (2.7) cfu/m³, ($p>0.05$)). GM (GSD) of TAB concentrations at the top of sink, the center of laboratory, and the front of ventilation device within laboratories, 182 (3.2) cfu/m³, 217 (2.2) cfu/m³, 176 (2.4) cfu/m³, respectively, were not significantly different ($p=0.48$). Related factors were measured such as temperature, relative humidity, floor of laboratory, number of persons and laboratory area. TAB concentrations were significantly related to temperature ($r=0.36$, $p<0.05$), and the floor of laboratory and temperature were also significantly related ($r=0.49$, $p<0.001$). However, other factors such as relative humidity, number of persons and laboratory area did not show any significant relationship with TAB concentrations ($p>0.05$). TAB concentrations were affected significantly by cleaning frequency ($p<0.001$) and floor of laboratory ($p<0.05$). There was also a significant difference ($p<0.01$) between TAB indoor concentrations and TAB outdoor concentrations. However, other factors such as general ventilation did not affect TAB concentrations ($p>0.05$) in this study.

Keywords: total airborne bacteria, gram-negative bacteria, chemical laboratory, microbial laboratory, indoor, temperature, bioaerosol

I. Introduction

Exposure to bioaerosols has become a public concern in recent years due to their adverse health effects.¹⁾ High level of airborne bacteria is indisputably harmful to public health.^{2,3)} Previous studies have reported airborne bacteria is recognized to cause respiratory conditions such as rhinitis, asthma, and pneumonia as well as other diseases and can fatal for those with other underlying health issues.^{4,5,7)} More over 87,000 graduate

students worked and studied in the university laboratories in Korea in 2008, and estimated an increase of numbers in 2009 (Ministry of Education, science and technology of Korea, 2009). Laboratory air quality in universities is immensely important for the health of laboratory personnel and students because a high concentration of airborne bacteria is harmful to public health.³⁾ Although many studies have been conducted on the indoor environment,⁸⁻¹²⁾ laboratory bacterial concentrations results were rarely published. Microorganisms are directly handled in a microbial laboratory whereas microbial concentration in a chemical laboratory can be an IAQ issues. Hypothesis of this study is that microbial concentration in a microbial laboratory is higher than that in chemical laboratory. This study investigated

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the total airborne bacterial concentrations, gram negative bacterial concentrations and other relative factors in microbial and chemical laboratories at the university in Seoul, Korea.

II. Materials and methods

2.1. Sampling and analysis of air samples

Sampling trials were carried out from October to November 2008, 58 air samples (indoor=33 (excluding undetected 6 air samples), outdoor=25) of total airborne bacteria (TAB) and 18 air samples of gram negative bacteria (GNB) were collected from seven microbial laboratories and six chemistry laboratories in a university. The samples were taken from three spots in each laboratory; the top of sink, the center of laboratory, and the front of ventilation device, i.e. fume hood at the chemical laboratory and clean bench/biosafety cabinet at the microbial laboratory. Air samples were collected using the single-stage Anderson sampler (Quick Take 30) at a flow rate of 28.3 l/min for 5 min on nutrient media in Petri-dishes located on the impactor. The sampler was about 1 m above the floor and at least 1 m from a wall. For comparison, outdoor air was sampled in a secure location sheltered from rain and direct sunlight approximately 1 m above the ground and at least 1 m away from an outside wall. Tryptic soy agar (TSA) and Macconkey agar (MAC) were used as culture media for TAB, GNB, respectively.¹⁵⁾ The TSA and MAC plates were incubated at room temperature (35°C) for 48 h and then colony forming units were determined. A total of 10% of the integrated samples were reserved for blank tests. The concentration of airborne bacteria was expressed as colony forming units per cubic meter of air (cfu/m³). During each sampling period, the temperature and relative humidity were recorded. No major environmental issues were reported or found at the laboratories during the entire survey period.

