Preplanned Studies

Industry Distribution Characteristics of Benzene-Exposed Workers with Cytopenia — Four Provinces, China, 2020

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Summary

What is already known about this topic?

Benzene is harmful to the hematopoietic system and can cause leukemia. However, benzene is still being used in various industries including furniture, rubber, plastic products, and metal product manufacturing.

What is added by this report?

The white blood cell count of workers in general equipment, special equipment, chemical raw materials, and chemical products manufacturing decreased significantly. The enterprises in which benzene concentration exceeded the occupational exposure limit were small enterprises and private enterprises.

What are the implications for public health practice?

Regular health examinations are necessary for benzene-exposed workers. In addition, the monitoring of benzene concentration in small enterprises and private enterprises should be strengthened.

Benzene is a common organic solvent, and it is the basic raw material or intermediate for industrial production, such as in the manufacturing of rubber, lubricants, fuels, detergents, and pesticides. Benzene is widely used in furniture manufacturing, printing and recording media reproduction, housing service, maintenance, and other service industries (*1*). Benzene is hemotoxic and carcinogenic, and long-term exposure to low levels (<6 mg/m^3) of benzene can cause a decrease in peripheral blood counts and increase the risk of developing aplastic anemia (AA), myelodysplastic syndrome (MDS), and acute myeloid leukemia (AML) (*2*). This study aims to analyze the industry distribution of benzene-exposed workers with cytopenia. Four provinces were selected for the study. Sichuan, Jiangsu and Zhejiang are high-incidence areas of chronic benzene poisoning (CBP) and benzene-induced leukemia (BIL) (*3*–*4*), while Fujian was selected because it has high manufacturing productivity (*1*). From 2005 to 2019, CBP and BIL cases in the four provinces were mainly distributed in general equipment, special equipment, chemical raw materials, and chemical products manufacturing (*3*–*4*). The industrial distribution of benzene-exposed workers with significantly lower white blood cell (WBC), neutrophil (NEUT), and platelet (PLT) counts was compared with that of workers with more CBP and BIL in Sichuan, Jiangsu, and Zhejiang Provinces.

The results suggested that workers whose WBC counts decreased significantly were mainly distributed in general equipment, special equipment, chemical raw materials, and chemical products manufacturing. These were also the main industries with CBP and BIL. Small enterprises and private enterprises had benzene exposure concentrations exceeding the occupational exposure limit (PC-TWA=6 mg/m^3), with benzene-exposed workers experiencing a significant reduction in WBC, NEUT, and PLT counts. Therefore, strengthening the health supervision of workers — in general equipment, special equipment, chemical raw material, and chemical product manufacturing — and improving the safety and health management system of small and private enterprises will effectively reduce the risk of hematotoxicity and leukemia caused by benzene.

The local Centers for Disease Control and Prevention (CDC) measured 8-hour time-weighted average concentrations of benzene by gas chromatography with flame ionization detection after obtaining air samples through sentinel sampling. Hematological indicators of workers were assessed through medical examinations. Standardized classification of the benzene industry was performed using the *Industrial Classification for National Economic Activities* (GB/T 4754–2017). Data were statistically analyzed using EXCEL software (version Home and Student 2019, Microsoft Office, USA) and SPSS software (version 25.0, SPSS Inc., Chicago, IL, USA).

A total of 2,530 benzene-exposed workers were

recruited from 17 industries in four provinces, and 526 unexposed age- and sex-matched workers from Jiangsu, Beijing and Tianjin were selected as controls. The mean age of the exposed group was 39.77±9.38 years, comprised of 1,521 males (60.1%) and 1,009 females (39.9%). The mean age of the control group was 40.56±10.00 years, comprised of 326 males (62.0%) and 200 females (38.0%). There was no statistical difference in age or gender between the two groups. As shown in Table 1, WBC, NEUT, erythrocytes (RBC) and hemoglobin (HGB) were significantly lower in the exposed group compared to the control group (P<0.05). The WBC counts of workers among the general equipment and special equipment manufacturing, chemical raw materials and chemical products manufacturing, furniture manufacturing, and wood processing and wood, bamboo, rattan, palm, and grass products manufacturing were also significantly lower than in the control group (P<0.05). The median benzene exposure concentrations in general equipment and special equipment manufacturing (median=2 mg/m^3); computer, communication and other electronic equipment manufacturing (median=2 mg/m^3); and chemical raw materials and chemical products manufacturing (median=1.4 mg/m^3) ranked in the top three of all industries.

Given that decreased WBC, NEUT or PLT counts are the main clinical indicators of benzene-induced hematotoxicity (*5*), differences in these three clinical indicators among benzene-exposed workers were further analyzed. The results suggest that benzene-exposed workers with significantly lower levels of these three indicators were mainly distributed in seven industries: general and special equipment manufacturing; chemical raw materials and chemical products manufacturing; furniture manufacturing; wood processing and wood, bamboo, rattan, palm and grass products manufacturing; railroad, ship, aerospace and other transportation equipment manufacturing; cultural, educational, industrial, aesthetic, sports and recreational goods manufacturing; and retail trade. Further comparison between these seven industries and the industries with high prevalence of CBP and BIL (*3–4*) revealed that general equipment and special equipment manufacturing as well as chemical raw materials and chemical products manufacturing were industries with high prevalence of CBP and BIL. Enterprise size and ownership type of the above seven industries were also further analyzed. As shown in Table 2, most of the enterprises were small enterprises, and medium-sized enterprises had the most employees. The majority of the enterprises were private, and private enterprises had the greatest number of employees. Excessive benzene exposure concentrations were found only in small enterprises and private enterprises.

