

## RESEARCH LETTER

# Prevalence of multiple exposures to occupational hazards in some industries in China

Hua-qing Liu<sup>1</sup> | Wei-min Gao<sup>2</sup> | Wen-yi Liu<sup>3,4,5</sup> | Liang-bin Xie<sup>6</sup> | Yan-mei Cao<sup>7</sup> <sup>1</sup>Gusu District Health Supervision Institute, Suzhou, Jiangsu, China<sup>2</sup>Department of Physical Examination Center, Suzhou Industrial Park Center for Disease Control and Prevention, Suzhou, China<sup>3</sup>Department of Health Policy Management, Bloomberg School of Public Health, Johns Hopkins University, Baltimore, Maryland, USA<sup>4</sup>Shanghai Bluecross Medical Science Institute, Shanghai, China<sup>5</sup>Institute for Hospital Management, Tsing Hua University, Shenzhen Campus, Shenzhen, Beijing, China<sup>6</sup>Department of General Family Medicine, Baita Community Health Service Center of Suzhou, Suzhou, China<sup>7</sup>Department of Occupational Disease, The Fifth People's Hospital of Suzhou, Suzhou, China**Correspondence**

Yan-mei Cao, Department of Occupational Disease, The Fifth People's Hospital of Suzhou, Suzhou, China.

Email: [cyme1227@163.com](mailto:cyme1227@163.com)**Funding information**

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## 1 | INTRODUCTION

It is widely known that many workers are exposed to more than one occupational hazard, but little is known about the prevalence of multiple exposures to occupational hazards in the real world. In most occupational hazard risk assessments and toxicological studies, only one single occupational hazard is targeted. Recent commentaries have underlined the massive challenges associated with the identification of combinations of occupational hazards.<sup>1,2</sup> Identification of exposure combinations is important for public health and epidemiology since it is hypothesized that exposures induce changes in phenotype, not as a single agent, but as a collection of agents acting in concert.<sup>3,4</sup> Compared to the hazard risk assessment of single hazards, coexposure risk assessment presents a greater challenge due to the common existence of many types and numbers of hazards. One way to deal with this challenge is to identify combinations that are prevalent, which, in turn, might help prioritize research and interventions.<sup>5</sup> Therefore, this study describes the prevalence of coexposure to chemical and physical hazards in China-based industrial enterprises using the database of occupational health surveillance.

## 2 | MATERIALS AND METHODS

### 2.1 | Subjects

According to China's mandatory regulations, enterprises must arrange an occupational examination for workers who are exposed to occupational hazards. Industrial workers who were exposed to occupational hazards and underwent occupational physical examinations in our institute were included. We defined occupational exposure as the process of workers' contact with occupational hazards through the respiratory tract, skin, and other organs during occupational activities. Multiple exposure was defined as when a worker is exposed to two or more occupational hazards in the same enterprise.

### 2.2 | The identification and data acquisition of occupational hazards

Enterprises in China must employ a third-party organization to identify and detect the occupational hazards that workers have been

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exposed to. Based on the categories of occupational hazards workers are exposed to described in the report of the third-party organization, the physical examination institution conducted examinations for workers according to technical specifications for occupational health surveillance (GBZ 188-2014). We obtained data on occupational hazards, age, and gender from the occupational physical examination system. Enterprises are classified according to the industrial classification system used for China's national economic activities (GB/T 4754-2017). All procedures performed in the study coincided with the 1964 Declaration of Helsinki as well as its later amendments or comparable ethical standards.