2.2. Statistical analyses

Statistical analyses were carried out by using the SPSS software package (version 12.0) on a personal computer. A Shapiro-Wilk test (W-test) was performed to determine the TAB and GNB

distribution at a significance level of 0.05.¹⁴⁾ Student *t*-test was used to assess significant differences of TAB concentration in seven factors. We also used Analysis of Variance (ANOVA) to significant difference of the TAB concentrations between sampling locations. Pearson correlation were calculated to check the relationships between TAB concentrations and other factors, such as outdoor TAB concentrations, temperature, relative humidity, floor level, number of laboratory personnel, laboratory scale.

III. Results

Results of the Shapiro-Wilk test indicated that concentrations of TAB were log-normally distributed ($p < 0.05$) in 33 sample, but concentrations of GNB were not log-normally distributed. General characteristics of surveyed laboratories were summarized in Table 1. The mean temperature and relative humidity were 24.5(20~27)°C, 45.7(30~59)%, respectively. Number of personnel stayed during survey was 2.6 (0~13) persons per laboratory. Laboratory area ranged from 60 m² to 567 m² with an average of 254.2 m². Laboratory floor ranged from 1 to 7 floors with an average of 3.8 floors. There were no significant differences in humidity, temperature, floor level, number of personnel stayed inside during sampling period, laboratory area between microbial laboratories and chemical laboratories.

Concentrations of TAB and GNB according to chemical and microbial laboratories were presented in Table 2. TAB was detected in 33 samples (100%) out of 33 samples from 13 laboratories, and GNB was detected in 11 samples (61%) out of 18 samples from 13 laboratories. The GM of TAB concentration was 194 (GSD 2.0), cfu/m³ with a range from 14 to 657 cfu/m³. The highest TAB concentration was 657 cfu/m³ followed by 587 cfu/m³. TAB concentrations in chemical laboratories (GM (GSD): 193 (2.0) cfu/m³) were not significantly different ($p > 0.05$) from those in microbial laboratories (GM (GSD) : 202 (2.7) cfu/m³). The ratios of indoor and outdoor concentration for TAB ranged from 0.7 to 33.5 with an average of 11.2.

The GM of GNB concentration was 24 (GSD 4.1) cfu/m³ with a range from 7 to 266 cfu/m³. Median value of GNB at the microbial laboratory

Table 1. The general characteristics of laboratories surveyed

	Laboratory	Temperature (°C)	Relative humidity (%)	Lab. Floor level	No. of persons during sampling	General ventilation	Lab. area (m ²)
Microbiology Laboratory	A	26	51	5	6	Yes	320
	B	26	59	5	3	Yes	168
	C	25	41	1	2	Yes	169
	D	24	56	2	0	No	64
	E	22	43	7	0	Yes	224
	F	25	39	3	4	No	182
	G	27	38	3	4	No	225
Chemistry Laboratory	H	25	56	4	0	No	60
	I	27	44	7	0	No	264
	J	23	57	5	13	Yes	308
	K	20	41	1	1	No	567
	L	22	30	1	1	Yes	434
	M	26	39	5	0	No	320
	Mean	24.5	45.7		2.6	No	254.2

NA = Not applicated

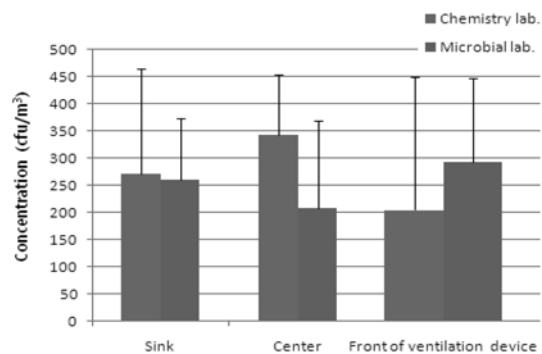
Table 2. Concentration distributions of TAB and GNB in chemical and microbial laboratories

Lab. Classification	Microbial types	No. of total samples	I/O Ratio	No. of samples detected (%)	Bacterial concentrations (cfu/m ³)			
					GM (GSD)	Median	Min	Max
Microbial Lab. (n=7)	TAB	14	12.1	14 (100)	193 (2.0)	209.5	28	589
	GNB	10		4 (40)	10 (1.7)	10.5	7	21
Chemistry Lab. (n=6)	TAB	19	9.3	19 (100)	202 (2.7)	283	14	657
	GNB	8		7 (88)	36 (5.0)	64	7	266
Total (n=13)	TAB	33		33 (100)	194(2.52)	274	14	657
	GNB	18		11 (61)	24 (4.1)	14	7	266

% = Occurrence of TBA and GNB

(64 cfu/m³) was much higher than that of chemical laboratory (10.6 cfu/m³).

