Preplanned Studies

The Distribution and Concentration Monitoring of Benzene Industries — Six PLADs, China, 2020

Xue Wang[1]; Jin Zhou[1]; Lei Han[2]; Xiurong Cheng[1]; Hua Shao[3]; Qiang Jia[3]; Peiyu Xu[4]; Jing Liu[5]; Jie Ren[5]; Jin Li[6]; Fei Li[7]; Baoli Zhu[2]; Meibian Zhang[1]; Caihong Xing[1,#]

Summary

What is already known about this topic?

Benzene is classified as a Class I human carcinogen by the International Agency for Research on Cancer. Long-term exposure to benzene increases the risk of chronic benzene poisoning and leukemia. However, benzene is still widely used in the manufacturing industry.

What is added by this report?

The scale of enterprises most exposed to benzene was small enterprises, and joint-equity enterprises had the highest number that exceeded the permissible concentration-time weighted average.

What are the implications for public health practice?

It is still necessary to strengthen the monitoring of benzene concentrations in the manufacturing industry, especially in small enterprises. The occupational exposure limit of benzene should be appropriately reduced.

Benzene was listed as Class I carcinogen by the International Agency for Research on Cancer (IARC) (*1*). Chronic exposure to high levels of benzene can cause leukemia and other hematopoietic malignancies in humans. Many studies have reported that long-term exposure to benzene at 6 mg/m^3 or less can cause blood toxicity, such as a decreased number of peripheral white blood cells, red blood cells, platelets, and lymphocytes, and can increase the risk of myelodysplastic syndrome and acute myeloid leukemia (*2*–*3*). In this study, benzene industries from six provincial-level administrative divisions (PLADs)[*] were analyzed and characterized by concentration, number of enterprises, enterprise scale[†], ownership of the enterprise[§], and industry distribution[¶]. At present, the production and use of benzene is still prevalent in many industries in China. In our study, manufacturing is the main industry of benzene-exposed industries, and the median concentration of benzene is below 3 mg/m^3 in more than 98% of benzene industries. Monitoring the concentration of benzene in benzene-exposed industries and taking corresponding measures can effectively reduce the harm of low-level benzene exposure.

The permissible concentration-time weighted average (PC-TWA) of benzene has been set to 6 mg/m^3 in China. Comparatively, the occupational benzene exposure limit is lower in many countries, such as the United States, where the national PC-TWA of 3.25 mg/m^3 is nearly half of that in China (*4*). This study reveals the exposure levels of benzene industries and their distribution characteristics in 2020, which can contribute to an improvement in the working environment. Jiangsu, Shandong, Tianjin, Fujian, and Zhejiang were selected because of their strong comprehensive ability in manufacturing (*5*), as well as Sichuan, which is the major benzene-exposed province. In workplaces, the 8-hour time-weighted average concentrations of benzene were measured using air samplers by local CDCs. The exposure group was divided into 3 subgroups with <3 mg/m^3 (the half concentration of PC-TWA), 3–6 mg/m^3 and > 6 mg/m^3. The *Industrial Classification for National Economic Activities* (GB/T 4754–2017) document was used to standardize industries associated with benzene. Data were processed with Excel software (version Home and Student 2019, Microsoft Office, USA).

There were 15 industries producing and/or using benzene in the 6 PLADs, including 2,841 enterprises (Table 1). Among them, the category of furniture

[*] Jiangsu Province, Shandong Province, Sichuan Province, Fujian Province, Zhejiang Province, and Tianjin Municipality.
[†] Large, medium, small, and mini-sized enterprises.
[§] State-owned, collective, pooling, private, foreign, joint-equity, and Hong Kong, Macao, and Taiwan-invested enterprises.
[¶] Furniture manufacturing, printing and recording media reproduction, residential services, repair and other services industry, etc. More information about industry category is available at http://www.stats.gov.cn/tjsj/tjbz/hyflbz/201710/t20171012_1541679.html.

TABLE 1. Benzene exposure concentrations (mg/m^3) for major industries exposed to benzene in six provincial-level administrative divisions* of China in 2020.

