Analysis of Noise Exposure Level and Influencing Factors of Small and Micro-Scale Enterprises in Beijing, China

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Abstract
Understand the noise exposure level and influencing factors of small and micro-scale enterprises in Beijing, and support the formulation of noise prevention and control policies. Noise hazards in small- and micro-scale enterprises were monitored from May to December 2021 using a combination of questionnaire survey and on-site noise monitoring. The survey included questions on the basic characteristics of the enterprise, the situation of noise protection facilities, and protective equipment. We calculated the equivalent to the sound level of 8 h per day ($L_{EX,8h}$) or the equivalent of the sound level of 40 h per week ($L_{EX,w}$) and the exceeding rate. Unconditional logistic regression was used to analyze the influencing factors. We recruited 194 enterprises in our study, including 145 small- and 49 micro-scale enterprises. Overall, 9.9% of the noise points exceeded the Chinese national standard, which was 85 dB(A). The detected noise of micro-enterprises significantly ($P<.001$) exceeded that of small enterprises. This is the first study to examine noise hazards of small and micro-scale enterprises in Beijing in recent years. Our results showed noise hazard prevention in Beijing is grim. It is suggested that the government should strengthen supervision, allocate responsibility to the employer, and guide them to establish and improve the management system for controlling noise hazards, to effectively reduce its impact on the health of workers.

Keywords
Noise, occupational exposure, risk factors, Beijing

What do we already know about this topic?
Noise hazards in enterprises are serious globally, but there is no reports on small and micro enterprises’ noise hazards and the risk factors in Beijing are still unclear at present.

How does your research contribute to the field?
Noise hazard prevention and control in Beijing is grim, and the incidence of noise hazards is significantly associated with micro-scale enterprises.

What are your research’s implications toward theory, practice, or policy?
These data suggest that the government should guide enterprises to establish and improve the management system to control noise hazards, so as to effectively reduce the impact of noise hazards on workers’ health.

Introduction
The World Health Organization (WHO) released the World Report on Hearing on March 2, 2021. It estimated that by 2050, nearly 2.5 billion (1 in 4) people would be living with some degree of hearing loss, and at least 700 million of them would require rehabilitation services.\(^1\) An estimated 16% of hearing loss may be contributed to exposure to high-levels of noise at the workplace.\(^2\) Occupational noise-induced hearing

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loss (NIHL) may have a serious impact on the workers’ quality of life, including their ability to communicate and their safety. It is estimated that the annual compensation for occupational NIHL, in the USA, is approximately $242.4 million.

High noise levels are the most focused on issue in occupational settings, worldwide. It was estimated that 600 million workers were exposed to harmful levels of noise globally. Each year, about 22 million workers were exposed to harmful levels of noise in the USA, while about 1.7 million workers were exposed to more than 85 dB(A) of noise in Britain. Five million people in Germany, were exposed to noise levels defined as hazardous by the WHO. In recent years, China has been experiencing a change in the spectrum of occupational diseases, that is, noise-induced deafness has become the largest occupational disease after pneumoconiosis, with an annual increase of 20%. It was estimated that approximately 80 million of a total of 574 million workers in industrial and service settings in China are exposed to hazardous noise. In some low-income countries, workers exposed to noise in the transportation and manufacturing industries account for a high prevalence of NIHL, ranging from 18% to 67%.

