

Preplanned Studies

Industry Distribution Characteristics of Benzene-Induced Leukemia — 7 PLADs, China, 2005–2019

Jinzhe Li^{1,8}; Yuan Zhao^{2,8}; Xiurong Cheng¹; Lei Han²; Xue Wang¹; Qiang Jia³; Shang Gao⁴; Peiyu Xu⁵; Zihuan Wang⁶; Jin Li⁷; Xinglin Fang⁸; Jiabin Chen⁹; Baoli Zhu²; Meibian Zhang¹; Caihong Xing^{1,8}

Summary

What is already known about this topic?

In the 1980s, benzene-induced leukemia (BIL) mainly occurred in shoemaking and painting industries. Now the industry distribution of benzene-induced leukemia may have changed over time.

What is added by this report?

BIL cases mainly occurred in the manufacturing industry from 2005–2019, especially in private enterprises and small/medium-sized enterprises. The industry with the largest number of new cases of BIL was the general and special equipment manufacturing. The number of leukemia cases in emerging industries such as computer/electronic product manufacturing was found to be increasing.

What are the implications for public health practice?

Strengthening supervision and regulation of manufacturing, especially of small/medium-sized enterprises and emerging manufacturing industry, may be effective in reducing BIL.

Benzene is the simplest aromatic hydrocarbon, which is widely used in industrial production. The International Agency for Research on Cancer (IARC) classified benzene as human carcinogen in 1982 (1). Benzene can cause acute myeloid leukemia and myelodysplastic syndrome and other hematological malignancies, such as non-Hodgkin's lymphoma (2). Chronic exposure to high concentration of benzene can cause chronic benzene poisoning (CBP) (3) which is strongly associated with an increased risk of leukemia and myelodysplastic syndromes (4). This study aims to analyze industry distribution of benzene-induced leukemia (BIL) from seven provincial-level administrative divisions (PLADs). A total of 699 BIL cases diagnosed from 2005 to 2019 (for four periods, 2005–2008, 2009–2012, 2013–2016, and 2017–2019) from 7 PLADs (Guangdong, Zhejiang,

Fujian, Sichuan, Jiangsu, Shandong, and Beijing) were included. The 7 PLADs were selected because most of them (5/7) had serious CBP hazards (5). The industrial distribution characteristics of BIL also were compared with that of CBP (5). The data have shown that BIL mainly occurs in the manufacturing industry and is dominated by small and medium-sized enterprises, just like CBP. Monitoring the benzene concentration in related industries and taking corresponding measures can effectively reduce the number of BIL.

The BIL cases in this study were obtained from the China Disease Control and Prevention Information System — Occupational Diseases and Occupational Health Monitoring Information System. All BIL cases were diagnosed by local occupational disease diagnostic teams. The *Industrial classification for national economic activities* (GB/T 4754–2017) and *Division Standard of Large/Medium/Small Sized Industrial Enterprises* (6) document were used to standardize benzene related industries. All data were processed via Excel software (version Home and Student 2019, Microsoft, Albuquerque, America).

The number of BIL cases in 7 PLADs was shown in Table 1. From 2005 to 2019, BIL mainly occurred in small and medium-sized enterprises (SMEs) ($\chi^2=56.07$, $P<0.05$). The proportion of BIL cases from SMEs increased from 47% in 2005–2008 to 72.7% in 2009–2012, decreased slightly to 62.4% in 2013–2016, and increased to 70.8% in 2017–2019 (Table 1). When enterprises with BIL cases were categorized according to the type of ownership, the total number of cases in private enterprises was the highest in 2005–2019 (170 cases, 24.3% of the total) and grew rapidly in 2009–2012 (175% year on year) (Table 1) ($\chi^2=80.55$, $P<0.05$). By comparing the enterprise distribution of BIL and CBP cases in 5 PLADs (Guangdong, Jiangsu, Sichuan, Shandong, and Beijing) from 2005 to 2019, we found that BIL and CBP cases were mainly distributed in private and SMEs (Supplementary Figures S1 and S2, available in

TABLE 1. Distribution of enterprise scale and ownership type with BIL in 7 PLADs, 2005–2019.

