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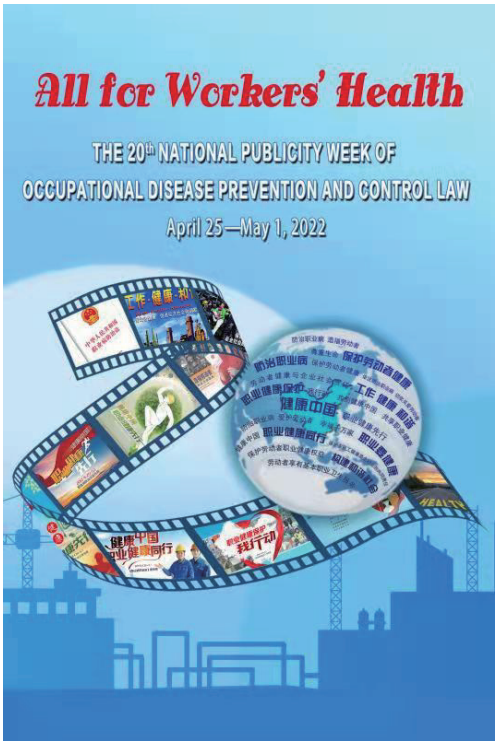

OCCUPATIONAL CANCER ISSUE

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This week's issue was organized by Guest Editor Xin Sun.

Preplanned Studies

Trend Analysis of Occupational Lung Cancer from Coke Oven Emission Exposure — China, 2008–2019

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Summary

What is already known about this topic?

Coke oven emissions are a complex mixture of particulate matter and gases, some with carcinogenicity, released during coke production. Lung cancer caused by coke oven emissions has been listed as a statutory occupational cancer in China and many countries.

What is added by this report?

In this study, coke oven emissions-induced lung cancer was mainly found in the manufacturing industries. Coke oven workers exposed to higher levels of polycyclic aromatic hydrocarbons in different workplaces had a high risk of occupational lung cancer.

What are the implications for public health practice?

It is necessary to take efforts to greatly reduce emissions from coke production and effectively monitor the health of workers.

China is the world's leading producer and exporter of coke, and its annual production are at leading level in the world. Coke oven emissions (COE) are the predominant pollutants generated in coking production, which mainly contain particulate matter and volatile organic compounds, especially polycyclic aromatic hydrocarbons (PAHs). Coke oven workers are liable to be at risk for occupational COE exposure and for developing respiratory disorders and diseases, even lung cancer. In the context, this study deals with the assessment of the carcinogenic risk attributable to PAHs exposure based on data collected from the national reporting system of occupational disease in China and interpreted with field investigations. Consequently, coke oven emissions-induced lung cancer was mainly found in manufacturing industries, especially in petroleum processing, coking and nuclear fuel processing, followed by chemical raw materials and chemical products. Coke oven workers exposed to higher levels of PAHs in different workplaces have a higher risk of occupational lung cancer. These findings reinforce the notion that it is necessary to continuously strengthen the monitoring of the COE, regulate emissions, and maintain health surveillance for occupational protection and health promotion among coke oven workers.

In this study, the data from the Chinese reporting system of occupational disease from 2008 to 2019 were systematically gathered based on the retrieval of character strings such as "coke oven emission" and "occupational cancer or tumor", etc., and the industrial distribution characteristics of lung cancer caused by coke oven emissions were then analyzed.

Based on this context, we selected some coking plants in the East and Southwest of China for further research. The selection of coking plants as key industries is based on these representative industries being closely related to coke oven emissions exposure. A total of 8 different working regions in different coking plants were selected for PAHs concentration detection by high-performance liquid chromatography. Meanwhile, the incremental lifetime cancer risks (ILCR) due to PAHs exposure in different working positions were calculated by using the following formula.

$$ILCR = \frac{CSF \times C \times IR \times EF \times ED}{AT \times BW}$$

CSF represented the cancer slope factor, which was adopted in this study as 1.38 kg·day/mg proposed by Judith Petts in 1997 (*1*), C represented the exposure concentration (mg/m^3), IR represented the respiration rate as 1.5 m^3/h, EF represented days of exposure per year, ED represented the years of exposure, AT represented the average time — which is typically set to 70 years — and BW represented body weight (kg) and was assumed to be 70 kg for adults (*2*). ILCR was acceptable if it was no more than 1×10^{-6}.

The industrial distribution of cases was shown in Figure 1. There were differences in the incidence of COE-induced lung cancer among occupational population in different industries, and the two industries with the highest incidence were petroleum processing and coking and nuclear fuel processing (60.93%), followed by chemical raw materials and

chemical products (14.88%).

Coke oven emissions-caused lung cancer is one of the most prominent occupational cancers in the national occupational disease reporting system. The change pattern of proportion of COE-induced lung cancer in occupational tumors over time were shown in Figure 2. According to the Chinese reporting system of occupational disease, the proportion of total lung cancer of coke oven workers accounted for more than 25% of total reported occupational tumors in four years (2008, 2011, 2017, and 2019), with the highest in 2011 (27.17%). The coke output in China from 2008 to 2019 was illustrated in Figure 3A, and Figure 3B showed the top ten provincial-level administrative divisions (PLADs) with the highest coke output in China from 2008 to 2019. The average annual coke output from 2008 to 2019 was 4.29 million tons. Shanxi, Hebei, Shandong, Shaanxi, and Inner Mongolia were all PLADs contributing to the production of coke in China.

Monitoring data of PAHs and risk analysis of lung cancer induced by coke oven emissions at different positions in coking plants in East and Southwest China were listed in Table 1. The riser platform had the highest carcinogenic risk in two coking plants.

DISCUSSION

Coke production has been steadily developing in China, with a large number of workers being exposed to the emissions in various industries. The lung cancer caused by coke oven emissions has been listed as a national statutory occupational cancer, and a definitive procedure for its diagnosis has been established. This study focused on the occurrence of coke oven emissions-induced occupational lung cancer in China from 2008 to 2019 and selected key industries for further exploration to provide the basis for the prevention of respiratory tumors. From 2008 to 2019

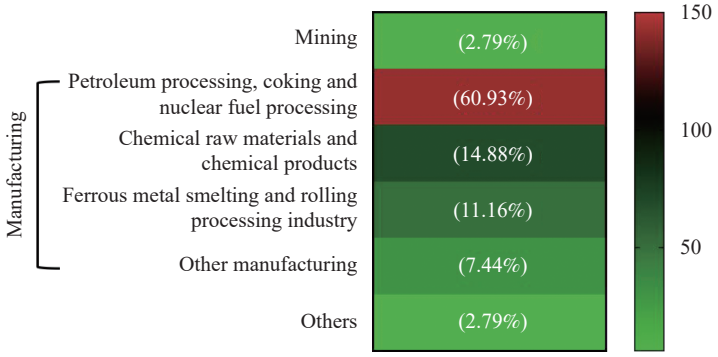

FIGURE 1. Industrial distribution of lung cancer cases caused by coke oven emissions in China from 2008 to 2019.

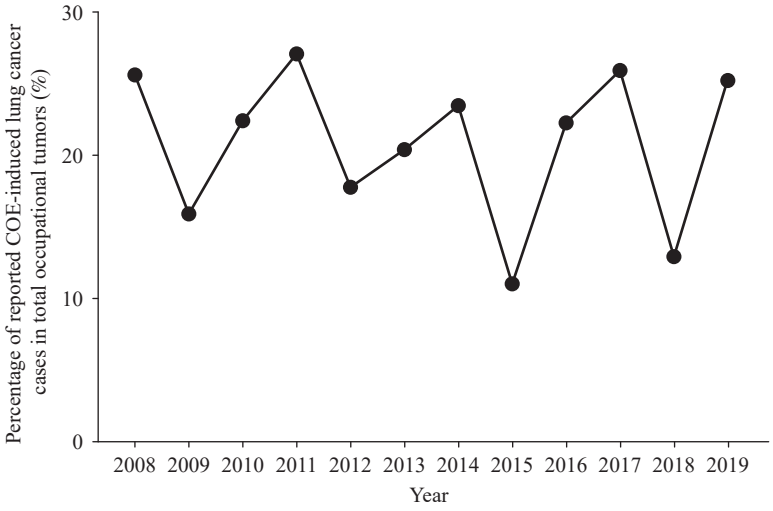

FIGURE 2. The proportion of lung cancer cases caused by coke oven emissions in occupational tumors from 2008 to 2019.
Abbreviation: COE=coke oven emissions.

