International Journal of Biology and Life Sciences
ISSN: 2957-9511 | Vol. 11, No. 1, 2025

Health Risk Assessment of the Total Number of Air Bacterial Colonies in Different Types of Public Places in Ulanqab City on Employees

Huijie Liu [1, 2], Wenhui Li [1, 2], Shuoyan Liu [1, 2], Yanjiao Wu [1], Fenglin Zhu [1, 2, *]

[1] Ulanqab Center for Disease Control and Prevention, Ulanqab, Inner Mongolia, 012000, China
[2] Key Laboratory of Population Health Hazard Factors, Ulanqab, Inner Mongolia, 012000, China

*** Corresponding author:** Fenglin Zhu

Abstract: Objective To understand the hygiene contamination status of total colony counts in the air of hotels, shopping malls, and gyms in Ulanqab City and assess their health risks to practitioners in these places. **Methods** The monitoring data of total colony counts in the air of 54 hotels, 32 shopping malls, and 8 gyms in Ulanqab City from 2021 to 2023 were analyzed to assess the pollution status. The Fisher exact probability method was used to compare the differences in the qualification rates of total colony counts in the air among different places. Use multiple independent sample rank sum tests to analyze the differences in total bacterial count concentrations between different locations. The non-carcinogenic risk assessment of total colony counts in the air of the three types of public places was conducted using the U.S. Environmental Protection Agency (US EPA) health risk assessment method. **Results** A total of 369 air samples was collected, including 168 from hotels, 177 from shopping malls, and 24 from gyms. The overall qualification rate of total colony counts in the air of the three types of places was 96.7%. The qualification rates of total colony counts in the air of hotels, shopping malls, and gyms were 94.0, 98.9, and 100%, respectively, and the differences were statistically significant ($\chi 2 = 6.17$, $P < 0.05$). The total bacterial count concentrations M (P_{25}, P_{75}) in the air of hotels, supermarkets, and gyms were 178 (387,710), 161 (294,679), and 368 (676,1353) CFU/m3, respectively, and the differences were statistically significant ($H = 12.08$, $P < 0.01$). The non-carcinogenic risks of total colony counts in the air of the three types of places to practitioners were all less than or equal to 1. **Conclusion** The hygiene status of total colony counts in the air of hotels, shopping malls, and gyms in Ulanqab City is good, and the non-carcinogenic risks to practitioners are low.

Keywords: Public Places; Total Colony Counts; Practitioners; Health Risk Assessment.

1. Introduction

Public places are typically densely populated and experience high personnel mobility, which increases the risk of disease transmission. The concentration of microorganisms in the air is one of the key indicators used to evaluate air quality [1]. Bacteria are the primary environmental microbial pollutants indoors and can cause various health issues, including eye irritation, allergies, respiratory diseases, and infectious illnesses [2]. Public places such as hotels, shopping malls, and gyms are generally enclosed environments with limited air circulation, and a mix of healthy and unhealthy individuals, creating favorable conditions for the spread of microorganisms. Poor sanitary conditions in such environments may facilitate disease transmission.

In this study, data from the 2021–2023 Public Place Health Hazard Monitoring Project were used to analyze the hygienic status of indoor airborne bacterial colony counts in hotels, shopping malls, and gyms in Ulanqab City. Additionally, a non-carcinogenic risk assessment based on employee exposure parameters was conducted. The findings provide an understanding of the status of airborne bacterial colony levels in indoor public venues in Ulanqab and offer technical support for health authorities in managing public place hygiene.

2. Subjects and Methods

2.1. Study Subjects

From 2021 to 2023, health hazard monitoring sites in public places across Ulanqab City were selected in accordance with the requirements of the Public Place Health Hazard Monitoring Program. Hotels (54 site-visits), shopping malls or supermarkets (32 site-visits), and gyms (8 site-visits) were selected, taking into account factors such as geographic distribution, visitor flow, and venue scale. Sampling was conducted twice in 2021 (from June to August and from October to December), once in October to December 2022, and once in June to August 2023.

At each site, ten employees with at least one year of service were randomly selected. If fewer than ten employees were available, all eligible staff were included as a cluster sample. A total of 731 individuals participated in the questionnaire survey.

2.2. Methods

2.2.1. Instruments and Equipment

Air sampling was conducted using a six-stage impactor air microbial sampler (Model SP30, Suzhou Lanhua Instruments Co., Ltd.), with a collection efficiency greater than 98%.