Item	Number of BIL (%) *			
	2005–2008	2009–2012	2013–2016	2017–2019
Total	115	260	216	108
Enterprise scale				
Large	36 (31.3)	46 (17.7)	57 (26.5)	16 (14.7)
Medium	33 (28.7)	108 (41.5)	64 (29.8)	43 (39.4)
Small	21 (18.3)	81 (31.2)	70 (32.6)	34 (31.2)
Mini-sized	0 (0)	0 (0)	1 (0.5)	5 (4.6)
Unrevealed	25 (21.7)	25 (9.6)	23 (10.7)	11 (10.1)
Ownership type				
State-owned	18 (15.7)	18 (6.9)	19 (8.8)	8 (7.3)
Collective	5 (4.3)	6 (2.3)	2 (0.9)	0 (0)
Pooling	1 (0.9)	4 (1.5)	1 (0.5)	2 (1.8)
Private	20 (17.4)	55 (21.2)	59 (27.3)	36 (33)
Foreign	14 (12.2)	54 (20.8)	34 (15.7)	12 (11)
Hong Kong, Macao, and Taiwan of mainland China	2 (1.7)	43 (16.6)	24 (11.1)	31 (28.4)
Stock	43 (37.4)	51 (19.7)	56 (25.9)	17 (15.6)
Unrevealed	12 (10.4)	28 (10.8)	21 (9.7)	3 (2.8)

Abbreviations: BIL=benzene-induced leukemia; PLADs=provincial-level administrative divisions.

* The proportion of new cases of leukemia in the total cases of leukemia in different enterprise categories.

<http://weekly.chinacdc.cn/>). The number of cases reported from SMEs in the 5 PLADs accounted for 65% of total BIL cases and 71 % of total CBP cases in the past 15 years.

For the industry distribution, BIL cases were mainly distributed in manufacturing industry, accounting for 86.4% of all cases from 2005 to 2019 (Figure 1A). Nine of the top ten industries with BIL cases were from the manufacturing industry (Figure 1C). Compared with the industrial distribution of CBP cases in the same period, the manufacturing industry also had the highest numbers of CBP cases (87.1% of the total). Although CBP and BIL cases were distributed slightly differently among manufacturing sub-industries, they were mainly distributed in the following seven sectors: general and special equipment, chemical, leather/fur/feather, shoe, computer/electronic, transportation equipment, culture/education, arts/crafts/sports, entertainment, and plastics and rubber products manufacturing (Figure 1C–D). We found that some BIL cases were from emerging industries, such as computer/electronic product manufacturing. The number and proportion of BIL cases in computer/electronics manufacturing increased from 3 cases in 2005–2008 (2.9% of the total number of leukemia cases in the same period) to 13 cases in 2017–2019 (11.9% of the total number of

leukemia cases in the same period). A total of 62 cases (8.9% of all BIL cases) were reported in the computer/electronics manufacturing over 15 years (2005–2019).

As shown in Table 2, among the 7 PLADs, the distribution of industries related to BIL cases differed. For example, from 2005 to 2016, the BIL cases were mainly distributed in general/special equipment manufacturing (7 case, 26.9% of the same period) and chemical raw materials and chemical products manufacturing (7 case, 26.9% of the same period) in Jiangsu Province, respectively; from 2017 to 2019, the total number of cases of BIL was only 3 in Jiangsu, involving the computer/electronic product manufacturing, transportation/warehousing and postal industry, and metal products for fire protection manufacturing. From 2005 to 2008, the petroleum exploitation industry, printing and recording media reproduction industry, and transportation equipment manufacturing have the highest number of BIL cases in Guangdong Province, with 2 cases (14.2% of the same period) in each of these 3 industries. From 2009 to 2019, BIL cases were mainly distributed in the computer/electronic product manufacturing (44 cases, 14.8% of the same period) and leather/fur/feather products and shoemaking manufacturing (52 cases, 17.5% of the same period). Third, from 2005 to 2019,