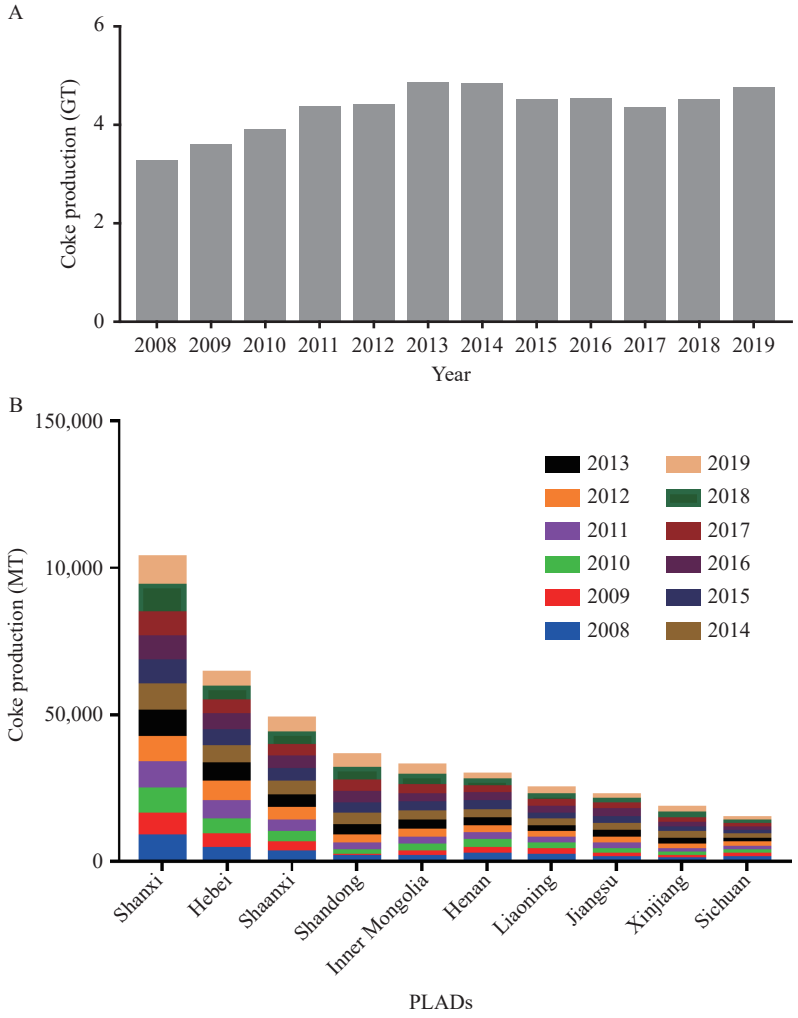

FIGURE 3. Coke production in China from 2008 to 2019 and the top ten PLADs in production from 2008 to 2019. (A) The coke output in China from 2008 to 2019, with with an average annual output of 4.29. (B) The top ten PLADs with the highest coke output in China from 2008 to 2019.
Abbreviations: GT=gigaton; MT=megaton; PLADs=provincial-level administrative divisions.

in China, the reported lung cancer cases from COE exposure accounted for 20.69% of the total of 11 occupational tumors. In terms of the industrial distribution of the disease, petroleum processing and coking and nuclear fuel processing industries accounted for more than 50% of total cases, followed by chemical raw materials and chemical products. Moreover, coke oven workers were a high-risk group for lung cancer caused by coke oven emissions with high PAHs concentrations; therefore, prevention and control of lung cancer caused by COE is still of great importance.

Occupational cancers are rapidly globalizing. Occupational cancers can arise due to extensive exposure to well-known and suspected occupational carcinogens. As early as 1976, coke production was classified as "Group 1 carcinogens" by the International Agency for Research on Cancer (IARC), and numerous epidemiological studies have shown that occupational exposure to PAHs was associated with an increased risk of occupational lung cancer (*3*). A 30 year follow-up study of 15,818 workers with a working history confirmed that coke oven emissions were associated with significant excess mortality of lung cancer with 4.45 times higher risk of respiratory cancer in coke oven workers than in non-oven workers (*4*).

There were many industries in contact with COE exposure, such as mining, manufacturing, etc. A cumulative meta-analysis of workers exposed to PAHs in various industries and occupations have found that workers in iron and steel foundries included a total of 2,903 lung cancer cases/deaths, with a pooled relative risk (RR) of 1.31 [95% Confidence Interval (CI): 1.07–1.61], and the lung cancer among aluminum

TABLE 1. PAHs monitoring and carcinogenic risk evaluation at working positions in coking plants.

Workplaces	A plant in East of China		A plant in Southwest of China	
	PAHs concentration (ng/m^3)	Carcinogenic risk*	PAHs concentration (ng/m^3)	Carcinogenic risk*
Furnace cover	8,218.77	5.71×10^{-4}	4,227.82	2.94×10^{-4}
Riser platform	12,560.43	0.87×10^{-3}	48,100.25	3.34×10^{-3}
Coal filling car driver	3,678.99	0.26×10^{-3}	24,145.17	1.68×10^{-3}
Coke blocking car driver	1,852.47	1.29×10^{-4}	1,620.04	1.13×10^{-4}
Coke side door of coke oven	1,758.37	1.22×10^{-4}	889.45	6.18×10^{-5}
Pusher side door of coke oven	4,135.63	2.87×10^{-4}	403.93	2.81×10^{-5}
Coke pushing car driver	1,757.64	1.22×10^{-4}	2,144.22	1.49×10^{-4}
Switch control	291.40	2.02×10^{-5}	681.45	4.73×10^{-5}

* The ILCR due to PAHs exposures in different working positions were calculated by using the following formula:

$$ILCR = \frac{CSF \times C \times IR \times EF \times ED}{AT \times BW}$$

where CSF represented the cancer slope factor which was adopted in this study as 1.38 kg·day/mg proposed by Judith Petts in 1997 (*1*), C represented the exposure concentration (mg/m^3), IR represented the respiration rate as 1.5 m^3/h, EF represented days of exposure per year, ED represented the years of exposure, AT represented the averaging time which is typically set to 70 years, BW represented body weight (kg) and is typically assumed to be 70 kg for adults (*2*).

Abbreviations: ILCR=lifetime cancer risks; PAHs=polycyclic aromatic hydrocarbons.

production workers included 1,314 cases with a pooled RR of 1.07 (95% CI: 0.93–1.23) (*5*). In this study, we found that lung cancer induced by coke oven emissions mainly occurred in manufacturing industries. PAHs were the main toxic compounds targeted for risk assessment of coke oven emissions. The characteristics of occupational activities determined the concentration and extent of PAHs exposure. To note, coke oven workers suffering from lung cancer mainly worked at the top of coke oven workshop (*6*), where concentrations of PAHs would have been highest. In addition, the difference of lung cancer cases among coke oven workers in different industries may be closely related to protective measures during occupational exposure. A study reported that mean PAH exposure levels were reduced by 60% when the coke oven workers used effective masks during work (*7*). Current evidence demonstrated that the concentration of PAHs in each working region still varied widely. More importantly, working positions with a high carcinogenic risk were more consistent in regions with a high concentration of PAHs. Therefore, it is more important to adopt suitable protection measures for different working positions.

All industries can benefit from comprehensive coke oven emissions exposure prevention. Therefore, it is necessary to carry out in-depth monitoring of hazard factors in work environments, especially among high-risk industries. As the incubation period of lung cancer in coke oven workers can last for decades (*8*), continuous health surveillance is crucial for health promotion among coke oven workers, even after retirement. In addition, identification of early biomarkers for PAHs exposure may facilitate effective preventive measures to COE related health impairments (*9*). It has been reported that the serum club cell protein levels may serve as a sensitive marker of pulmonary damage in Chinese populations with COE exposure (*10*).

This study had strengths as we combined the data obtained from the Chinese reporting system of occupational disease and with field investigations to analyze the lung cancer burden in coke oven workers associated with COE exposure. Second, our risk assessment of PAH exposure incorporated information about the types of work, and the long-time span of this study provided valid information on the pattern of change over time.

This study was subject to some limitations. There was a lack of criteria for occupational PAHs risk assessment in China. In this study, the carcinogenic effects of PAHs inhalation in workers at different work positions in a coking plant were evaluated by using an EPA assessment model. In addition, we could not evaluate the age of onset and occupational history of lung cancer in coke oven workers in reported cases, and the industry classification of coke oven worker was relatively difficult, including only 2 large-scale industries (mining and manufacturing) with the rest being classified as other industries.