### 2.3 | Statistical analysis

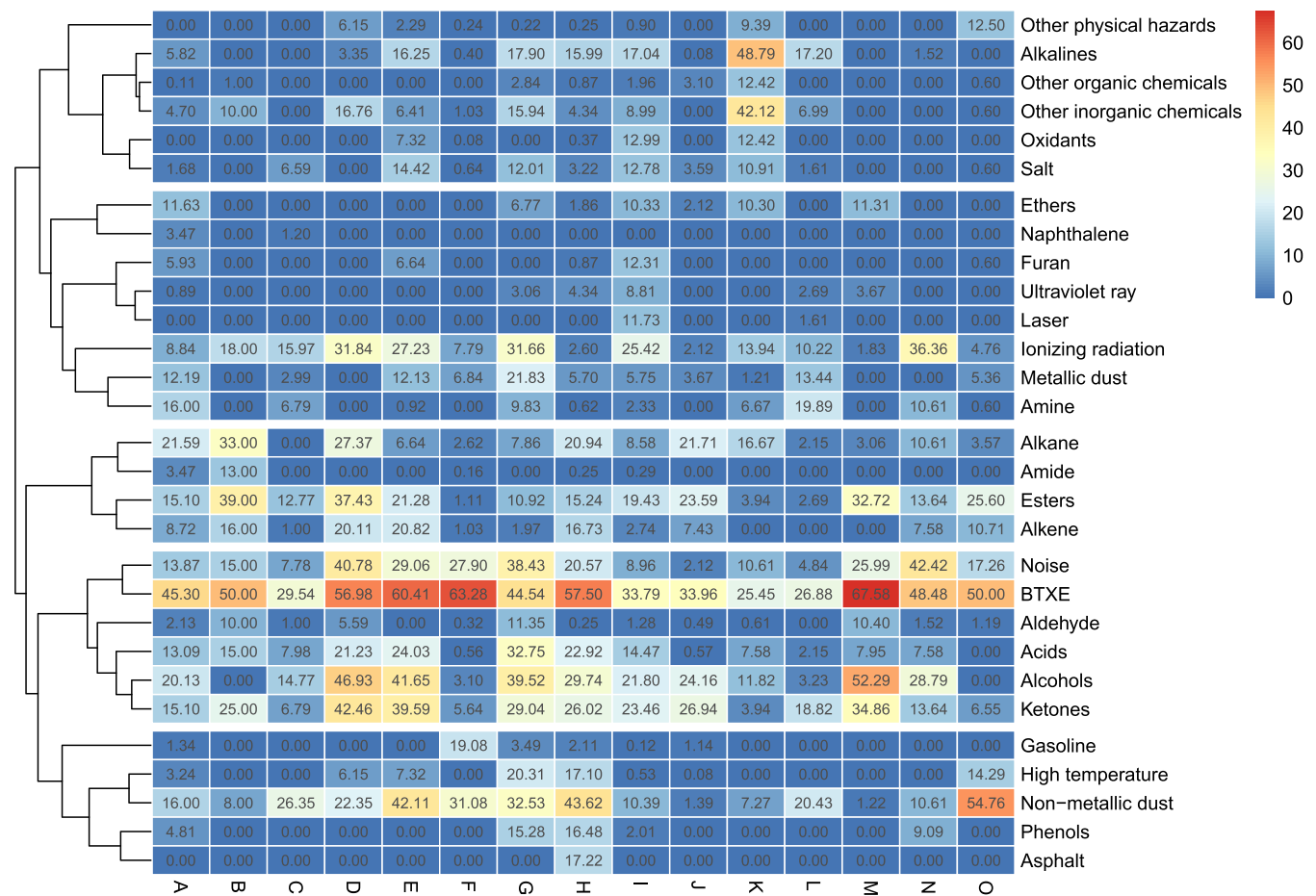
Categorical variable was described by frequency (percentage), and continuous variable was described by mean  $\pm$  standard deviation or

median (interquartile range, IQR). All statistical analyses were performed using the R version 4.1.1 software (R Core Team, 2021), with the pheatmap package for the heat-map procedure and the igraph package for the network procedure.