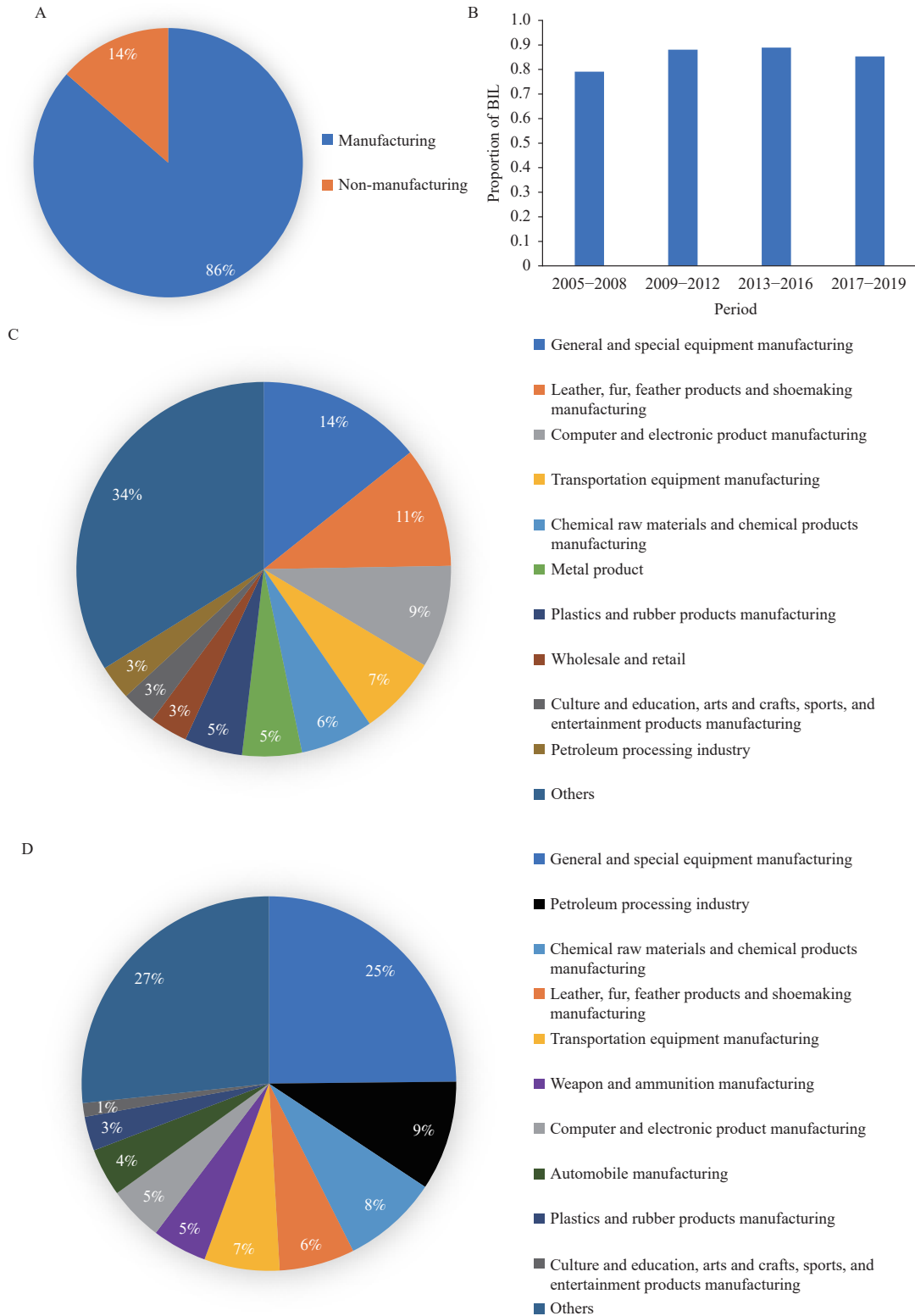


FIGURE 1. The industry distribution of BIL and CBP cases from 2005–2019. (A) Distribution of BIL cases between manufacturing and non-manufacturing industries; (B) The proportion of manufacturing with BIL in 7 PLADs in 4 periods (2005–2008, 2009–2012, 2013–2016, 2017–2019); (C) The top ten industries with BIL cases; (D) The top ten industries with CBP cases.