In summary, PAHs composition is a definitive hazard for cancer in coke oven workers as evidenced by the health risk assessment analysis, accounting for a leading cause for COE-induced occupational tumor in

China. There was more urgent demand to place great emphasis on the supervision and monitoring of PAHs exposure during coke production. Meanwhile, it is necessary to strengthen the effective measures on wearing of personal protective equipment, and biomarkers of early health surveillance in the process of manufacture and cancer prevention.

Conflicts of interest: No conflicts of interest reported.

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Preplanned Studies

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

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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) (χ^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) (χ^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,

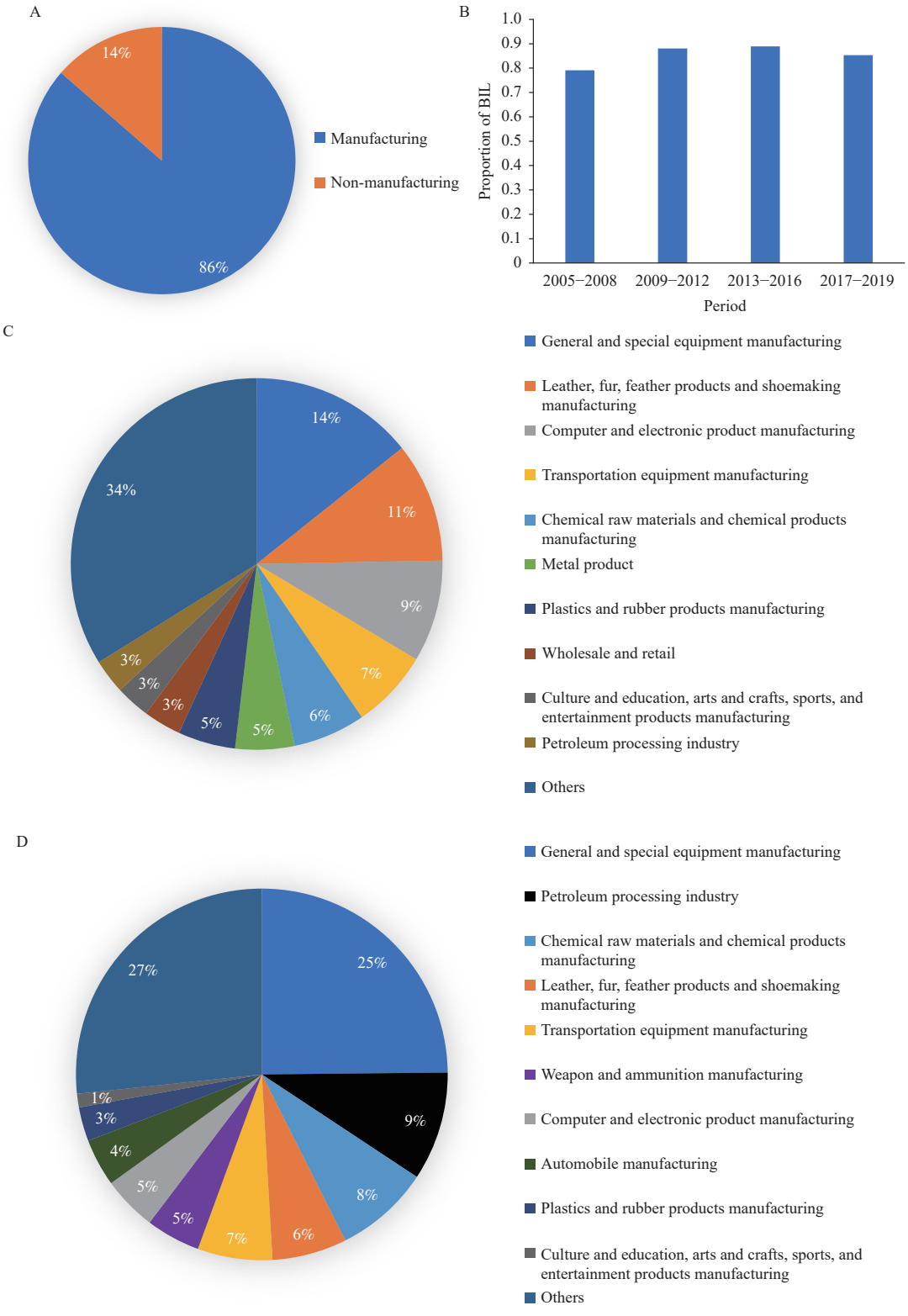

FIGURE 1. The industry distribution of BIL and CBP cases from 2005–2019. (A) Distribution of BIL cases between manufacturing and non-manufacturing industries; (B) The proportion of manufacturing with BIL in 7 PLADs in 4 periods (2005−2008, 2009−2012, 2013−2016, 2017−2019); (C) The top ten industries 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/m^3 and 4.32 mg/m^3, 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/m^3 and the highest benzene exposure reaching 67.08 mg/m^3 (*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.

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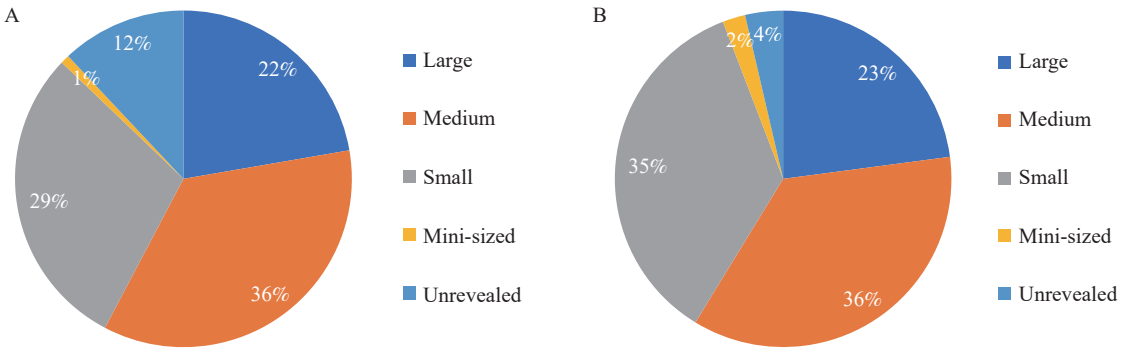
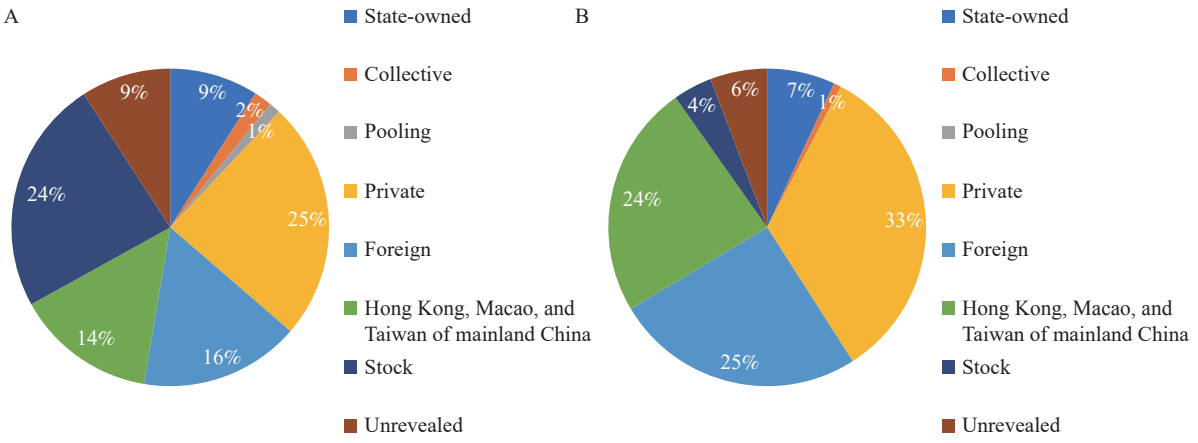
Supplemental Material



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.

Preplanned Studies

Risk of Lung Cancer and Occupational Exposure to Polycyclic Aromatic Hydrocarbons Among Workers Cohorts — Worldwide, 1969–2022

Huige Yuan[1]; Yanhua Wang[1]; Huawei Duan[1,#]

Summary

What is already known about this topic?

Lung cancer has a high mortality, resulting in a severe disease burden. Polycyclic aromatic hydrocarbons (PAHs) are definitive carcinogen to human, and occupational exposure to PAHs is associated with lung cancer.

What is added by this report?

We analyzed the cancer cases from cohort studies on various PAHs exposed workers in China and other countries, calculated the quantitative risk of lung cancer based on meta-analyses, and confirmed the increased risk from lung cancer in selected PAHs exposed occupations.

What are the implications for public health practices?