## 3 | RESULTS

### 3.1 | Distribution of occupational hazards in various industries

The study focused on 10,363 workers (71.4% males) exposed to occupational hazards who came from 371 industrial enterprises. The average age of workers was  $29.0 \pm 6.5$  years. The distribution of occupational hazards in various industries is shown in Figure 1. In most industries, benzene and its homologs (including toluene, xylene, and ethyl benzene, etc., BTXE) were the primary hazards for



**FIGURE 1** Distribution heat map of workers exposed to occupational hazards in various industries. The letters in the abscissa indicate the industry classification. A. Electrical machinery manufacturing; B. Cottonocracy; C. Nonmetallic mineral products; D. Chemical fiber manufacturing; E. Chemical raw material production; F. Vehicle manufacturing; G. Metal smelting and processing; H. Equipment manufacturing; I. Communication and electronic equipment manufacturing; J. Rubber and plastic products; K. Pharmaceutical manufacturing; L. Instrument manufacturing; M. Printing; N. Paper industry; O. Others. The number in the block is the proportion of workers' exposure by industry, for example, the value of the box corresponding to the letter M and BTXE is 67.58, which means that 67.58% of the workers from the printing industry are exposed to BTXE. The tree branches on the left side indicate the clustering of workers' exposure to various occupational hazards.

occupational exposure, accounting for 43.2% of the total. Exposure to noise, ionizing radiation, nonmetallic dust, alcohols, ketones, ester, acid, alkane, and alkaline also play an important role in several industries, accounting for about 10%–20% of occupational hazards.

### 3.2 | Multiple exposures

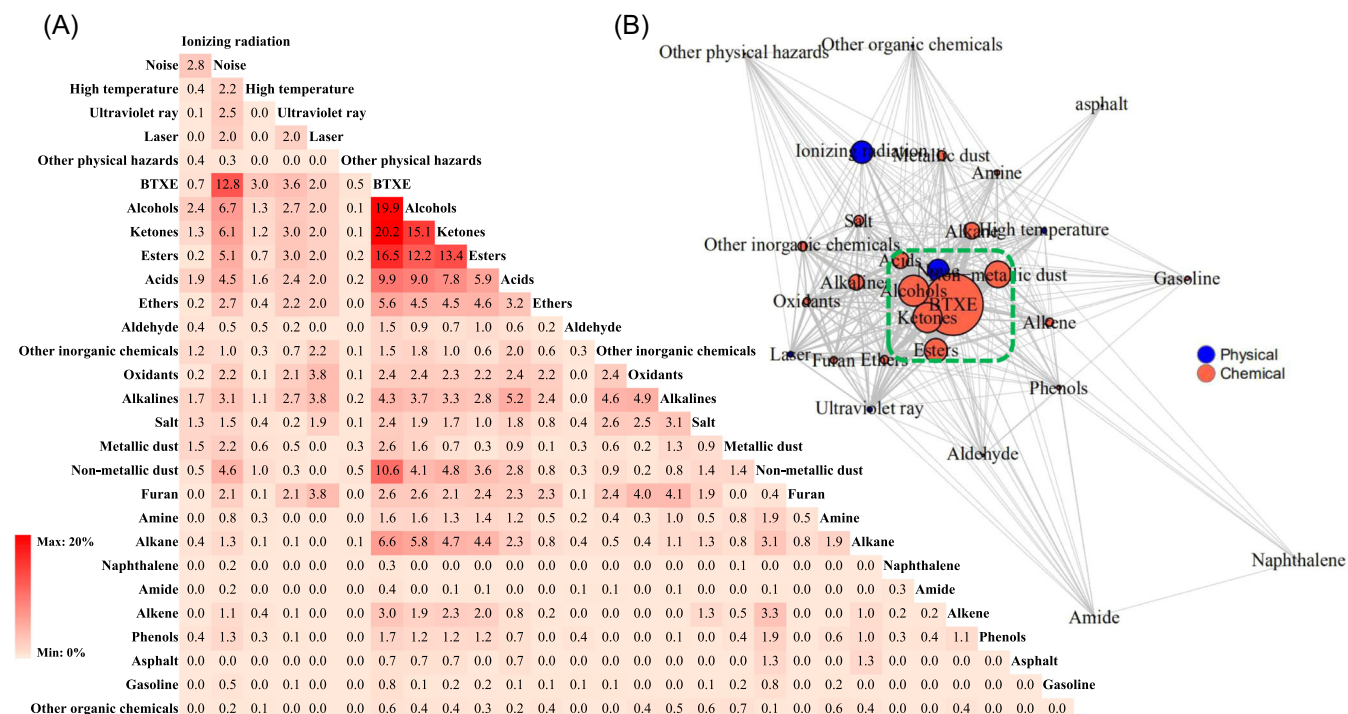
The median number of occupational hazards workers experienced was 3.0 (IQR: 3.0–5.0). The proportion of workers exposed to two or more hazards reached 75.2%, those exposed to five or more hazards reached 33.8%, and exposure to 10 hazards or more reached 7.2%.