Abbreviations: BIL=benzene-induced leukemia, CBP=Chronic benzene poisoning, PLADs=provincial-level administrative divisions.

TABLE 2. Distribution characteristics in the top three industries with the most benzene-induced leukemia (BIL) cases in Jiangsu, Guangdong, and Shandong, 2005–2019.

PLAD	Year	The top three industries	Number of BIL (%)*
Jiangsu	2005–2008	General and special equipment manufacturing	3 (37.5)
		Chemical raw materials and chemical products manufacturing	3 (37.5)
		Leather, fur, feather products and shoemaking manufacturing	1 (12.5)
	2009–2012	General and special equipment manufacturing	2 (40)
		Chemical raw materials and chemical products manufacturing	1 (20)
		Petroleum exploitation	1 (20)
	2013–2016	Leather, fur, feather products and shoemaking manufacturing	3 (23.1)
		Chemical raw materials and chemical products manufacturing	3 (23.1)
		General and special equipment manufacturing	2 (15.3)
	2017–2019	Computer and electronic product manufacturing	1 (33.3)
		Transportation, warehousing, and postal Industry	1 (33.3)
		Manufacturing of metal products for fire protection	1 (33.3)
Guangdong	2005–2008	Petroleum exploitation	2 (14.3)
		Printing and recording media reproduction industry	2 (14.3)
		Transportation equipment manufacturing	2 (14.3)
	2009–2012	Computer and electronic product manufacturing	26 (19.5)
		Leather, fur, feather products and shoemaking manufacturing	21 (15.8)
		Plastics and rubber products manufacturing	14 (10.5)
	2013–2016	Leather, fur, feather products and shoemaking manufacturing	20 (20.2)
		Computer and electronic product	10 (10.1)
		Metal product	9 (9.1)
	2017–2019	Leather, fur, feather products and shoemaking	11 (16.9)
		Plastics and rubber products	9 (13.8)
		Computer and electronic product	8 (12.3)
Shandong	2005–2008	General and special equipment manufacturing	20 (22.2)
		Transportation equipment manufacturing	11 (12.2)
		Petroleum processing industry	9 (10.0)
	2009–2012	General and special equipment manufacturing	39 (33.3)
		Transportation equipment manufacturing	22 (18.8)
		Chemical raw materials and chemical products manufacturing	10 (8.5)
	2013–2016	Chemical raw materials and chemical products manufacturing	11 (11.8)
		General and special equipment manufacturing	10 (10.8)
		Petroleum processing industry	6 (6.5)
	2017–2019	General and special equipment manufacturing	4 (11.8)
		Computer and electronic product	4 (11.8)
		Chemical raw materials and chemical products manufacturing	3 (8.8)

Abbreviations: BIL=benzene-induced leukemia; PLAD=provincial-level administrative division.

* The proportion of benzene-induced leukemia cases in all cases of the same period.

general/special equipment manufacturing (73 cases, 21.7% of the same period) and transportation equipment manufacturing (39 cases, 11.7% of the same period) have been the industry with the largest

number of BIL cases in Shandong Province.

DISCUSSION

The incidence of leukemia in China was on the rise from 2005 to 2017, reaching 10.00/100,000 in 2017 (7). Benzene exposure significantly increases the risk of leukemia (3). This study found that BIL mainly occurred in manufacturing industries, especially in private enterprises and SMEs. Consistent with our study, private enterprises and SMES also have the highest number of benzene poisoning cases (4), suggesting the need to strengthen supervision and monitoring of these enterprises. The number of BIL cases in SMEs has been accounting for more than 60% of the total number of leukemia cases in all enterprises. Since 2009, the number of BIL cases in SMEs has increased significantly. This phenomenon may be related to the further development of SMEs in China during the Eleventh Five-Year Plan period. Although SMEs are developing rapidly, their production technology and occupational health conditions are relatively poor compared with large state-owned enterprises. As a result, the number of BIL cases in SMEs has increased.