There is a clear need to prevent lung cancer on a wide range of PAHs-related occupations in China and around the world. It is crucial to establish guidelines for improving the monitoring on exposure and health promotion in related working environments.

Polycyclic aromatic hydrocarbons (PAHs), the chemical mixture characterized by two or more benzene rings, which mainly derive from the insufficient combustion of organic materials, can cause some respiratory diseases and lung cancer. Globally, lung cancer cases and deaths are increasing. In 2018, International Agency for Research on Cancer (IARC) estimated 2.09 million new cases and 1.76 million deaths, due partly to occupational exposure to PAHs (*1*). IARC has identified 12 occupational exposures to lung carcinogens, including aluminum production, coke, and coal gasification fumes (*2*). Coal tar and bitumen are also occupational carcinogens identified by IARC, containing a variety of carcinogenic PAHs in volatile compounds. Exposure industries include coal tar products, coke, gas, aluminum, steel plants, paving and construction, etc. Lung cancer caused by coke oven emissions has been listed as a national statutory occupational cancer in China and most countries (*3*). In China, the manufacturing industry is developing with many workers. Lung cancer caused by occupational exposure to PAHs is a serious public health problem that needs attention. The relationship between PAHs and lung cancer is inconsistent in different industries. To explore the status of lung cancer caused by PAHs, a meta-analysis of related cohorts was conducted in this study.

We conducted a systematic literature analysis in the databases of PubMed, Embase, Web of Science, China National Knowledge Infrastructure (CNKI), Wan Fang, China Science and Technology Journal Database from January 1, 1969 to March 1, 2022. Combining subject words and free words, taking PubMed as an example, the retrieval formula was "[(polycyclic aromatic hydrocarbons) OR PAHs] AND [(lung cancer) OR (lung neoplasm)] AND [(cohort OR prospective OR longitudinal OR retrospective)]". We hand-searched references that have been included in the articles to identify relevant studies. The retrieved studies were selected through inclusion and exclusion criteria by two researchers independently. The eligible articles were read in full and extracted key information. Concrete inclusion criteria included: (a) studies published before March 2022; (b) study type was prospective or retrospective cohort study; (c) subjects were occupational populations exposed to PAHs; and (d) number of cases, standardized incidence ratio (SIR)/standardized mortality ratio (SMR) and 95% confidence interval (CI) of lung cancer were reported in the paper. Some studies were excluded: 1) non-occupational exposure to PAHs; 2) study types other than cohort studies; 3) the required information could not be retrieved completely from the study; and 4) for repeated population studies, only the most complete articles were included. We assessed the quality of the included cohort studies by the Newcastle-Ottawa Scale (NOS). The quality assessments were completed by

two researchers independently, and the disagreement was discussed. Stata (17.0, StataCorp, LP, TX, USA) was used for statistical analysis of the research data, and the evaluation indicators were mainly standardized morbidity or mortality and 95% CI.

PAHs are one of the main risks of lung cancer, and some PAHs-related industries increased the risk of lung cancer among workers. The literature results were in Supplementary Figure S1 (available in https://weekly.chinacdc.cn/), a total of 2,843 studies were initially retrieved from 6 databases. 2,678 articles were excluded after reading the titles and abstracts, and 121 articles were excluded after reading the full text. After screening, 44 articles were identified as eligible literature for meta-analysis. The included articles and retrieved information of articles were shown in Table 1. The random-effects model and fixed-effects model were used separately to combine the results. In Table 2, we presented the results of a pooled analysis of the risk of lung cancer exposure to PAHs across industries and the results of various subgroup analyses. In the random-effects model analysis, the overall pooled relative risks (RR) (95% CI) was 1.32 (1.22–1.43) for 44 studies. Among them, a total of 2,024 lung cancer cases were observed in 11 studies on aluminum production, the pooled RR (95% CI) was 1.15 (1.05–1.26). A total of 571 lung cancer cases were observed totally in 9 studies on coke plants, the pooled RR (95% CI) was 1.82 (1.42–2.32); 1,053 lung cancer cases were collected in 8 cohort studies on iron and steel industries, the pooled RR (95% CI) was 1.39 (1.26–1.53). A total of 650 lung cancer cases were found in 7 cohort studies on asphalt tar production, the pooled RR (95% CI) was 1.28 (1.04–1.59), and 126 lung cancer cases in 6 cohort studies on carbon electrode, the pooled RR (95% CI) was 1.01 (0.77–1.33). Figure 1 showed the meta-analysis of 7 cohort studies on PAHs-related industries in China. For a total of 385 cases, the pooled RR (95% CI) was 1.75 (1.33–2.30). In addition, the three carbon black articles retrieved were not merged due to the small number of articles and the large heterogeneity. Coke production had the highest carcinogenic risk of lung cancer in different industries.

Publication bias analyses were conducted in various industry studies. There was no significant publication bias in any analyses, results were presented in Supplementary Table S1 (available in https://weekly.chinacdc.cn/) (Begg's test all $P>0.05$). Among them, the Egger's test was $P<0.05$ of the aluminum factory research, but its Begg's test was $P>0.05$. We further conducted a sensitivity analysis, and the result was relatively stable. Sensitivity analyses were performed by serially excluding each study to determine the influence of individual studies on the overall risk of lung cancer. The results of sensitivity analysis were shown in Supplementary Figure S2 (available in https://weekly.chinacdc.cn/). We did not find that a study significantly affected the pooled effect size.

DISCUSSION

In this study, an excess risk of lung cancer mortality was found for aluminum production workers, and the difference was statistically significant. This was different from the existing research results. The risk of lung cancer has increased in coke, iron and steel, coal tar, asphalt PAHs-related industries, but no excess risk was found in the carbon electrode industry, which is consistent with the existing meta-analysis results (*48*). Results across industries in China were consistent with global findings that exposure to PAHs increases lung cancer risk. Comparing with the cancer risk from PAHs, the risk of the two cohorts in China was higher than that of pooled RR on coke production, and one study in China had the highest carcinogenic risk in all cohorts on asphalt tar industry. This may be related to higher exposure in these two industries in China.

There are more than 770 million workers in China, and more than 200 million workers are exposed to occupational hazards. There were 323,833 (95% uncertain interval 283,780–369,061) deaths and 14.1 million disability-adjusted life years (DALYs) attributable to total occupational risks in 2017, China, which accounted for 27.9% of global attributable deaths (*49*). A study estimated that 5.8% [interquartile range (IR), approximately 2%–11%] of China's land area, where 30% (IR, approximately 17%–43%) of the population lives, exceeded the national ambient B[a]P(eq) standard of 10 ng/m^3. The overall population attributable fraction of lung cancer caused by inhalation exposure to PAHs was 1.6% (IR, approximately 0.91%–2.6%), corresponding to an excess annual lung cancer incidence rate of 0.65×10^{-5}. Biomass and coke production generate about 83% of the total PAHs emission in China (*50*). A study on coal tar pitch factory in China showed that workers were exposed to PAHs with a maximum exposure concentration of 1,931.45 ng/m^3. The lifetime risk of workers was significantly higher than the acceptable range, with workers losing up to 1,033.95 hours of life

TABLE 1. Summary of worker cohort studies of occupational exposure to PAHs and lung cancer in China and other countries.