DISCUSSION

Workers exposed to high concentrations of benzene for a long time can have pancytopenia, and the persistent deterioration of symptoms can lead to benzene poisoning and leukemia (*6*). This study found that WBC counts of benzene-exposed workers were significantly lower in general and special equipment manufacturing and in chemical raw materials and chemical products manufacturing. These industries were also ones with high incidences of CBP and BIL. This may be related to the relatively high exposure to benzene in the two industries. From 1983 to 2014, the median benzene exposure in general and special equipment manufacturing, chemical raw materials and chemicals manufacturing, and leather, fur, feather and feather products and footwear manufacturing ranked in the top three of all benzene exposure industries (*6*). In 2020, the median benzene exposure concentration in general and special equipment manufacturing and chemical raw materials and chemical products manufacturing industries remained in the top three of the 17 industries in this study. It was found that chronic low benzene exposure (<3.25 mg/m^3) resulted in hematopoietic toxicity and significantly increased micronucleus frequency and sister chromatid exchange frequency, resulting in pancytopenia and an increased risk of leukemia (*7–8*). Therefore, the study suggests that workers in general and special equipment manufacturing and chemical raw materials and chemical products manufacturing may be at high risk of developing CBP and BIL, and that monitoring of benzene concentration in these two industries should be strengthened.

In industries that had a majority of workers with significantly reduced WBC, NEUT or PLT counts, excessive benzene exposure concentrations were found only in small enterprises and private enterprises. It is important to note that private enterprises also had the largest number of enterprises. The excessive benzene concentration may be related to their substandard protective equipment, poor occupational health conditions and lack of corporate supervision. In 2020, the concentration monitoring results of benzene-exposed enterprises in six provinces of China showed

TABLE 1. Analysis of blood cell counts of workers exposed to benzene in different benzene industries in Sichuan, Jiangsu, Zhejiang, and Fujian, 2020.

Groups	Median CTWA (range) (mg/m^3)	Number of workers	WBC	NEUT	RBC	HGB	PLT
Control	0	526	6.6 (3.6–9.5)	3.8 (1.9–6.3)	4.9 (4.3–5.8)	149 (130–175)	208 (125–350)
Benzene	0.6 (0.1–84.8)	2,530	6.3 (3.0–9.7)*	3.7 (1.3–7.2)*	4.8 (3.4–6.3)**	146 (89–187)**	226 (52–357)**
General and special equipment manufacturing	2.0 (0.2–4.0)	320	6.3 (3.4–9.7)*	3.6 (1.5–6.9)*	4.9 (3.5–6.1)	148 (92–187)	221 (73–352)*
Computer, communications and other electronic equipment manufacturing	2.0 (0.6–2.0)	98	7.2 (4.0–9.6)**	3.9 (1.9–5.9)	4.8 (3.7–5.8)*	147 (90–181)*	228 (131–335)**
Chemical raw materials and chemical products manufacturing	1.4 (0.1–8.0)	148	5.8 (3.6–9.7)**	3.1 (1.6–5.7)**	4.9 (3.9–6.1)	150 (91–185)	202 (98–348)*
Printing and recording media reproduction	0.7 (0.6–84.8)	189	6.5 (3.4–9.5)	3.6 (1.8–6.8)	5.1 (4.0–6.2)**	152 (90–181)*	221 (102–344)*
Metal product manufacturing	0.6 (0.2–1.5)	34	6.1 (3.9–9.4)	3.8 (1.9–7.0)	4.8 (3.6–5.7)	148 (90–172)	222 (85–340)
Non-ferrous metal smelting and rolling processing industry	0.6 (0.1–0.6)	37	6.1 (4.2–9.1)	4.1 (2.1–4.8)	5.1 (4.0–5.8)*	150 (121–173)	226 (150–337)**
Rubber and plastic products industry	0.6 (0.6–0.6)	118	6.2 (3.0–9.4)	3.7 (1.5–6.3)	5.2 (4.0–5.8)**	160 (123–175)**	231 (120–329)**
Railway, ship, aerospace and other transportation equipment manufacturing	0.6 (0.6–0.6)	50	6.2 (3.5–9.5)	3.5 (2.0–6.1)*	4.8 (3.7–5.8)*	142 (100–173)*	236 (81–342)*
Automobile manufacturing	0.6 (0.1–1.4)	60	6.2 (3.7–9.4)	3.9 (1.9–5.7)	5.0 (4.0–6.2)	152 (115–183)	212 (121–356)
Retailing	0.6 (0.1–2.1)	17	5.9 (3.8–8.7)	2.9 (1.7–4.7)*	5.1 (4.6–5.9)	150 (133–175)	243 (143–346)*
Motor vehicle, electronic products and daily products repair industry	0.6 (0.1–80.7)	24	6.5 (4.4–9.2)	3.5 (2.0–5.5)	5.3 (4.3–6.0)**	159 (135–174)**	251 (145–329)**
Wholesale of petroleum and petroleum products	0.6 (0.6–0.6)	409	6.5 (3.1–9.6)	3.8 (1.7–7.2)	4.7 (3.5–6.3)**	140 (89–182)**	239 (76–357)**
Leather, fur, feather and their products and shoemaking	0.5 (0.1–2.6)	311	6.5 (3.8–9.7)	3.7 (1.8–6.2)	4.4 (3.4–6.0)**	135 (90–173)**	215 (101–356)
Culture and education, arts and crafts, sports, and entertainment products manufacturing	0.1 (0.1–0.9)	141	6.5 (3.2–9.5)	3.8 (1.7–6.3)	4.6 (3.5–5.7)**	136 (91–173)**	199 (52–349)*
Wood processing and wood, bamboo, rattan, palm, and grass products	0.1 (0.1–73.9)	289	6.1 (3.0–9.5)**	3.4 (1.3–6.1)**	4.9 (3.6–5.9)	149 (96–176)	233 (108–346)**
Furniture manufacturing	0.1 (0.1–15.5)	243	6.2 (3.3–9.4)**	3.6 (2.0–5.1)	4.8 (3.6–5.8)**	145 (92–175)**	241 (70–354)**
Electrical machinery and equipment manufacturing	0.1 (0.1–10.8)	42	6.2 (3.6–9.3)	3.2 (1.8–6.0)	4.8 (4.0–5.7)	147 (118–166)	216 (99–341)