2.2.2. Sampling Layout and Requirements

Sampling and point layout for hotels, shopping malls (or supermarkets), and gyms were carried out in accordance with the national standard Hygienic Inspection Methods for Public Places – Part 6: Technical Specifications for Health Monitoring (GB/T 18204.6-2013) [3]. **For hotels**: When the number of guest rooms was ≤100, 3%–5% of the rooms were randomly selected for monitoring; When >100 rooms, 1%–3% of the rooms were selected; For room areas <50 m², one sampling point was set; For areas between 50–200 m², two

sampling points were set; For areas >200 m², 3–5 sampling points were arranged. **For shopping mall**s (supermarkets): For areas <200 m², one sampling point was set; For areas between 200–1,000 m², two points; For areas >1,000 m², 3–5 points; Sampling points were preferentially arranged on floors with high foot traffic. **For gyms:** For areas <50 m², one sampling point was set; For areas between 50–200 m², two points; For areas >200 m², 3–5 sampling points were arranged.

2.2.3. Field Investigation

A standardized questionnaire was used to collect information from employees regarding their daily working hours and number of working days per week. All participants signed an informed consent form prior to the survey to ensure the scientific rigor and legality of the investigation.

2.2.4. Testing Methods and Evaluation Criteria

According to the *Hygienic Inspection Methods for Public Places – Part 3: Air Pollutants* (GB/T 18204.3-2013) [4], air sampling points were set at a height of 1.2–1.5 meters from the ground and at least 1 meter from walls. Sampling points were placed away from air vents, ducts, and other ventilation facilities. Before sampling, windows and doors were closed for 15–30 minutes, and the number of people in the room, temperature, humidity, and weather conditions were recorded. Under sterile conditions, impact sampling was conducted using a six-stage sieve impactor microbial air sampler with a flow rate of 28.3 L/min for 5 minutes. Samples were stored in the dark at 4 °C and tested for total airborne bacterial colonies within 4 hours.

According to the *Hygienic Indicators and Limits for Public Places* (GB 37488-2019) [5], the indoor air colony count should not exceed 1,500 CFU/m³ in hotels, and should not exceed 4,000 CFU/m³ in shopping malls and gyms.

Non-carcinogenic risk was assessed using the hazard quotient (HQ), where HQ ≤ 1 indicates low non-carcinogenic risk, and HQ > 1 indicates higher non-carcinogenic risk [6].

2.2.5. Health Risk Assessment

The U.S. Environmental Protection Agency (US EPA) health risk assessment model [6] was employed in this study. Studies have shown that the exposure risk coefficient for inhaling bacterial aerosols is significantly higher than that for dermal contact, and the cumulative risk from inhalation and skin contact can be approximated by the inhalation route alone [7–8].

Therefore, this study calculated the non-carcinogenic risk of total bacterial colonies based solely on inhalation exposure, as shown in formulas (1) and (2).

$$HQ = \frac{ADD}{RfC} \quad (1)$$

$$ADD = \frac{c \times IR \times ET}{BW \times AT} \quad (2)$$

where: HQ is the Hazard Quotient. ADD is the Average Daily Dose, expressed in CFU/(day·kg). RfC is the Reference Concentration, expressed in CFU/(day·kg). c is the Airborne bacterial colony concentration, expressed in CFU/m³. IR is the Inhalation rate, expressed in m³/day. ET is the Cumulative exposure time, expressed in hours. BW is the Body weight, expressed in kilograms (kg). AT is the Averaging time, expressed in hours; for non-carcinogenic effects, it represents the total number of hours corresponding to the exposure duration. In this study, a 30-year exposure period was assumed, totaling 262,800 hours.

The inhalation rate and body weight were referenced from the *Chinese Exposure Factors Handbook – Adult Volume* [9]. The national average values for adult males and females were used: the average inhalation rates were 17.7 m³/day for males and 14.5 m³/day for females, and the average body weights were 66.1 kg and 57.8 kg, respectively. The reference concentration (RfC) for total bacterial colony count was set at 500 CFU/m³, based on the study by Hou Jie et al. [11]. Cumulative exposure time is a critical parameter in environmental health risk assessment. When the concentration of pollutants in environmental media is accurately quantified, the closer the selected exposure parameters reflect the actual exposure of the target population, the more accurate the health risk assessment results will be [10]. In this study, the cumulative exposure time for employees in different venues was calculated using the median values of daily working hours and weekly working days obtained from questionnaire surveys conducted in Ulanqab (see Table 1).

Table 1. Working Time of Employees in Public Places in Ulanqab City

Venue Type	Daily Working Time (h)	Working Days per Week (d)	Working Days per Year (d)	Working Years (a)	Cumulative Exposure Time (h)
Hotels	9	6	312	30	84240
Shopping Malls	8	7	364	30	87360
Gyms	8	6	312	30	74880

Note: Cumulative Exposure Time = Daily Working Time × Working Days per Year × Working Years

2.2.6. Quality Control

Before the survey, all investigators received standardized training, and efforts were made to maintain a relatively fixed team of investigators. During the survey, questionnaire reviewers checked each completed questionnaire for completeness, standardization, and logical consistency. Only after verification and signature by the reviewer were questionnaires accepted. After the survey, 3% of the questionnaires were randomly selected for repeat surveys. If the consistency rate of responses was below 90%, the entire batch was re-investigated.