Major industry groups	Number	Median of C_{TWA} (range) (mg/m^3)	Corresponding number of enterprises (%)		
			<3 mg/m^3 (%)	3–6 mg/m^3 (%)	>6 mg/m^3 (%)
Furniture manufacturing	588	0.60 (0.001–86.30)	585 (99.49)	1 (0.17)	2 (0.34)
Printing and recording media reproduction	431	0.60 (0.001−9.80)	427 (99.07)	3 (0.70)	1 (0.23)
Residential services, repair, and other services	358	0.60 (0.004−14.20)	355 (99.16)	2 (0.56)	1 (0.28)
Automobile manufacturing	189	0.60 (0.01−10.19)	187 (98.94)	1 (0.53)	1 (0.53)
Metal products	179	0.60 (0.005−23.09)	176 (98.32)	1 (0.56)	2 (1.12)
Chemical raw materials and chemical products manufacturing	175	0.60 (0.04−3.16)	174 (99.43)	1 (0.57)	0
Leather, fur, feather and their products and shoemaking	147	0.60 (0.001−67.08)	142 (96.60)	1 (0.68)	4 (2.72)
General equipment manufacturing	142	0.60 (0.04−6.65)	138 (97.18)	3 (2.11)	1 (0.70)
Wood processing and wood, bamboo, rattan, palm, and grass products	124	0.60 (0.01−5.20)	119 (95.97)	5 (4.32)	0
Non-metallic mineral products industry	121	0.60 (0.06−2.00)	121 (100.00)	0	0
Rubber and plastic products industry	104	0.60 (0.02−3.70)	102 (98.08)	2 (1.92)	0
Special equipment manufacturing	92	0.60 (0.01−2.00)	92 (100.00)	0	0
Railway, ship, aerospace, and other transportation equipment manufacturing	66	0.60 (0.02−0.90)	66 (100.00)	0	0
Culture and education, arts and crafts, sports, and entertainment products manufacturing	63	0.60 (0.01−6.40)	62 (98.41)	0	1 (1.59)
Electrical machinery and equipment manufacturing	62	0.60 (0.04−10.80)	61 (98.39)	0	1 (1.61)
Total	2,841	0.60 (0.001−86.30)	2,807 (98.80)	20 (0.70)	14 (0.49)

Abbreviation: C_{TWA}=concentrations of time weighted average.
* Jiangsu Province, Shandong Province, Sichuan Province, Fujian Province, Zhejiang Province, and Tianjin Municipality.

manufacturing enterprises had the highest figure (588 enterprises), and the median benzene concentration in these enterprises was 0.60 mg/m^3 (range: 0.001–86.30 mg/m^3). The printing and recording media replication industry was the second largest industry producing and/or using benzene (431 enterprises), and the median benzene concentration in these enterprises was 0.60mg/m^3 (range: 0.001–9.80 mg/m^3). More than 98% enterprises of printing and recording media replication had benzene concentrations of less than 3 mg/m^3, and there were 0.49% (14/2,841) of enterprises that exceeded the PC-TWA (6 mg/m^3). Leather, fur, feathers and their related products, and the shoemaking industry appeared to have a greater probability (2.72% of enterprises) for significant exposure (>6 mg/m^3).

Industries were classified according to the *Division Standard of Large/Medium/Small Sized Industrial Enterprises* issued by the National Bureau of Statistics of China (*6*). In Table 2, the proportion of medium-sized enterprises exceeding the PC-TWA of benzene concentration was the highest (2 enterprises, 0.88% of the total). However, the scale of enterprises with the largest number exposed to benzene was small enterprises, and the proportion exceeding the PC-TWA of benzene was 0.56%.

According to the classification by economic type, it can be found that the number of joint-equity enterprises was the highest, and there were 8 enterprises (0.48% of the total) which exceeded the PC-TWA. It was followed by private enterprises with 898 enterprises, and 5 businesses exceeded the PC-TWA (0.56% of the total).

DISCUSSION

Among the 6 PLADs, the proportion of those exceeding the PC-TWA in leather, fur, feathers and related products, and the shoemaking enterprises was the highest, up to 2.72%. We also found that the smaller the scale, the higher the maximum concentration of benzene (Table 2). There were more small enterprises with benzene concentration exceeding PC-TWA. It was speculated that the production equipment and occupational health conditions of small enterprises were not as well-controlled as those of large enterprises, such as imperfect ventilation facilities or unqualified protective equipment. Private enterprises had the highest rate (0.56%) of exceeding the PC-

TABLE 2. Distribution of enterprise scale and ownership type with industries exposed to benzene in six provincial-level administrative divisions of China in 2020.