Authors and year	Country	Industry exposure	Follow-up	Outcome	Cases	Population	RR* 95% CI
Mur 1987 (*4*)	France	Aluminum	1950–1976	Mortality	37	6,544	1.14 (0.85–1.48)
Chu 1996 (*5*)	China	Aluminum	1984–1993	Mortality	8	989	1.22 (0.50–2.28)
Ronneberg 1999 (*6*)	Norway	Aluminum	1953–1993	Incidence	42	2,888	0.96 (0.69–1.29)
Romundstad 2000c (*7*)	Norway	Aluminum	1953–1996	Incidence	189	11,103	1.00 (0.90–1.20)
Moulin 2000 (*8*)	France	Aluminum	1968–1994	Mortality	19	2,133	0.63 (0.38–0.98)
Spinelli 2006 (*9*)	Canada	Aluminum	1957–1999	Mortality	120	6,423	1.07 (0.89–1.28)
				Incidence	147	6,423	1.10 (0.93–1.30)
Gibbs 2007 (*10*)	Canada	Aluminum	1950–1999	Mortality	538	5,977	1.36 (1.25–1.48)
Gibbs and Sevigny 2007b (*11*)	Canada	Aluminum	1950–1999	Mortality	140	10,454	1.16 (0.97–1.36)
Bjor 2008 (*12*)	Sweden	Aluminum	1958–2005	Incidence	40	2,264	1.48 (1.06–2.02)
Armstrong and Gibbs 2009 (*13*)	Canada	Aluminum	1950–1999	Mortality	677	16,431	1.32 (1.22–1.42)
Sim 2009 (*14*)	Australia	Aluminum	1983–2002	Mortality	28	4,396	1.08 (0.75–1.57)
				Incidence	39	4,396	1.23 (0.90–1.72)
Gustavsson 1990 (*15*)	Sweden	Coke gasification	1966–1986	Incidence Mortality	4	295	0.82 (0.22–2.11)
Berger and Manz 1992 (*16*)	Germany	Coke gasification	1953–1989	Mortality	78	4,908	2.88 (2.28–3.59)
Reid and Buck 1956 (*17*)	UK	Coke	1950–1954	Mortality	14	8,000	1.40 (0.80–2.30)
Wu 1988 (*18*)	China	Coke	1971–1982	Mortality	93	21,995	2.55 (2.13–3.03)
Swaen 1991 (*19*)	Netherlands	Coke	1954–1984	Mortality	62	5,639	1.29 (0.99–1.66)
Costantino 1995 (*20*)	USA and Canada	Coke	1951–1982	Mortality	255	5,321	1.95 (1.59–2.33)
Bye 1998 (*21*)	Norway	Coke	1962–1993	Incidence	7	888	0.82 (0.33–1.70)
Yu 2004 (*22*)	China	Coke	1988–2001	Mortality	16	5,571	2.77 (1.70–4.52)
Miller 2013 (*23*)	UK	Coke	1972–1988	Mortality	42	3,698	1.51 (1.06–2.15)
Hansen 1991 (*24*)	Denmark	Iron and steel	1970–1980	Mortality	9	632	1.37 (0.63–2.60)
Sherson 1991 (*25*)	Denmark	Iron and steel	1967–1985	Incidence	166	6,144	1.30 (1.12–1.51)
Fan 1992 (*26*)	China	Iron and steel	1972–1974	Mortality	76	18,242	1.04 (0.82–1.31)
Sorahan 1994 (*27*)	UK	Iron and steel	1946–1990	Mortality	551	10,438	1.46 (1.34–1.58)
Hao 1995 (*28*)	China	Iron and steel	1971–1992	Mortality	11	622	2.04 (1.15–3.61)
Moulin 2000 (*29*)	France	Iron and steel	1946–1990	Mortality	54	4,897	1.19 (0.89–1.55)
Hoshuyama 2006 (*30*)	China	Iron and steel	1980–1993	Mortality	133	21,175	1.54 (1.39–1.69)
Westberg 2013 (*31*)	Sweden	Iron and steel	1958–2004	Incidence	53	3,045	1.58 (1.18–2.06)
Miller 1986 (*32*)	UK	Asphalt Tar	1950–1982	Mortality	84	6,064	0.86 (0.70–1.07)
Gong 1996 (*33*)	China	Asphalt Tar	1977–1993	Mortality	48	1,793	1.77 (1.30–2.35)
Swaen 1997 (*34*)	Netherlands	Asphalt Tar	1947–1988	Mortality	48	907	1.18 (0.87–1.57)
Boffetta 2003 (*35*)	European countries	Asphalt Tar	1953–2000	Mortality	330	29,820	1.17 (1.04–1.30)
Wong and Harris 2005 (*36*)	USA	Asphalt Tar	1979–2001	Mortality	34	2,179	1.34 (0.93–1.87)
Behrens 2009 (*37*)	Germany	Asphalt Tar	1965–2004	Mortality	101	7,919	1.77 (1.46–2.16)
Zanardi 2013 (*38*)	Italy	Asphalt Tar	1964–2001	Mortality	5	415	1.00 (0.40–2.40)
Sorahan 2001 (*39*)	UK	Carbon black	1951–1996	Mortality	61	1,147	1.73 (1.32–2.22)
Dell 2006 (*40*)	USA	Carbon black	1930–2003	Mortality	138	5,011	0.97 (0.82–1.15)
Wellmann 2006 (*41*)	Germany	Carbon black	1976–1998	Mortality	50	1,535	2.18 (1.61–2.87)
Teta 1987 (*42*)	USA	Carbon electrode	1974–1983	Mortality	29	2,219	0.85 (0.57–1.21)
Moulin 1989 (*43*)	France	Carbon electrode	1975–1985	Incidence	7	1,302	0.79 (0.32–1.63)
Moulin 1989 (*43*)	France	Carbon electrode	1957–1984	Mortality	13	1,115	1.18 (0.63–2.01)
Gustavsson 1995 (*44*)	Sweden	Carbon electrode	1969–1989	Mortality	2	901	1.68 (0.20–6.07)
Donato 2000 (*45*)	Italy	Carbon electrode	1955–1996	Mortality	34	1,006	0.77 (0.53–1.08)
Mori 2002 (*46*)	Japan	Carbon electrode	1951–1988	Mortality	9	332	2.62 (1.20–4.98)
Merlo 2004 (*47*)	Italy	Carbon electrode	1950–1997	Mortality	32	1,291	0.97 (0.67–1.37)

Abbreviations: RR=Relative risks, CI=confidence interval.

* Relative risks of lung cancer (including other respiratory cancers not specified).

TABLE 2. Summary of pooled RR (95% CI) of lung cancer and exposure to PAHs in different industries.

Industry	No. of cohorts	Number	Pooled RR (95% CI)*	I^2	*P* for heterogeneity
Aluminum	11	69,602	1.15 (1.05–1.26)	63.9%	0.001
			1.23 (1.18–1.29)		
Coke production	9	56,315	1.82 (1.42–2.32)	80.4%	<0.0001
			2.06 (1.88–2.27)		
Iron and steel	8	65,195	1.39 (1.26–1.53)	52.7%	0.039
			1.43 (1.36–1.51)		
Asphalt tar	7	49,097	1.28 (1.04–1.59)	80.8%	<0.0001
			1.24 (1.15–1.34)		
Carbon electrode	7	8,166	1.01 (0.77–1.33)	43.6%	0.100
			0.96 (0.80–1.15)		
Overall industries	44	256,068	1.32 (1.22–1.43)	83.3%	<0.0001
			1.34 (1.31–1.38)		

Notes: I^2 Statistics for the Heterogeneity Test; Number: Total number of people included in the combined cohorts.
Abbreviations: RR=relative risks, PAHs=polycyclic aromatic hydrocarbons; CI=confidence interval.
* The corresponding results are that the former is a random-effects model, and the latter is a fixed-effects model.

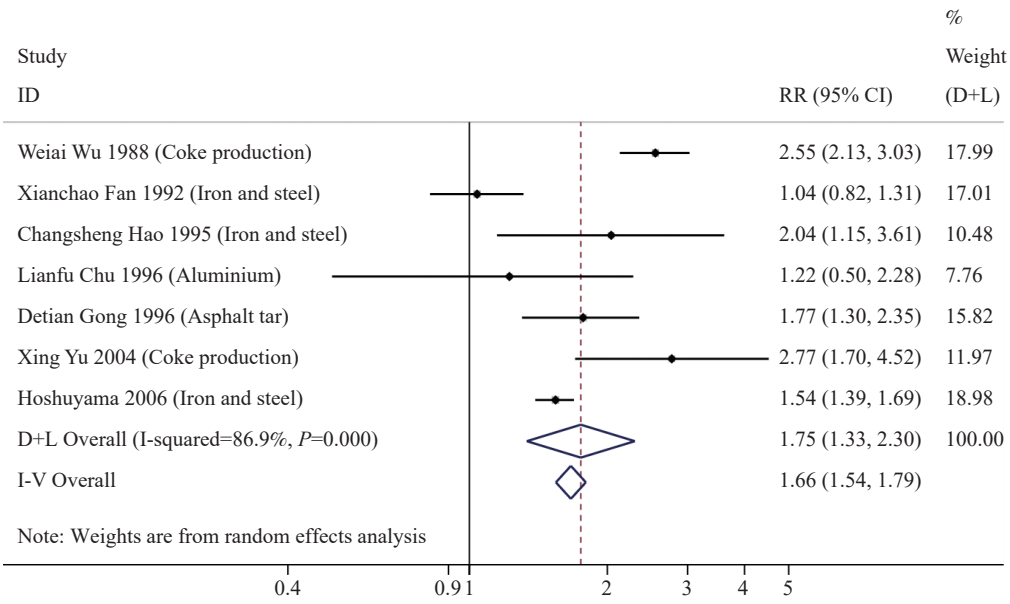


FIGURE 1. RR (95% CI) for lung cancer in workers in PAHs-related industries in China.
Abbreviations: RR=relative risks, PAHs=polycyclic aromatic hydrocarbons.

expectancy (*51*). A biomonitoring study of carbon and coal tar processing workers in China showed that the urine PAHs surrogates of 1-hydroxynaphthalene, 2-hydroxynaphthalene, and 1-hydroxypyrene in contact group tar and asphalt were 12.20, 12.55, 7.08 and 10.62, 8.73, 3.07 μg/g creatinine, respectively, which was higher than the general range (*52*).