Sampling quality was controlled using field blanks, transport blanks, and parallel field samples. All microbiological personnel were trained and assessed on aseptic operation procedures. Field sampling equipment was calibrated for airflow rate prior to use.

2.2.7. Statistical Analysis

Data were entered using an online data entry platform and included in the analysis after verification. Statistical analysis was performed using SPSS version 27.0.

The test results for airborne bacterial colony counts in the three types of venues showed non-normal distributions and

were described using the median and interquartile range, M (P_{25}, P_{75}). Differences in qualification rates across venue types were tested using Fisher's exact test, with $P < 0.05$ considered statistically significant.

3. Results

3.1. General Information

A total of 369 air samples were collected in this study, including 168 from hotels, 177 from shopping malls (supermarkets), and 24 from gyms. A total of 731 employee surveys were conducted: 374 from hotels, 320 from shopping malls, and 37 from gyms (see Table 2).

Table 2. Monitoring Overview of Three Types of Public Places in Different Years

Year	Hotels		Shopping Malls		Gyms	
	No. of Samples	No. of Employees	No. of Samples	No. of Employees	No. of Samples	No. of Employees
2021	108	242	86	160	12	12
2022	—	—	43	80	6	15
2023	60	132	48	80	6	10
Total	168	374	177	320	24	37

Note: "—" indicates that due to the impact of the COVID-19 pandemic, hotels were used as quarantine sites and were not included in the monitoring.

3.2. Airborne Bacterial Colony Pollution Status

In this study, the overall qualification rate of airborne bacterial colony counts was 96.7%. The qualification rates for hotels, shopping malls (supermarkets), and gyms were 94.0%, 98.9%, and 100%, respectively, with statistically significant differences ($\chi^2 = 6.17$, $P < 0.05$).

The concentrations of airborne bacterial colonies [expressed as median (P_{25}, P_{75})] in hotels, shopping malls, and gyms were 178 (387, 710), 161 (294, 679), and 368 (676, 1353) CFU/m³, respectively. The differences in concentrations across the three types of public places were statistically significant, as determined by the Kruskal-Wallis rank sum test ($H = 12.08$, $P < 0.01$) (see Table 3).

Table 3. Airborne Bacterial Colony Counts in Three Types of Public Places in Ulanqab City (2021–2023)

Venue Type	Colony Count Concentration $M(P_{25}, P_{75})$/(CFU/m^3)	Kruskal-Wallis Test		No. of Qualified Samples	Qualification Rate (%)	Chi-square Test	
		H value	*P value*			χ^2 value	*P value*
Hotels	178(387,710)	12.08	0.002	175	94.0	6.17	0.035
Shopping Malls	161(294,679)			158	98.9		
Gyms	368(676,1353)			24	100		

3.3. Non-Carcinogenic Health Risk Assessment

The non-carcinogenic health risks (HQ) associated with airborne bacterial colony counts in hotels, shopping malls (supermarkets), and gyms were 6.64×10^{-2}, 5.23×10^{-2}, and 1.03×10^{-1} for male employees, and 6.22×10^{-2}, 4.90×10^{-2}, and 9.66×10^{-2} for female employees, respectively. All HQ values were ≤ 1, indicating a low non-carcinogenic risk. The HQ values for males were higher than those for females across all venue types (see Table 4).

Table 4. Non-Carcinogenic Risk (HQ) of Airborne Bacterial Colonies for Male and Female Employees in Different Venues

Venue Type	ADD/(CFU/(d · kg))		HQ	
	Male	Female	Male	Female
Hotels	33.22	31.12	6.64×10^{-2}	6.22×10^{-2}
Shopping Malls	26.17	24.52	5.23×10^{-2}	4.90×10^{-2}
Gyms	51.54	48.28	1.03×10^{-1}	9.66×10^{-2}

4. Discussion

In recent years, pathogens responsible for infectious diseases such as COVID-19, Mycoplasma pneumonia, and seasonal influenza have been shown to spread via airborne droplets, particularly in enclosed and densely populated public places. These pathogens pose significant threats to public health, and as a result, public concern over indoor air quality has increased. Through the monitoring and analysis of total airborne bacterial colony counts in hotels, shopping malls (supermarkets), and gyms in Ulanqab City, this study found that the microbial air quality in these three types of venues is generally good. The qualification rates exceeded 90% in hotels and malls and reached 100% in gyms. However, statistically significant differences in colony count concentrations were observed among the three venue types. These findings are consistent with those reported by Li Bei [12] in her analysis of health hazard monitoring data from public places in Jilin Province between 2016 and 2020. The slightly higher qualification rate observed in Ulanqab hotels may be attributed to lower occupancy and more frequent disinfection measures in recent years due to the pandemic.