Item	Enterprise number	Median of C_{TWA} (range) (mg/m^3)	Number of enterprises exceeding PC-TWA (%)
Enterprise scale			
Large	40	0.60 (0.05−2.00)	0
Medium	228	0.60 (0.040−10.19)	2 (0.88)
Small	1,603	0.60 (0.001−67.08)	9 (0.56)
Mini-sized	970	0.60 (0.001−86.30)	3 (0.31)
Ownership type			
Hong Kong, Macao, and Taiwan-invested enterprises	37	0.60 (0.06−2.00)	0
joint-equity	1,661	0.60 (0.001−86.30)	8 (0.48)
Private	898	0.60 (0.004−67.08)	5 (0.56)
Collective	42	0.60 (0.03−3.80)	0
Foreign	76	0.60 (0.01−2.00)	0
State-owned	47	0.60 (0.04−4.10)	0
Joint-operate	6	0.60 (0.15−6.00)	0
Unrevealed	74	0.60 (0.01−14.20)	1 (1.35)
Total	2,841	0.60 (0.001−86.30)	14 (0.49)

Abbreviations: C_{TWA}=concentrations of time weighted average; PC-TWA=permissible concentration-time weighted average.

TWA, which might have been due to the lack of enterprise supervision.

Since the 1960s, the exposure concentration of benzene in working environments has gradually decreased in China. In 1962, the maximum allowable concentration of benzene decreased from 80 mg/m^3 to 50 mg/m^3, and the PC-TWA fell from 57 mg/m^3 in 1965 to 6 mg/m^3 in 2002 (*7*). Accordingly, the benzene poisoning rate was also decreasing. By 2017, the rate of chronic benzene poisoning in 6 PLADs (Guangdong, Shandong, Jiangsu, Sichuan, Beijing, and Tianjin) had decreased from 1.1% to 0.054% (*8*). In this study, most of the investigated enterprises had benzene concentrations lower than 3 mg/m^3. The decreased exposure limit of occupational benzene in China and the improvement of health protection measures and production processes in factories and workshops may have been the main reasons for the decrease of concentration of benzene exposure in enterprises. It had been reported that long-term benzene exposure of low concentration (<3.25 mg/m^3) could cause hematopoietic toxicity, which may cause the decrease of blood cell counts and increase the risk of leukemia (*9*). Low levels of benzene exposure can lead to chromosomal aneuploidy in offspring and significantly increase micronucleus frequency and sister chromatid exchange frequency (*10*). Given that health damage may occur even when the concentration of benzene is not exceeded the PC-TWA, the current benzene exposure limit (6 mg/m^3) in China needs to be reduced further. By controlling the concentration of benzene exposure, the health of occupational exposure to benzene can be effectively protected.

In general, compared with the prior studies, the concentration of benzene exposure in all the industries in China have significantly decreased, from the average exposure of 54.3 mg/m^3 in 1987 (*7*) to 98.80% of enterprises were less than 3 mg/m^3 in 2020 from this study. But the harm of low-level benzene exposure could not be underestimated. Therefore, China should reduce the current occupational exposure limit and protect the health of the occupational population as much as possible.

This study was subject to some limitations. First, the different monitoring methods in different PLADs may have caused some deviations in measurement. Second, this study only involved six PLADs. To accurately reflect the real situation of benzene exposure in China, it is necessary to expand the scale of investigation, which is beneficial to put forward more perfect prevention strategies and measures.

According to the results of this investigation, several suggestions to reduce the exposure hazards of low-level benzene are listed as follows: 1) strengthen the monitoring of benzene and its homologues in the workplaces of small and medium-sized enterprises,

improve the ventilation in workplaces, and lower the concentration of benzene in the air as much as possible; 2) physical examination and health education should be carried out for workers, self-protection awareness should be strengthened, and the use of personal protective tools should be increased; 3) some industries (such as the manufacturing industry), in which the benzene exposure is high, should be controlled within the PC-TWA in China, and the time workers are exposed to benzene should be reduced as far as possible.