In the Healthy China Action (2019–2030), the occupational health protection action was proposed, and workers have the right to occupational health protection in accordance with the law. This study showed that workers in multiple occupations are exposed to PAHs, increasing the risk of lung cancer. Therefore, it is crucial for factories and workers to take protective measures. Specific measures include reducing the toxicity of raw materials, applying new technologies, monitoring environmental PAHs concentration, wearing protective clothing, and ventilating and detoxifying to minimize exposure to PAHs (*53*). Moreover, global economic integration is the main trend of today's world economic development, along with avoiding hazard transfer, to

serve a healthy China.

China is a large developing country with a booming manufacturing industry. PAHs are widely distributed, and occupational groups have a high probability of exposure to PAHs (*54*). The incidence of lung cancer may be related to the pollution of PAHs caused by rapid and immature industrialization. The Occupational Disease Prevention and Control Plan (2021–2025) in the 14th Five-Year Report pointed out that we should deepen prevention at the source, improve working conditions in the workplace, strictly supervise law enforcement, improve the efficiency of occupational health supervision, strengthen publicity and training, and enhance the awareness of occupational health in the whole society, etc. The Chinese government can further revise occupational health laws, monitor occupational lung cancer, and develop intelligent production. Therefore, it is necessary to control the emission of PAHs, strengthen protection, and reduce the exposure of PAHs during the rapid development.

This study was subject to some limitations. First, there were few cohort studies among Chinese workers, which needs to be conducted in related occupations from now on. Second, there was heterogeneity in the literature without considering confounding factors.

In conclusion, there is an increased risk of death from lung cancer in PAHs-related industries in China and other countries. There is a prominent need to prevent lung cancer in a wide range of occupations. It is necessary to establish guidelines to cut down the generation and emission of PAHs during the production process, to improve health promotion in the occupational population and industries.

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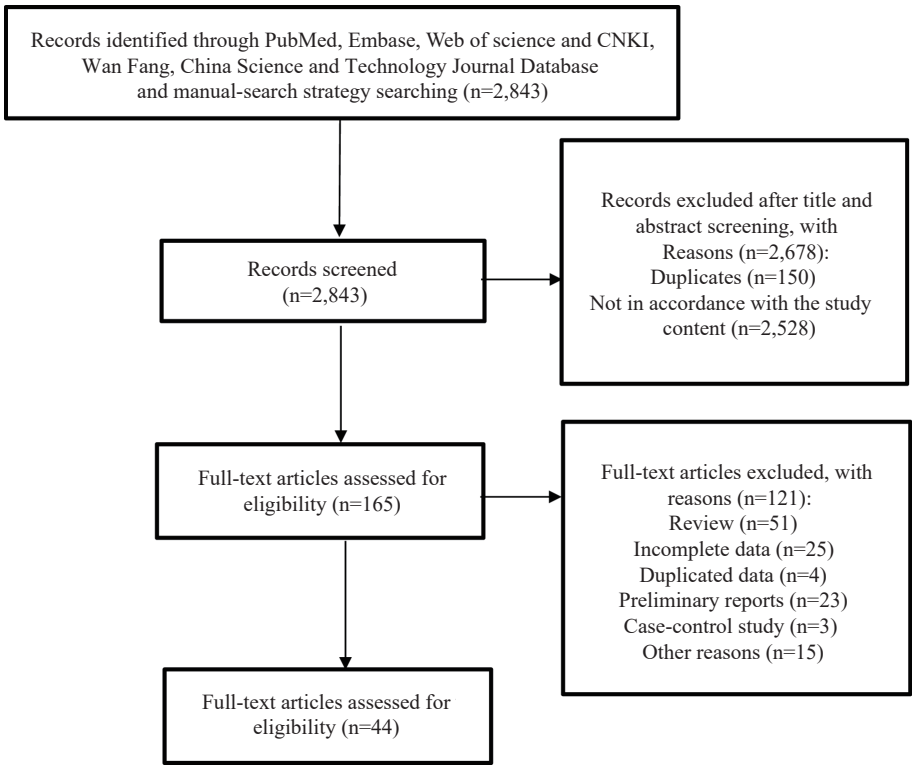
Supplementary Material

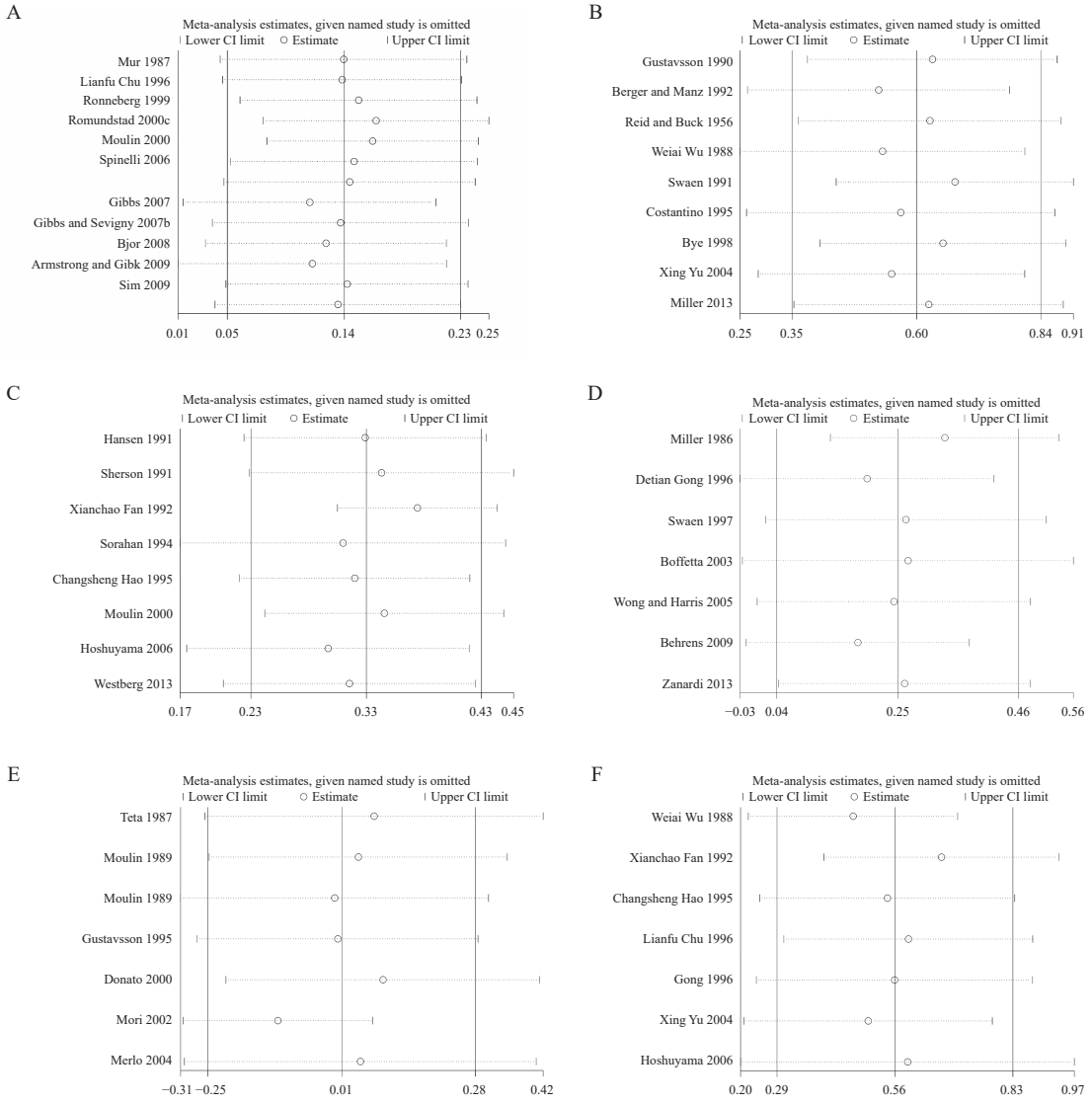


SUPPLEMENTARY FIGURE S1. Flowchart of the literature search.

SUPPLEMENTARY TABLE S1. Publication bias analysis of cohorts in different industries.