It was reported that 16% of respondents in a national phone survey in Australia, had an estimated noise exposure equal to or over the recommended exposure limit of 85 dB(A). According to the report of the China Center for Disease Control and Prevention (China CDC), the current national noise exceeding rate is 25.14%, but the noise exceeding rate varied greatly among provinces. A cross-sectional survey of 6557 automotive workers in Hubei Province showed that the noise exceeding rate was 62.53%. An analysis on noise hazards of 273 industrial enterprises in Suzhou City indicated that the proportion of tested points exceeding 85 dB(A) was 43.34%, and the detected points exceeding 85 dB(A) was 20.60% in Sichuan Province. The China CDC monitoring results showed that the proportion of small and micro enterprises with noise exposure exceeding 85 dB(A) was 24.0% and 30.11%, which was higher than that of large (22.0%) and medium enterprises (23.0%), and the difference between these 2 groups was statistical significance ($P < .05$). Most of the enterprises in Beijing are small and micro enterprises. According to the “Notice of the National Bureau of Statistics on Printing and Distributing Statistical Classification of Large, Medium, Small and Micro-sized Enterprises,” a small enterprise is defined as having 100 to 300 employees, and a micro-enterprise is defined as having 10 to 100 employees. But at present, there are few reports on their noise hazards and their risk factors in Beijing are still unclear. The main purpose of this study was to analyze the noise exposure level and influencing factors of small and micro-scale enterprises, and to provide a basis for the formulation of noise hazard prevention and control policies.

**Methods**

**Enterprise Selection for Study**

From May to December 2021, according to the 20 key industries stipulated in the “Beijing Work Plan for Surveillance of Occupational Hazards in the Workplace (2021)” issued by the Beijing Municipal Health Commission, 20 small and micro-scale enterprises companies were randomly selected in 16 districts of the city, and a total of 320 companies underwent noise monitoring. According to telephone verification, due to the reform of production process, 268 of them have noise hazards. Taking into account the representativeness of the industry, this study selected industries with 3 or more companies as the research object, including 9 industries, and finally a total of 194 companies were included in the study. The 8 industries included metal products industry, printing and reproduction of recorded media, automotive manufacturing, furniture manufacturing, general equipment manufacturing, etc.

**Data Collection**

This survey adopted a combination of on-site investigation and on-site examination. The on-site investigation adopts the “Workplace Occupational Disease Hazardous Factors Monitoring Project Questionnaire” formulated by China CDC. The questionnaire was completed by the occupational health staff responsible for the testing with the person in charge of the enterprise. The survey content included the basic information of the enterprises (industrial classification, enterprise-scale, and ownership type), noise protection facilities and protective equipment, and identifying the positions where noise existed in the enterprise, formulating a testing plan, and preparing for on-site examination. The on-site examination used a unified sampling sheet to record the noise intensity value and inspection date. The study protocol was reviewed and approved by the Institutional Review Board of the Beijing Center for Disease Control and Prevention (IRB #201920). The written informed consent was obtained from the respondents before the interviews.

**Noise Intensity Measurement**

Personal noise exposure level was measured using a personal noise dosimeter (Svantek, SV 104S, Poland). Before the measurement, each dosimeter was calibrated using a Sound Level Calibrator (Svantek, SV 34B, Poland). The participants were required to wear the dosimeter throughout an entire work shift. The criterion level of the individual noise dosimeter is 94 decibels and the dynamic range of the dosimeters was 40 to 140 dB(A). One working day during the normal production of the factory was selected, and the research subjects were counted as 1 working day from the start of work to the end of the work, wearing individual noise
dosimeters. Individual noise dosimeters were clipped to the participants' collars. The measurement of noise intensity was based on the Measurement of Physical Agents in the Workplace Part 8: Noise (GBZ/T 189.8-2007), and the calculation was the equivalent to the sound level of 8h per day ($L_{EX,8h}$) or the equivalent of the sound level of 40h per week ($L_{EX,w}$). The acceptable noise limit was 85 dB(A).

**Statistical Analysis**

Categorical variables were compared using the $\chi^2$ test, and Fisher’s exact probability method was used when the theoretical frequency was less than 1 or the sample size was less than 40. The median and interquartile range (IQR) were calculated to describe the number of workers who exposed to noise levels at or above 85 dB(A). Kruskal-Wallis $H$ test was used to analyze the number of workers exposed to noise, which did not obey the normality test. Unconditional Logistic regression was used to conduct multivariate analysis on the influencing factors of noise exceeding the standard in small and micro-scale enterprises. The dependent variable was whether the noise intensity equal or more than 85 dB(A), and the independents were ownership type, enterprise-scale, industrial classification, number of workers exposed to noise, and distribution of anti-noise earmuffs or earplugs. The significance level of tests was $P < .05$. All analyses were conducted using the Statistical Analysis System (SAS) software, version 9.4 (SAS Institute, Inc., Cary, NC, USA).