Conflicts of Interest: No conflicts of interest were reported.

Funding: The study was funded by the Project of Occupational Health Risk Assessment and National Occupational Health Standard Formulation of the National Institute of Occupational Health and Poison Control (Project No.: 131031109000150003).

doi: 10.46234/ccdcw2021.220

[#] Corresponding author: Caihong Xing, caihongxing2013@163.com.

[1] Key Laboratory of Chemical Safety and Health, National Institute for Occupational Health and Poison Control, Chinese Center for Disease Control and Prevention, Beijing, China; [2] Jiangsu Provincial Center for Disease Control and Prevention, Nanjing, Jiangsu, China; [3] Shandong Academy of Occupational Health and Occupational Medicine, Shandong First Medical University & Shandong Academy of Medical Sciences, Jinan, Shandong, China; [4] Department of Nutrition, Food Safety and Toxicology, West China School of Public Health, Sichuan University, Chengdu, Sichuan, China; [5] Tianjin Centers for Disease Control and Prevention, Tianjin, China; [6] Fujian Center for Prevention and Control of Occupational Diseases and Chemical Poisoning, Fuzhou, Fujian, China; [7] Zhejiang Provincial Center for Disease Control and Prevention, Hangzhou, Zhejiang, China.

Submitted: September 09, 2021; Accepted: October 19, 2021

REFERENCES

1. IARC. Some industrial chemicals and dyestuffs. IARC Monogr Eval Carcinog Risk Chem Hum 1982;29:1–398. https://pubmed.ncbi.nlm.nih.gov/6957379/.
2. Lan Q, Zhang LP, Li GL, Vermeulen R, Weinberg RS, Dosemeci M, et al. Hematotoxicity in workers exposed to low levels of benzene. Science 2004;306(5702):1774 – 6. http://dx.doi.org/10.1126/science.1102443.
3. Li L, Li H, Wang L, Zhang XM, Xu LH. Influence of low level occupational benzene exposure on human peripheral blood leukocyte counts: a meta-analysis. J Environ Health 2012;29(7):637 – 9. http://dx.doi.org/10.16241/j.cnki.1001-5914.2012.07.013. (In Chinese).
4. Capleton AC, Levy LS. An overview of occupational benzene exposures and occupational exposure limits in Europe and North America. Chem Biol Interact 2005;153-154:43 – 53. http://dx.doi.org/10.1016/j.cbi.2005.03.007.
5. Li LS, Cheng ZH, Liu J. The "new pattern" of Chinese manufacturing industry and its evaluation research. China Ind Econ 2015(2):63 – 75. http://dx.doi.org/10.19581/j.cnki.ciejournal.2015.02.007. (In Chinese).
6. National Bureau of Statistics of China. Division standard of large/medium/small sized industrial enterprises. 2017. http://www.stats.gov.cn/tjgz/tzgb/201801/t20180103_1569254.html. [2017-12-28]. (In Chinese).
7. Dosemeci M, Li GL, Hayes RB, Yin SN, Linet M, Chow WH, et al. Cohort study among workers exposed to benzene in China: II. Exposure assessment. Am J Ind Med 1994;26(3):401 – 11. http://dx.doi.org/10.1002/ajim.4700260313.
8. Zhou J, Han L, Zhao JX, Cheng XR, Hou FX, Jia Q, et al. Characteristics in the distribution of chronic benzene poisoning associated industries -6 PLADs, China, 2005–2019. China CDC Wkly 2020;2(47):891 – 6. http://dx.doi.org/10.46234/ccdcw2020.243.
9. Koh DH, Jeon HK, Lee SG, Ryu HW. The relationship between low-level benzene exposure and blood cell counts in Korean workers. Occup Environ Med 2015;72(6):421 – 7. http://dx.doi.org/10.1136/oemed-2014-102227.
10. Zhou YH, Wang K, Wang BS, Pu YP, Zhang J. Occupational benzene exposure and the risk of genetic damage: a systematic review and meta-analysis. BMC Public Health 2020;20(1):1113. http://dx.doi.org/10.1186/s12889-020-09215-1.