Exposure parameters are key to accurate health risk assessments. This study used exposure factor data reflective of actual conditions among the Chinese population, as well as locally collected data on employees' working hours in Ulanqab, thereby improving the accuracy of risk estimates. The hazard quotient (HQ) values for both male and female workers in hotels, shopping malls, and gyms in Ulanqab were

all ≤ 1, indicating a low level of non-carcinogenic risk.

Nevertheless, some uncertainties in this study may affect the reliability of the risk assessment results. These include:

(1) Biological variability, such as differences in the types of bacterial toxins present and varying susceptibilities among individuals;

(2) The lack of locally specific inhalation rates and body weight data for Ulanqab workers—national averages were used, which may not fully reflect local characteristics;

(3) The assumed 30-year working duration used in exposure calculations, which was not based on probabilistic modeling.

Although the overall qualification rates for airborne bacterial colony counts were high across venues, occasional exceedances were observed at individual sampling points, warranting continued monitoring. Personnel in public venues should adopt purification, ventilation, and disinfection measures to improve indoor air quality. Meanwhile, it is recommended that health regulatory authorities strengthen public place management in accordance with the law by expanding the scope and frequency of inspections and sampling, thus enhancing the overall hygiene status of public places in Ulanqab. Additionally, the following suggestions are proposed:

(1) Future questionnaires used in the Public Place Health Hazard Monitoring Project should include items on monthly rest days and annual paid leave to enable more accurate estimation of annual working hours and exposure time;

(2) Identification of bacterial species and viral detection should be conducted to provide a more comprehensive understanding of the microbial population structure in indoor air environments.

Conflict of Interest

All authors declare that there are no conflicts of interest.

Acknowledgments

Environmental Health Research Project of Inner Mongolia Autonomous Region Preventive Medicine Association (2023NMYF-HJ010).

References

[1] Lü QY, Han Y, Xiao B. Air microbial monitoring in public places in Dalian in 2013. *China School Doctor*, 2014, 28(12): 915, 917.

[2] Luo J, Su LQ, Han X, et al. Current status and influencing factors of microbial pollution in waiting rooms in China. *Journal of Environmental Hygiene*, 2023, 13(2): 85–91. DOI:10. 13421/j.cnki.hjwsxzz.2023.02.003.

[3] General Administration of Quality Supervision, Inspection and Quarantine of the People's Republic of China, Standardization Administration of China. Hygienic Inspection Methods for Public Places – Part 6: Technical Specifications for Health Monitoring (GB/T 18204.6-2013) [S]. Beijing: China Standards Press, 2014.

[4] General Administration of Quality Supervision, Inspection and Quarantine of the People's Republic of China, Standardization Administration of China. Hygienic Inspection Methods for Public Places – Part 3: Air Microorganisms (GB/T 18204.3-2013) [S]. Beijing: China Standards Press, 2014.

[5] State Administration for Market Regulation, Standardization Administration of China. Hygienic Indicators and Limits for Public Places (GB 37488-2019) [S]. Beijing: China Standards Press, 2019.

[6] U.S. Environmental Protection Agency (US EPA). Risk Assessment Guidance for Superfund Volume I: Human Health Evaluation Manual (Part A) [R]. Washington, DC: US EPA, Office of Emergency and Remedial Response, 1989.

[7] Qiu XH, Li YP, Zhang YR, et al. Exposure risk assessment of microbial aerosols in wastewater treatment plants. Journal of Safety and Environment, 2012, 12(3): 89–92. DOI:10.3969/ j. issn.1009-6094.2012.03.022.

[8] Li YJ, Yang Q, Zhao RH, et al. Emission characteristics and exposure risk assessment of microbial aerosols in A2O process wastewater treatment plants. Acta Scientiae Circumstantiae, 2021, 41(9): 3457–3463. DOI: 10.13671/j.hjkxxb.2021.0293.

[9] Ministry of Environmental Protection. Chinese Exposure Factors Handbook – Adult Volume [M]. Beijing: China Environmental Science Press, 2014.

[10] Duan XL, Huang N, Wang BB, et al. Comparative analysis of exposure parameters in environmental health risk assessments at home and abroad. Journal of Environment and Health, 2012, 29(2): 99–104.

[11] Hou J, Qu YH, Ning DL, et al. Characteristics of exposure parameters among Chinese residents and their impact on risk assessment. Environmental Science and Technology, 2014, 37(8): 179–187. DOI: 10.3969/j.issn.1003-6504.2014.08.035.

[12] Li B. Analysis of Public Place Health Hazard Monitoring Results in Jilin Province from 2016 to 2020 [D]. Jilin: Jilin University, 2022.