**Results**

Overall, 20 small and micro-scale enterprises companies were randomly selected in 16 districts of Beijing, and a total of 320 companies underwent noise monitoring. According to telephone verification, due to the reform of production process, 268 of them have noise hazards. Taking into account the representativeness of the industry, this study selected industries with 3 or more companies as the research object, including 9 industries, and finally a total of 194 companies were included in the study, including 145 small enterprises and 49 micro-scale enterprises. Detailed information is presented in Figure 1.

**Basic Characteristics of Small and Micro-Scale Enterprise**

The ownership type was dominated by limited liability companies, accounting for 57.7%, and the difference between small and micro-scale enterprise among the various ownership type was statistically significant ($P < .01$). The industrial classification was dominated by printing and reproduction of recorded media, accounting for 44.8%, and the difference between small and micro-scale enterprises among the industrial classification was statistically significant ($P < .01$). The median number of workers exposed to noise in small enterprises (18 persons) was significantly higher than that in micro-scale enterprises (9 persons), the difference of which was statistically significant ($P < .01$; Table 1).
Characteristics of Noise Protection Facilities and Protective Equipment

A 54.1% of the enterprises installed anti-noise facilities; 52.1% of the anti-noise facilities had effective protection; 96.4% of the enterprises provided anti-noise earmuffs or earplugs, and the difference was statistically significant between small enterprises and micro-scale enterprises ($P = .05$); 76.3% of the enterprises wore anti-noise earmuffs or earplugs; and 85.6% of enterprises had warning signs about noise hazard and instructions of anti-noise facilities (Table 2).

Noise Exposure Level of Small and Micro-Scale Enterprises

As shown in Table 3, a total number of 1053 location points with noise hazards were detected. The number of location points exceeding the Chinese national standard for noise of 85 dB(A) was 104 (9.9%). The noise exceeding rate of micro-scale enterprises was higher than that of small enterprises, and the difference was statistically significant ($P = .05$); 76.3% of the enterprises wore anti-noise earmuffs or earplugs; and 85.6% of enterprises had warning signs about noise hazard and instructions of anti-noise facilities (Table 2).

Multivariate Logistic Regression Analysis of Noise Hazards

As shown in Table 4, the noise exposure level of noise hazards was significantly associated with enterprises-scale and industrial classification ($P < .05$). The risk of noise hazards in micro enterprises was higher than that in small enterprises (OR = 2.3, 95% CI [1.3, 4.0]). Compared with metal products manufacturing, printing and reproduction of recorded media (OR = 3.0, 95% CI [1.7, 5.3]) or automotive manufacturing (OR = 4.1, 95% CI [1.6, 10.7]) or general equipment manufacturing (OR = 5.2, 95% CI [1.7, 15.8]).

Discussion

The workers exposed to hazardous noise may experience multiple adverse health outcomes, including hearing difficulty, hypertension, high fasting blood glucose, depression, dementia, fall, increased hospitalization, and health care costs.\textsuperscript{5,9,25-28} The results of this study showed that the risk of noise exposure levels equal to or exceeding 85 dB(A) in Beijing was lower than the national level, which was reported by Chinese Center for Disease Control and Prevention in 2021, the proportions of 9926 small enterprises and 7116 micro enterprises with noise exposure levels equal or exceeding 85 dB(A) were 24.00% and 30.11%, respectively.\textsuperscript{16} But the situation of noise hazard prevention and control was