Industry	No. of cohorts	Obs/Exp	SMR/SIR	Egger's test	Begg's test
				P	*P*
Aluminum	11	2,024/1,657.67	1.22	0.036	0.760
Coke production	9	571/299.31	1.91	0.149	0.251
Iron and steel	8	1,053/755.69	1.39	0.530	0.902
Asphalt Tar	7	650/522.22	1.24	0.754	1.000
Carbon electrode	7	126/135.85	0.93	0.206	0.230
Chinese industries	7	385/227	1.70	0.738	1.000

Note: Both Begg's test and Egger's test are for publication bias in the same industry cohorts.
Abbreviations: Obs/Exp=observed number of cancer cases or deaths/expected number of cancer cases or deaths; SMR/SIR=standardized mortality ratio/standardized incidence ratio.



SUPPLEMENTARY FIGURE S2. Sensitivity analysis of lung cancer among different polycyclic aromatic hydrocarbons exposed occupations.
(A) aluminum factory workers. (B) coke production factory workers. (C) iron and steel factory workers. (D) asphalt tar workers. (E) carbon electrode factory workers. (F) various industries workers in China.

Vital Surveillances

Epidemiological Characteristics of Occupational Cancers Reported — China, 2006–2020

Xinxin Li[1]; Dan Wang[1]; Anqi Liu[1]; Weijiang Hu[1]; Xin Sun[1,2,#]

ABSTRACT

Introduction: Occupational cancers are a major threat to workers' health in China. The latest version of the Classification and Catalogue of the Occupational Diseases includes 11 occupational cancers. This study analyzed the epidemiological characteristics of occupational cancers in China reported to the National Occupational Disease Reporting System during 2006–2020.

Methods: Occupational cancers reported during 2016–2020 were obtained from the National Occupational Disease Reporting System. Epidemiological characteristics were analyzed by year, region, industry, gender, age at diagnosis, and exposure duration to occupational hazards.

Results: Overall, a total of 1,116 cases of occupational cancers were reported between 2006 and 2020. The main types reported were leukemia caused by benzene exposure (511, 45.79%), lung cancer caused by coke oven exhaust exposure (266, 23.84%), and lung cancer and mesothelioma caused by asbestos exposure (226, 20.25%). There were 6 provincial-level administrative divisions (PLADs) that had reported over 50 new cases in the last 15 years. Most cases (913, 81.18%) were distributed in the manufacturing industry. There were 870 (77.96%) male cases and 246 (22.04%) female cases. The average age at diagnosis of all reported cases was 51.91±15.85 years, and the median exposure duration to occupational hazards was 12 (5.29–23.25) years.

Conclusions: There is a large discrepancy between the high morbidity of occupational cancers and a low number of cases diagnosed and reported cases. Occupational cancers in China may be underestimated, and comprehensive measures should be taken to improve the diagnosis and reporting of occupational cancers.

Occupational cancers are specific cancers suffered by workers after long-term exposure to carcinogenic factors in the working environment after a long latent period (*1*). The International Agency for Research on Cancer (IARC) has identified 40 carcinogens with relevant occupational exposure conditions (*2*). Approximately 2%–8% of all cancers were estimated to be caused by occupational exposures to carcinogens (*3*). In China, with the rapid development of industries, occupational cancers due to carcinogens in the workplace have become a major threat to workers' health. A total of 11 occupational cancers were included in the latest version of "Classification and Catalogue of Occupational Diseases" (*4*) published in 2013, including: 1) lung cancer and mesothelioma caused by asbestos; 2) bladder cancer caused by benzidine; 3) leukemia caused by benzene; 4) lung cancer caused by chloromethyl ether and dichloromethyl ether; 5) lung cancer and skin cancer caused by arsenic and its compounds; 6) hepatic angiosarcoma caused by vinyl chloride; 7) lung cancer caused by coke oven emissions; 8) lung cancer caused by hexavalent chromium compounds; 9) lung cancer and pleural mesothelioma caused by erionite; 10) skin cancer caused by coal tar, coal tar pitch and petroleum pitch; and 11) bladder cancer caused by β-naphthylamine.

Since 2006, occupational diseases, including occupational cancers, have been reported directly online to the National Occupational Disease Reporting System by occupational disease diagnosis institutions. The total number of occupational cancers reported each year is published annually by the National Health Statistical Bulletin. To better understand the prevalence of occupational cancers in China, we abstracted the case-based data from the system between 2006 and 2020, and analyzed the epidemiological characteristics of occupational cancers in China.

METHODS

Cases of occupational cancers reported between January 1, 2006 and December 31, 2020 were obtained from the National Occupational Disease

Reporting System. The system is a network-based reporting system that includes all occupational disease diagnostic institutions in the mainland of China. To ensure the integrity and accuracy of the data, all data reported will be reviewed at county, city, and provincial levels. Descriptive analysis was conducted by year, region, disease type, industry, gender, the average age at diagnosis and exposure duration to occupational hazards. Categorical variables were described using frequencies and constituent ratios, and numerical variables were described using mean and standard deviation or median and interquartile range. Statistical analysis was carried out in SPSS (version 26.0, SPSS Inc, Chicago, IL, USA).

RESULTS

A total of 1,116 cases were reported between 2006 and 2020, and the cases reported annually were shown in Figure 1. As shown in Table 1, the three main types of reported cases were leukemia caused by benzene, lung cancers caused by coke oven exhaust, and lung cancer and mesothelioma caused by asbestos, with the numbers of reported cases being 511 (45.79%), 266 (23.84%), and 226 (20.25%), respectively. There were 6 types of occupational cancers (lung cancer caused by hexavalent chromium compounds; bladder cancer caused by benzidine; lung cancer and skin cancer caused by arsenic and its compounds; lung cancer caused by chloromethyl ether and dichloromethyl ether; skin cancer caused by coal tar; coal tar pitch, petroleum pitch, and bladder cancer caused by β-naphthylamine) with less than 50 reported cases. There were 2 types of occupational cancers (hepatic angiosarcoma caused by vinyl chloride, lung cancer and pleural mesothelioma caused by erionite) for which no cases were reported.

There were 6 provincial-level administrative divisions (PLADs) with reported cases above 50: Guangdong Province (335, 30.02%), Shandong Province (135, 12.1%), Liaoning Province (122, 10.93%), Hubei Province (93, 8.33%), Beijing Municipality (86, 7.71%), and Jiangsu Province (68, 6.09%).

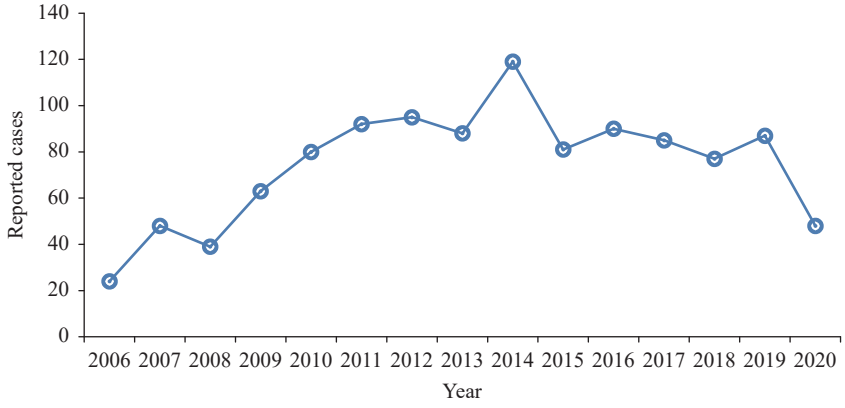


FIGURE 1. Reported cases of occupational cancers in China, 2006−2020.

TABLE 1. Occupational cancer cases reported by disease type, 2006−2020.

Disease type	Number of cases	Proportion (%)
Leukemia caused by benzene	511	45.79
Lung cancer caused by coke oven emission	266	23.84
Lung cancer and mesothelioma caused by asbestos	226	20.25
Lung cancer caused by hexavalent chromium compounds	42	3.76
Bladder cancer caused by benzidine	41	3.67
Lung cancer and skin cancer caused by arsenic and its compounds	15	1.34
Lung cancer caused by chloromethyl ether and dichloromethyl ether	13	1.16
Skin cancer caused by coal tar, coal tar pitch, petroleum pitch	1	0.09
Bladder cancer caused by β-naphthylamine	1	0.09
Total	1,116	100.00

As for the industrial distribution, the cases were mainly distributed in manufacturing (913, 81.18%), followed by mining (41, 3.67%), transportation, storage, and postal services (39, 3.49%) (Table 2). In manufacturing, leukemia caused by benzene topped the list of occupational cancers cases, while mining and transportation reported the most lung cancer and mesothelioma cases caused by asbestos. Among the total reported cases of occupational cancers, 870 (77.96%) were male and 246 (22.04%) were female cases. The average age at diagnosis of all reported cases was 51.91±15.85 years old, and the median exposure duration to occupational hazards was 12 (5.29–23.25) years. The distribution characteristics of the 3 major occupational cancers showed that for leukemia caused by benzene, 68.88% of the cases were male, the average age at diagnosis was (39.76±10.57) years, and the median exposure duration to occupational hazards was 6.17 years (Table 3). Compared with leukemia caused by benzene, the proportions of male cases of lung cancer caused by coke oven emissions and lung cancer and mesothelioma caused by asbestos were higher at 96.24% and 70.35%, respectively. The average age at diagnosis were higher than that of leukemia caused by benzene, which were (62.64±10.99) years and (63.52±11.19) years, respectively. The exposure duration to occupational hazards were longer than that of leukemia caused by benzene which were 24.25 years and 18.54 years, respectively.