The cross and net analysis results of coexposure are shown in Figure 2. BTXE hazards were the most common partner in coexposures. Cross-combination analysis showed that the proportion of workers exposed to BTXE combined with noise reached 12.8%, with nonmetallic dust reached 10.6%, and with alcohols or ketones reached even 20%. BTXE combined with noise, nonmetallic dust, alcohols, ketones, esters, and acids formed a coexposure cluster. This clustering trend can also be seen in the tree in Figure 1. The proportion of workers exposed to any two or more of the seven hazards reached 37.4%, the proportion of any three or more reached 26.8%, and the proportion of any four or more reached 15.3%. The combined exposure frequency of alkane, alkaline, furan, and other hazards was also striking.

## 4 | DISCUSSION

This study has described the multiple, coexposures of workers to occupational hazards in the real world in China. Utilizing the monitoring database to analyze multiple exposures to occupational hazards has also been reported in other studies.<sup>2,6</sup> The group of workers analyzed in the study came from the largest industrial enterprises zone in China, where there are many types of industrial enterprises. To some extent, the results of this study can represent the current situation of workers' multiple occupational exposures. The prevalence of multiple exposures poses a more difficult challenge for industrial enterprises as they seek to provide effective protective measures for workers. For example, if a worker is exposed to splashing harmful chemicals and works in a high-temperature environment, wearing protective equipment to prevent splashing contact will inevitably make it more difficult for a worker to adapt to the high-temperature working environment. Industrial enterprises need to make more efforts in the design and improvement of protective equipment, shift work and rest, mechanized operation, and so on.

Among the occupational hazards workers are exposed to in various industries, BTXE were the primary hazards, and they also cross-linked with noise, nonmetallic dust, alcohols, ketones, esters, and acids to form a significant coexposure cluster. The detrimental health effects on workers exposed to BTXE in combination with



**FIGURE 2** Multiple exposure maps of workers. (A) Heat map for in-pair exposure combinations of occupational hazards. The number in the block represents the proportion of workers, for example, the value of the box corresponding to the noise and BTXE is 12.8, which means that 12.8% of the workers are coexposed to noise and BTXE. (B) Coexposure network of occupational hazards. Network nodes represent occupational hazards and the larger the size of network nodes, the higher the proportion of workers exposed. Conversely, the closer the distance between nodes, the higher the probability of coexposure. Edges represent that there is coexposure between the two nodes.

other occupational hazards has been observed by some researchers. For example, it was found that noise combined with benzene–toluene–xylene exposures in painting workshops of automobile manufacturing enterprises had a positive influence on the systolic blood pressure of workers.<sup>7</sup> Male occupational exposures to multiple solvents (benzene, methylene chloride, toluene, trichloroethylene, perchloroethylene, and 1,1,1-trichloroethane) increased the risk of amyotrophic lateral sclerosis.<sup>8</sup> Nevertheless, the current understanding of the health effects of multiple exposures is far from sufficient.