| Table 1. Basic Characteristics of the Subjects (N = 194). |
|----------------|----------------|----------------|----------------|
| Variables                     | Small enterprise n (%) | Micro-scale enterprise n (%) | $\chi^2$ | P-value |
| Ownership type | 14.713 < .01 |
| State-owned                        | 19 (13.1) | 2 (4.1) |
| Limited liability company       | 83 (57.2) | 29 (59.2) |
| Private                          | 12 (8.3) | 13 (26.5) |
| Others                           | 31 (21.4) | 5 (10.2) |
| Industrial classification | < .01 |
| Metal products industry          | 17 (11.7) | 4 (8.2) |
| Printing and reproduction of recorded media | 61 (42.1) | 26 (53.1) |
| Automotive manufacturing        | 18 (12.4) | 6 (12.2) |
| Furniture manufacturing          | 5 (3.4) | 4 (8.2) |
| Auto repair and maintenance      | 12 (8.3) | 0 (0.0) |
| Non-metallic mineral products industry | 9 (6.2) | 3 (6.1) |
| General equipment manufacturing  | 12 (8.3) | 2 (4.1) |
| Electrical machinery and equipment manufacturing | 4 (2.8) | 3 (6.1) |
| Chemical raw materials and chemical products manufacturing | 7 (4.8) | 1 (2.0) |
| Training of enterprise’s leader | 0.720 .40 |
| Yes                              | 134 (92.4) | 47 (95.9) |
| No                               | 11 (7.6) | 2 (4.1) |
| Training of enterprise occupational health management person | 0.309 .58 |
| Yes                              | 136 (93.8) | 47 (95.9) |
| No                               | 9 (6.2) | 2 (4.1) |
| Number of workers exposed to noise (M, IQR) | 0.01 |
| Yes                              | 18 (10-33) | 9 (5-18) |
| No                               | 145 (100) | 49 (100) |
severe. The exceeding rate of micro-scale enterprises were higher than small enterprises, and the risk of excessive noise in printing and reproduction of recorded media, automotive manufacturing, and general equipment manufacturing was higher than metal products industry.

The results of this study showed that the overall noise excess rate of small and micro enterprises in Beijing was 9.9%, of which small enterprises and micro enterprises were 8.4% and 16.7% respectively. This is lower than 24.00% and 30.11% reported by the China CDC. Possible explanations

Table 2. Characteristics of Noise Protection Facilities and Protective Equipment.

| Variables                                      | Small enterprise | Micro-scale enterprise | Total | $\chi^2$ | P-value |
|------------------------------------------------|------------------|------------------------|-------|---------|---------|
| Installation of anti-noise facilities*        |                  |                        |       |         |         |
| Yes                                           | 76 (52.4)        | 29 (59.2)              | 105 (54.1) | 1.737 | .42     |
| Partly                                        | 13 (9.0)         | 6 (12.2)               | 19 (9.8) |       |         |
| No                                            | 56 (38.6)        | 14 (28.6)              | 70 (36.1) |       |         |
| Protection effect of anti-noise facilities    |                  |                        |       |         |         |
| Yes                                           | 76 (52.4)        | 25 (51.0)              | 101 (52.1) | 5.083 | .08     |
| Partly                                        | 13 (9.0)         | 10 (20.4)              | 23 (11.9) |       |         |
| No                                            | 56 (38.6)        | 14 (28.6)              | 70 (36.1) |       |         |
| Provided of anti-noise earmuffs or earplugs   |                  |                        |       |         |         |
| Yes                                           | 142 (97.9)       | 45 (91.8)              | 187 (96.4) | 3.911 | .05     |
| No                                            | 3 (2.1)          | 4 (8.2)                | 7 (3.6) |       |         |
| Wear of anti-noise earmuffs or earplugs       |                  |                        |       |         |         |
| Yes                                           | 116 (80.0)       | 32 (65.3)              | 148 (76.3) | 4.704 | .10     |
| Partly                                        | 24 (16.6)        | 13 (26.5)              | 37 (19.1) |       |         |
| No                                            | 5 (3.4)          | 4 (8.2)                | 9 (4.6) |       |         |
| Warning signs and instructions of anti-noise  |                  |                        |       |         |         |
| Yes                                           | 127 (87.6)       | 39 (79.6)              | 166 (85.6) | 2.164 | .34     |
| Partly                                        | 11 (7.6)         | 7 (14.3)               | 18 (9.3) |       |         |
| No                                            | 7 (4.8)          | 3 (6.1)                | 10 (5.2) |       |         |
| Total                                         | 145 (100)        | 49 (100)               | 194 (100) |       |         |