The two manufacturing sub-industries with the highest number of leukemia cases were the leather/fur/feather products and shoemaking, and general/special equipment manufacturing. These two industries also have the highest number of benzene poisoning cases (4). This may be related to the relatively higher concentration of benzene exposure in these two industries. During 1983–2014, the mean benzene concentrations in the above two industries in China were 5.68 mg/m³ and 4.32 mg/m³, respectively, ranking the top two in all benzene exposure industries (8). In 2020, benzene concentrations in leather/fur/feather products and shoemaking manufacturing were still relatively high, with 2.72% of enterprises exceeding 6 mg/m³ and the highest benzene exposure reaching 67.08 mg/m³ (9).

This study had limitations. First, we could not calculate the incidence because there was no accurate count of benzene exposed workers in 7 PLADs. Therefore, the effect of an increase in the number of workers exposed to benzene on the results could not be eliminated. Second, our BIL cases only come from 7 PLADs; the description of the distribution characteristics of BIL industry in China may not be comprehensive.

This study suggests a reduction in the hazards of occupational benzene exposure and the occurrence of BIL and strengthening of the detection of benzene and its homologues in the workplace of SMEs, private

enterprises, and emerging industries. Additionally, measurements must be taken to reduce the air benzene concentration in the workplace and improve the working environment. Also, enterprises with high benzene poisoning incidence should be supervised in order to provide regular occupational health examinations for workers. Finally, health education should be provided to workers to raise their awareness of self-protection and encourage them to wear protective equipment.

Conflicts of Interest: No conflicts of interest reported.

Funding: The National Natural Science Foundation of China (Project No: 82070116).

doi: 10.46234/ccdcw2022.084

Corresponding author: Caihong Xing, xingch@niohp.chinacdc.cn.

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 Occupational and Radiation Health Institute, Sichuan Center for Disease Control and Prevention, Chengdu, Sichuan, China; ⁵ Department of Nutrition, Food Safety and Toxicology, West China School of Public Health, Sichuan University, Chengdu, Sichuan, China; ⁶ Beijing Center for Disease Prevention and Control, Beijing Research Center for Preventive Medicine, Beijing, China; ⁷ Fujian Center for Prevention and Control of Occupational Diseases and Chemical Poisoning, Fuzhou, Fujian, China; ⁸ Zhejiang Provincial Center for Disease Control and Prevention, Hangzhou, Zhejiang, China; ⁹ Guangdong Provincial Key Laboratory of Occupational Disease Prevention and Treatment, Guangzhou, Guangdong, China.

[‡] Joint first authors.

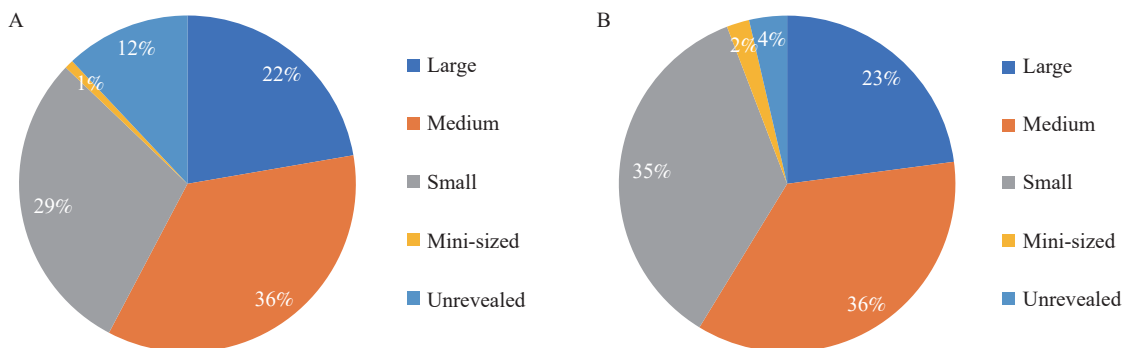
Submitted: March 29, 2022; Accepted: April 26, 2022