TAB concentration by sampling site (in front of sink, center of laboratory, in front of ventilation device) was presented in Fig. 1. TAB concentrations were not significantly different in sampling locations ($p=0.48$). The mean TAB concentrations in chemical laboratory were 343 cfu/m³ at the center, 271 cfu/m³ at the sink, and 205 cfu/m³ in front of ventilation device, respectively. The mean TAB concentrations in microbial laboratory were 293 cfu/m³ in front of ventilation device, 261 cfu/m³ at the sink, and 208 cfu/m³ at the center of laboratory, respectively.

**Fig. 1.** Concentration levels of TAB according to the type of laboratory and the sampling points.

3.1. The factors related with TAB concentration in the laboratory

Table 3 presents correlation between TAB concentrations and related factors in the university laboratory. It was found that there was a significant relationship between TAB concentrations and temperature ($r=0.36$, $p<0.05$). There was also a significant relationship between floor level and temperature ($r=0.49$, $p<0.001$). However, relative humidity, number of persons and laboratory area did not show significant relationships with the TAB concentrations in indoor laboratory at the university ($p>0.05$).

T-test results of TAB concentrations with some variables are summarized in Table 4. The TAB

concentration with frequent cleaning was significantly higher (356 cfu/m³) than that of infrequent cleaning (169 cfu/m³) ($p=0.001$). The TAB concentration with the general ventilation was lower (236 cfu/m³) than that of no general ventilation (296 cfu/m³) with no significant difference. The indoor TAB concentrations (265 cfu/m³) were much higher than that of outdoor air (78 cfu/m³). The TAB concentrations of low-floor and high-floor were 173 cfu/m³ and 305 cfu/m³, respectively ($p<0.05$).

IV. Discussion

Hypothesis that microbial concentration in a

Table 3. Pearson correlation between TAB concentrations and related factors in the university laboratory

	Indoor TAB concentrations (cfu/m ³)	Outdoor TAB concentrations (cfu/m ³)	Temperature (°C)	Relative humidity (%)	Floor level	No. of persons	Lab. area (m ²)
Indoor TAB concentrations (cfu/m ³)	1.00						
Outdoor TAB concentrations (cfu/m ³)	-0.32	1.00					
Temperature (°C)	0.36*	-0.72**	1.00				
Relative humidity (%)	-0.00	-0.1	0.37	1.00			
Floor level	0.29	-0.33	0.49**	0.26	1.00		
No. of persons	0.22	-0.84	-0.08	0.61	0.13	1.00	
Lab. area (m ²)	0.02	-0.1	-0.21	-0.09	0.08	0.30	1.00

* $p<0.05$

** $p<0.01$

Table 4. Comparison of average concentration of TAB according to cleaning frequency, general ventilation, TAB concentrations of indoor and outdoor and floor

	Cleaning frequency (Wash a floor)		General ventilation		TAB concentrations		Floor level	
	Within week (N)	Over 1 week (N)	Existence (N)	Non-existence (N)	Indoor (N)	Outdoor ^a (N)	Low ^b (N)	High ^c (N)
Average conc. of TAB (cfu/m ³)	169 (16)	356 (17)	236 (17)	296 (16)	265 (33)	78 (25)	173 (10)	305 (23)
P-value	0.001		0.33		<0.001		0.047	

Total N = 33 except for outdoor samples

^aN = 25

^bLower than third floor

^cEqual or Higher than third floor

microbial laboratory is higher than that in chemical laboratory was not supported in this study. Log-normally distributed TAB concentration in microbial laboratory was not significantly different from chemical laboratory concentrations (GM, 202 vs 193 cfu/m³, $P>0.05$). But the fact that median GNB concentration in microbial laboratory was much higher than that of chemical laboratory suggests that some caution and control measure is necessary to reduce possible health hazard in the microbial laboratory.