CONCLUSIONS

Work-related carcinogens were responsible for a significant disease burden worldwide. According to Global Burden of Disease 2016 estimates (*5*), the burden of cancer due to exposure to 14 IARC Group 1 occupational carcinogens (asbestos, benzene, diesel engine exhaust, silica, etc.) was estimated at 349,000

TABLE 2. Occupational cancer cases reported by industry, 2006−2020.

Industrial classification	Number of cases	Proportion (%)
Manufacturing	913	81.81
Mining	41	3.67
Transport, storage, and postal services	39	3.49
Production and Supply of Electricity, Heat, Gas and Water	21	1.88
Leasing and commercial services	20	1.79
Wholesale and retail trades	18	1.61
Construction	16	1.43
Public administration, social security, social organizations	13	1.16
Resident, repair and other services	9	0.81
Scientific research and technical services	7	0.63
Education	7	0.63
Health and social services	5	0.45
Agriculture, forestry, animal husbandry and fishery	3	0.27
Administration of water conservancy, environment, public facilities	2	0.18
Finance	1	0.09
Real estate	1	0.09
Total	1,116	100.00

TABLE 3. Demographic characteristics of 3 main occupational cancers, 2006−2020.

Demographic characteristics	Leukemia caused by benzene (N=511)	Lung cancer caused by coke oven emission (N=266)	Lung cancer and mesothelioma caused by asbestos (N=226)
Gender, n (%)			
Male	352 (68.88)	256 (96.24)	159 (70.35)
Female	159 (31.12)	10 (3.76)	67 (29.65)
Age ($\bar{X}$±s)	39.76±10.57	62.64±10.99	63.52±11.19
Exposure duration, Median (inter quartile range)	6.17 (3.17−11.58)	24.25 (14.33−31.33)	18.54 (11.83−28.17)

deaths and 7.2 million disability-adjusted life years (DALYs) in 2016, accounting for 3.9% of all cancer deaths and 3.4% of all cancer DALYs. The World Health Organization/International Labour Organization joint estimates of the work-related burden of disease and injury (*6*) found that estimates for mesothelioma attributable to exposure to asbestos were 177,614 deaths and 3.29 million DALYs, and estimates for lung cancer were 23,104 deaths and 0.51 million DALYs, respectively.

However, in our study, only 1,611 cases have been abstracted from the national occupational disease reporting system over the last 15 years, which is far less than the data reported in some other countries. In Germany, for example, according to occupational disease data published by German Social Accident Insurance (*7*), the number of cases of lung, larynx, or ovarian cancer caused by asbestos; mesothelioma caused by asbestos; and lung cancer caused by asbestos and polycyclic aromatic hydrocarbon during 2018–2020 were 1,995, 2,533, and 102, respectively. This may be due to the different diagnostic criteria and disease types included in the list of occupational diseases in different countries. Moreover, the diagnosis and treatment of malignant cancers in China were mainly carried out in comprehensive medical institutions or specialized cancer hospitals. Data from the annual report of the China Cancer Registry (*8*) showed that the number of mesothelioma cases reported to the cancer registry in 2016 was 583.

Asbestos is the most important contributor to occupational mesothelioma, and there is a large discrepancy between the high morbidity of occupational cancers and the low number of cases diagnosed and reported. The problem is that most workers probably lack relevant knowledge and awareness and that the long latency period of cancer onset makes it difficult to determine occupational carcinogen exposure history. According to the diagnostic criteria for an occupational cancer in China (*9*), there must be a clear history of long-term occupational exposure to carcinogens, and after a comprehensive analysis, the occurrence of primary cancers should meet the requirements of years of total cumulative occupational exposure to carcinogens in the workplace and the latency period for the occurrence and development of occupational cancers. As there is a high mobility of workers in China, who are usually employed by several employers with similar jobs and exposed to the same industrial disease hazards, the working year of some patients at the last employer may not meet the diagnostic criteria of exposure years (*10*), which makes the diagnosis of occupational cancers difficult.

In summary, occupational cancers may be underestimated in China. Diagnosis and surveillance of occupational cancers should be strengthened, and a comprehensive surveillance system including occupational health monitoring, carcinogens monitoring in workplaces, and occupational disease reporting should be established and improved to better evaluate the prevalence and disease burden of occupational cancers and protect workers' health.

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Notifiable Infectious Diseases Reports

Reported Cases and Deaths of National Notifiable Infectious Diseases — China, February 2022

Diseases	Cases	Deaths
Plague	0	0
Cholera	0	0
SARS-CoV	0	0
Acquired immune deficiency syndrome*	3,364	1,252
Hepatitis	117,382	37
Hepatitis A	830	0
Hepatitis B	96,787	29
Hepatitis C	16,733	8
Hepatitis D	23	0
Hepatitis E	2,443	0
Other hepatitis	566	0
Poliomyelitis	0	0
Human infection with H5N1 virus	0	0
Measles	44	0
Epidemic hemorrhagic fever	330	0
Rabies	7	4
Japanese encephalitis	1	0
Dengue	0	0
Anthrax	9	0
Dysentery	2,043	0
Tuberculosis	52,596	313
Typhoid fever and paratyphoid fever	280	1
Meningococcal meningitis	9	0
Pertussis	2,576	0
Diphtheria	0	0
Neonatal tetanus	1	0
Scarlet fever	990	0
Brucellosis	4,689	0
Gonorrhea	6,979	0
Syphilis	34,683	4
Leptospirosis	2	0
Schistosomiasis	5	0
Malaria	30	0
Human infection with H7N9 virus	0	0
COVID-19†	3,387	0
Influenza	98,696	1
Mumps	4,491	0

Continued

Diseases	Cases	Deaths
Rubella	55	0
Acute hemorrhagic conjunctivitis	1,561	0
Leprosy	28	0
Typhus	38	0
Kala azar	23	1
Echinococcosis	213	0
Filariasis	0	0
Infectious diarrhea[§]	92,535	0
Hand, foot and mouth disease	18,134	1
Total	445,181	1,614

[*] The number of deaths of Acquired immune deficiency syndrome (AIDS) is the number of all-cause deaths reported in the month by cumulative reported AIDS patients.
[†] The data were from the website of the National Health Commission of the People's Republic of China.
[§] Infectious diarrhea excludes cholera, dysentery, typhoid fever and paratyphoid fever.
The number of cases and cause-specific deaths refer to data recorded in National Notifiable Disease Reporting System in China, which includes both clinically-diagnosed cases and laboratory-confirmed cases. Only reported cases of the 31 provincial-level administrative divisions in the mainland of China are included in the table, whereas data of Hong Kong Special Administrative Region, Macau Special Administrative Region, and Taiwan are not included. Monthly statistics are calculated without annual verification, which were usually conducted in February of the next year for de-duplication and verification of reported cases in annual statistics. Therefore, 12-month cases could not be added together directly to calculate the cumulative cases because the individual information might be verified via National Notifiable Disease Reporting System according to information verification or field investigations by local CDCs.

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The 20th National Publicity Week of Occupational Disease Prevention and Control Law — April 25 to May 1, 2022

The Occupational Diseases Prevention and Control Law had been issued by the Standing Committee of the Ninth National People's Congress on October 27, 2001 and formally implemented on May 1, 2002.

The last week of April each year, from April 25 to May 1, has been set as the Publicity Week of the Occupational Disease Prevention Law since 2003. Its purpose is to publicize and implement the Occupational Disease Prevention and Control Law and further promote employers to take responsibility for occupational disease prevention and control and effectively protect occupational health and the wellbeing of workers.

This year is the 20th anniversary of the implementation of this law. The slogan of the 20th National Publicity Week is "All for Workers' Health."

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