REFERENCES

- IARC Working Group on the Evaluation of Carcinogenic Risks to Humans. Exposure data. In: IARC Working Group on the Evaluation of Carcinogenic Risks to Humans, editor. Benzene. Lyon (FR): International Agency for Research on Cancer. 2018. <https://www.ncbi.nlm.nih.gov/books/NBK550161/>. [2022-03-10].
- Khalade A, Jaakkola MS, Pukkala E, Jaakkola JJK. Exposure to benzene at work and the risk of leukemia: a systematic review and meta-analysis. *Environ Health* 2010;9:31. <http://dx.doi.org/10.1186/1476-069X-9-31>.
- Snyder R. Leukemia and benzene. *Int J Environ Res Public Health* 2012;9(8):2875 – 93. <http://dx.doi.org/10.3390/ijerph9082875>.
- Yin SN, Li Q, Liu Y, Tian F, Du C, Jin C. Occupational exposure to benzene in China. *Br J Ind Med* 1987;44(3):192 – 5. <http://dx.doi.org/10.1136/oem.44.3.192>.
- 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>.
- 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].

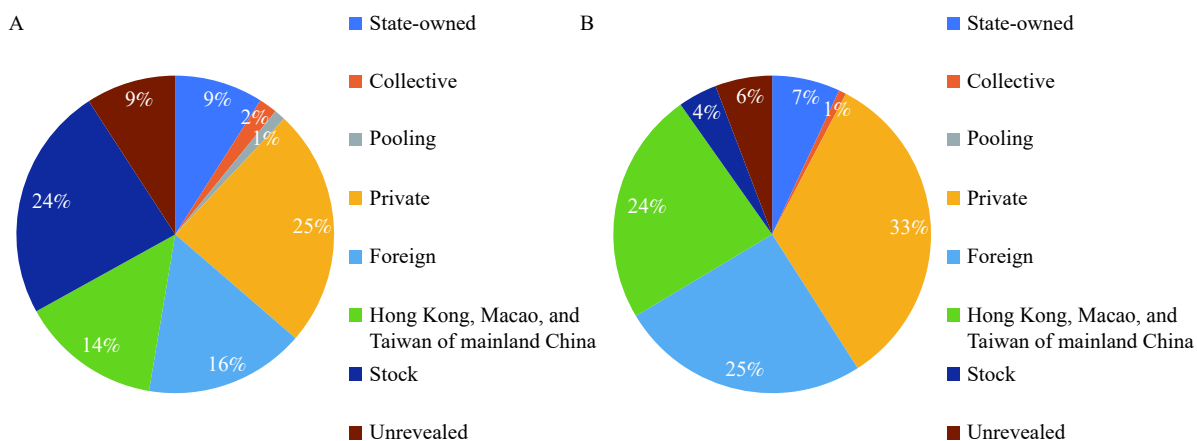
- (In Chinese).
7. Chen WF, Yu CH, Hu Y. Analysis of the disease burden of leukemia in China from 1990 to 2017. *Chin J Prev Control Chronic Dis* 2021;29(10):797 – 800. <http://dx.doi.org/10.16386/j.cjpccl.issn.1004-6194.2021.10.018>. (In Chinese).
 8. Wen CJ, Li RZ, Xu HJ, Liu M, Su SB, Wen XZ. Meta regression analysis on evaluation of occupational benzene exposure. *J Environ Occup Med* 2018;35(8):750 – 5. <http://dx.doi.org/10.13213/j.cnki.jeom.2018.18153>. (In Chinese).
 9. Wang X, Zhou J, Han L, Cheng XR, Shao H, Jia Q, et al. The distribution and concentration monitoring of benzene industries—six PLADs, China, 2020. *China CDC Wkly* 2021;3(43):897 – 900. <http://dx.doi.org/10.46234/ccdcw2021.220>.

Supplemental Material



SUPPLEMENTARY FIGURE S1. Case distribution of BIL and CBP in different enterprise sizes from 2005–2019. (A) BIL cases; (B) CBP cases.

Abbreviations: BIL=benzene-induced leukemia, CBP=Chronic benzene poisoning.



SUPPLEMENTARY FIGURE S2. Case distribution of BIL and CBP in different enterprise ownership from 2005–2019. (A) BIL cases; (B) CBP cases.

Abbreviations: BIL=benzene-induced leukemia, CBP=Chronic benzene poisoning.