*Anti-noise facilities refer to the protective measures set against noise hazards in the workplace, such as sound insulation, sound absorption, noise reduction, vibration reduction, and other protective facilities.

Table 3. Noise Exposure Level of Small and Micro-Scale Enterprises.

| Characteristics                        | Numbers of location points | Median of $\frac{L_{EX,8h}}{L_{EX,w}}$ (dB(A)) | Numbers of exceeding points | Exceeding rate (%)* | $\chi^2$ | P-value |
|----------------------------------------|----------------------------|-----------------------------------------------|-----------------------------|---------------------|---------|---------|
| Total                                  | 1053                       | 78.9                                          | 104                         | 9.9                 |         |         |
| Enterprise-scale                       |                            |                                               |                             |                     |         |         |
| Small enterprise                       | 861                        | 78.9                                          | 72                          | 8.4                 |         |         |
| Micro enterprise                       | 192                        | 80.2                                          | 32                          | 16.7                |         |         |
| Industrial classification              |                            |                                               |                             |                     |         |         |
| Metal products industry                | 137                        | 78.9                                          | 26                          | 19.0                |         | <.01    |
| Printing and reproduction of recorded media | 452                    | 79.8                                          | 39                          | 8.5                 |         |         |
| Automotive manufacturing               | 117                        | 79.4                                          | 6                           | 5.1                 |         |         |
| Furniture manufacturing                | 72                         | 80.8                                          | 10                          | 13.9                |         |         |
| Auto repair and maintenance            | 28                         | 78.1                                          | 2                           | 7.1                 |         |         |
| Non-metallic mineral products industry | 49                         | 80.1                                          | 10                          | 20.4                |         |         |
| General equipment manufacturing        | 101                        | 77.6                                          | 4                           | 4.0                 |         |         |
| Electrical machinery and equipment manufacturing | 74                    | 78.3                                          | 6                           | 8.1                 |         |         |
| Chemical raw materials and chemical products manufacturing | 23                     | 73.1                                          | 1                           | 4.3                 |         |         |

*Exceeding rate was calculated as the proportion of individual noise exposure level equal or more than 85 dB(A).
are that the economic foundation of micro-enterprises is relatively weak, the production technology is relatively backward, and the unreasonable layout of noise-generating equipment is the main reason for the excessive noise. Another possibility is that the awareness of occupational disease prevention and control in micro-enterprises is not strong, and the enterprises are poorly equipped with protective facilities and protective equipment. Therefore, the government should strengthen occupational health supervision of noise hazards in micro-scale enterprises, implement the main responsibility on employers, and take effective noise reduction measures to reduce the impact of noise hazards on workers’ health.

The multivariate results showed that the risk of excessive noise in the printing industry was 3 times that of the metal manufacturing industry. In 2011, Aleksandra et al reported that in Serbia forty percent of the printing machines produced noise levels above the limiting threshold level of 85 dB(A). The possible reason for the excessive noise in the printing industry was that the printing industry was more of
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Author Contributions

AL wrote the main manuscript text and analyzed the data. YY conducted the analysis and contributed to study design. ZC contributed to draw figures. LH, GY, and ZH contributed to data collection. LH, GY, and ZC helped to review the manuscript outline and suggested revisions. All authors have reviewed the manuscript and approved the submitted version. YY was responsible for the overall content as the guarantor.

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