Abbreviation: CTWA=concentrations of time weighted average; WBC=white blood cell; NEUT=neutrophil; RBC=erythrocytes; HGB=hemoglobin; PLT=platelet.

* denotes $P \leq 0.05$ as tested by Mann-Whitney U when compared to the control group,

** denotes $P \leq 0.001$ as tested by Mann-Whitney U when compared to the control group.

that private enterprises accounted for the largest proportion of benzene exposure levels exceeding the PC-TWA (*1*). Therefore, the monitoring of benzene exposure concentration in private enterprises should be strengthened. The majority of the CBP and BIL cases were found in small enterprises and private enterprises in China from 2005 to 2019 (*3*–*4*), suggesting that health screening among workers in small enterprises and private enterprises is also essential.

This research had the following limitations: 1) the blood cell count of workers may be affected by recently ingested drugs and food. As a result, the data from a single physical examination may have information bias. It is necessary to obtain information on diet and medication of workers in conjunction with epidemiological questionnaires. 2) This study only analyzed the information of benzene-exposed workers in four provinces, which does not accurately reflect the real health situation of benzene-exposed workers in China. Expanding the scope of investigation will help suggest and implement better prevention strategies and measures.

TABLE 2. Distribution of enterprise scale and ownership type in industries with significantly reduced WBC, NEUT, and PLT counts in Sichuan, Jiangsu, Zhejiang, and Fujian, 2020.

Item	Number of enterprises	Number of workers	Median CTWA (rang) (mg/m³)	Number of enterprises exceeding PC-TWA (%)
Enterprise scale				
Large	8	222	0.1 (0.1–0.6)	0
Medium	23	696	0.8 (0.1–3.6)	0
Small	54	365	0.6 (0.1–73.9)	18 (33)
Mini-sized	5	23	0.1 (0.1–4.5)	0
Ownership type				
State-owned	12	208	2.0 (0.2–2.0)	0
Joint-stock	3	105	0.1 (0.1–3.6)	0
Foreign-owned	5	25	0.6 (0.6–0.6)	0
Hong Kong-, Macao- and Taiwan-invested enterprises	7	116	0.1 (0.1–2.0)	0
Private	61	846	0.1 (0.1–73.9)	18 (30)
Unknown	2	6	0.6 (0.6–0.6)	0

Abbreviation: CTWA=concentrations of time weighted average; PC-TWA=permissible concentration-time weighted average; WBC=white blood cell; NEUT=neutrophil; PLT=platelet.

According to the results of this investigation, targeted prevention for healthy benzene-exposed workers should be the most proactive, effective and economical measure: 1) Early detection and diagnosis of cytopenia for workers in general and special equipment manufacturing and in chemical raw materials and chemical product manufacturing, including regular physical examinations and occupational contraindications (i.e., various hematological diseases, severe systemic dermatoses, etc.), are key to control the development of malignant hematological diseases. 2) Through technical transformation and ventilation measures (i.e., such as replacing benzene with non-toxic or low-toxic substances and applying automated machinery to reduce workers' contact time), the concentration of benzene can be reduced to the lowest possible level. 3) Management measures should be taken to control the risk factors that may cause CBP and BIL in small enterprises and private enterprises. Measures include strengthening the monitoring of benzene concentration in the workplace, promoting the wearing of protective equipment and improving the employee safety and health management system.

Conflicts of interest: No conflicts of interest.

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