When understanding this study, the following limitations should be noted. First, the health monitoring database used in this study recorded the categories of occupational hazards workers are exposed to and the results of occupational health examination parameters, but there were no data on the duration and dose of workers exposed to various occupational hazards. Hence, when analyzing multiple exposures, this study could not identify the weight of exposure time and dose of each hazard. Second, the sample selection of this study is nonrandom sampling, which may have potential bias.

In conclusion, multiple exposures of industrial workers to occupational hazards are prevalent, and BTXE, noise, nonmetallic dust, alcohols, ketones, esters, and acids often cross-link to form a significant coexposure cluster in industrial workers.

#### AUTHOR CONTRIBUTIONS

*Conceptualization:* Yan-mei Cao and Wen-yi Liu. *Data collection:* Weimin Gao and Liang-bin Xie. *Analysis and interpretation of data:* Hua-qing Liu. *Writing—original draft preparation:* Hua-qing Liu, Wen-yi Liu, and Yan-mei Cao. *Writing—review and editing:* Hua-qing Liu and Yan-mei Cao. All authors have read and approved the final version of the manuscript.

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#### CONFLICTS OF INTEREST

The authors declare no conflicts of interest.

#### DATA AVAILABILITY STATEMENT

The data supporting the findings of this study are available from the corresponding author upon reasonable request.

#### ETHICS STATEMENT

The work was performed at the Fifth People's Hospital of Suzhou and was approved by the Medical Ethics Committee of the Fifth People's Hospital of Suzhou on June 11, 2021 (code: 2021016).

#### TRANSPARENCY STATEMENT

The corresponding author confirms that the manuscript is an honest, accurate, and transparent account of the study being reported.

#### ORCID

Yan-mei Cao  <http://orcid.org/0000-0002-6194-6364>

#### REFERENCES

1. Patel CJ. Analytic complexity and challenges in identifying mixtures of exposures associated with phenotypes in the exposome era. *Curr Epidemiol Rep.* 2017;4:22-30.
2. Qian H, Chen M, Kransler KM, Zaleski RT. Assessment of chemical co-exposure patterns based upon phthalate biomonitoring data within the 2007/2008 National Health and Nutrition Examination Survey. *J Expo Sci Environ Epidemiol.* 2015;25:249-255.
3. Carpenter DO, Arcaro K, Spink DC. Understanding the human health effects of chemical mixtures. *Environ Health Perspect.* 2002; 110(Suppl 1):25-42.
4. Carlin DJ, Rider CV, Woychik R, Birnbaum LS. Unraveling the health effects of environmental mixtures: an NIEHS priority. *Environ Health Perspect.* 2013;121:A6-A8.
5. Kapraun DF, Wambaugh JF, Ring CL, Tornero-Velez R, Setzer RW. A method for identifying prevalent chemical combinations in the U.S. population. *Environ Health Perspect.* 2017;125:087017.
6. Bosson-Rieutort D, Sarazin P, Bicout DJ, Ho V, Lavoué J. Occupational co-exposures to multiple chemical agents from workplace measurements by the US Occupational Safety and Health Administration. *Ann Work Expo Health.* 2020;64:402-415.
7. Zhou HL, Jiang L, Mai SQ, et al. Analysis of the cardiovascular effects on workers expose to occupational benzene-toluene-xylene and noise in a painting workshop of an automobile company. *Zhonghua Lao Dong Wei Sheng Zhi Ye Bing Za Zhi.* 2019;37:280-283 (in Chinese).
8. Dickerson AS, Hansen J, Thompson S, Gredal O, Weisskopf MG. A mixtures approach to solvent exposures and amyotrophic lateral sclerosis: a population-based study in Denmark. *Eur J Epidemiol.* 2020;35:241-249.

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