The ratios of indoor and outdoor concentration for TAB ranged from 0.7 to 33.5 with an average of 11.2. This result was consistent with that the concentrations of airborne bacteria in indoor environments are higher than those in outdoor environments.^{15,16)}

The TAB concentration of this study (GM: 194 cfu/m³) was comparable to other studies even though sampling sites were different; GM concentrations were 104 cfu/m³ in the sawmill factory,¹⁷⁾ 105 cfu/m³ in swine confinement buildings,⁴⁾ 113 cfu/m³ in the feedstuff manufacture factory,⁶⁾ 198 cfu/m³ at pelleting process and powdering process. However, there was a report that TAB concentration in general offices were 426 cfu/m³ as an arithmetic mean, which is much higher than that of this study and other studies mentioned above. The reason why the concentrations at the microbial laboratory and other sites quoted above except general office are lower than that of general office is partly explained with the fact that some control measures to reduce microorganism are practiced even though these sites could be good habitats for microorganism. For example, in microbial laboratory, it is a general practice to use disinfectant including 70% alcohol to prevent contamination, which can reduce the airborne microorganisms.

There was a significant relationship between TAB concentrations and temperature (Table 3). This result was consistent with a previous study.¹⁸⁾ Typically, high temperature and relative humidity favor microbial growth.¹⁹⁾ Relative humidity has been known to crucial factor for microorganism growth even in the condition of low temperature.²⁰⁾ However, in this study, relative humidity was not shown the relationship to TAB concentrations. This discordance may be due to a comparatively

lower relative humidity (30~59%) of this study rather than in other study.²¹⁾ This result was supported by Lin and Li (2000), who reported that microbial growth was favored by moderated relative humidity of 60-70%. The variation of outdoor bioaerosol concentrations according to atmospheric height was closely related to local meteorological parameters such as turbulence and mixing height.²²⁾

Floor level might be a confounding factor to explain TAB concentration profile in this study. The temperature, known to be an important factor for microorganism growth,¹⁹⁾ was closely related to the floor level so that floor level seems to be one variable to be relevant to TAB concentration. In this study, the personnel who worked at the high floor level were more exposed to microorganism than who in lower floor level phenomenally due to the temperature differences (Table 4). It is unclear why the room temperature at upper floor level is higher than in lower floor level.

This study indicated that indoor TAB concentrations were significantly higher than those of outdoor concentrations (Table 4). Similarly, Scheff *et al.* (2000)²³⁾ studied that in a middle school of Springfield, Illinois, for total bacteria, indoor concentrations (arithmetic mean (AM): science room, 561 cfu/m³; art room, 811 cfu/m³; lobby, 482 cfu/m³; cafeteria, 460 cfu/m³) were significantly higher than outdoor concentrations (AM: 389 cfu/m³). Moreover, Lee *et al.*²⁴⁾ found that, at low and high floor of high-rise apartment building, indoor bacterial concentrations (GM: low, 280 cfu/m³; high, 288 cfu/m³) were significantly higher than outdoor bacterial concentrations (GM: low, 280 cfu/m³; high, 288 cfu/m³).

Regular cleaning could be an element to reduce the TAB levels in the laboratory as shown in Table 4.

The limitation of this field study was a relatively small sample size and no specification of TAB and GNB found in this study. GNB species might suggest an important implication in microbial laboratory as well as chemical laboratory in terms of health hazard. Also, Performance characteristics of ventilation devices such as fume hood in chemical laboratory and biosafety/clean bench cabinet in microbial laboratory should be measured

to assess health hazard in a laboratory.

V. Conclusions

- TAB concentrations show no significant difference between microbiology and chemistry laboratory, and also no significant difference at each three locations (sink, center, front of ventilation device) in chemical and microbial laboratory, thus, hypothesis that microbial concentration in a microbial laboratory is higher than that in chemical laboratory was not supported in this study.
- A significant correlation was found between TAB concentrations and temperature in the university laboratories, and there were significant temperature variations according to floor level.
- Cleaning frequency was revealed as a significant difference with TAB concentrations in the university laboratories.
- Indoor TAB concentrations were significantly higher than outdoor TAB concentrations.

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