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Cover photo: Staff from an occupational health service institute sampling field occupational hazards in an automobile factory in Chongqing City, June 6–10, 2020.

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

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

Summary

What is already known about this topic?

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

What is added by this report?

The largest number of enterprises exposed to benzene are small enterprises, and the joint-equity enterprises has the highest number which exceeds the permissible concentration-time weighted average.

What are the implications for public health practice?

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

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

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

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

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

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

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

Abbreviation: C_{TWA}=concentrations of time weighted average.

* Jiangsu Province, Shandong Province, Sichuan Province, Fujian Province, Zhejiang Province, and Tianjin Municipality.

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

Industries were classified according to the *Division Standard of Large/Medium/Small Sized Industrial Enterprises* issued by the National Bureau of Statistics of China (*6*). In Table 2, the proportion of medium-sized enterprises exceeding the PC-TWA of benzene concentration was the highest (2 enterprises, 0.88% of the total). However, it is worth noting that the largest number of enterprises exposed to benzene are small enterprises, and the proportions of exceeding the PC-TWA of benzene are 0.56% and 0.31%, respectively.

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

DISCUSSION

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

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

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

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

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

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

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

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

According to the results of this investigation, several suggestions to reduce the exposure hazards of low-level benzene are listed as follows: 1) strengthen the monitoring of benzene and its homologues in the workplaces of small and medium-sized enterprises, improve the ventilation in workplaces, and lower the concentration of benzene in the air as much as possible; 2) physical examination and health education should be carried out for workers, self-protection awareness should be strengthened, and the use of personal protective tools should be increased; 3) some industries (such as the manufacturing industry), in which the benzene exposure is high, should be controlled within the PC-TWA in China, and the time workers are exposed to benzene should be reduced as far as possible.

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Corresponding author: Caihong Xing, caihongxing2013@163.com.

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

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Preplanned Studies

Occupational Dust Hazards and Risk Assessment of Coal-Fired Thermal Power Plants of Different Capacities — China, 2017–2019

Xin Wang[1]; Weijiang Hu[1]; Siyu Zhang[1]; Ning Kang[1]; Hongfei Wang[1]; Yiwen Dong[1]; Hongying Bian[1]; Ye Meng[1,#]

Summary

What is already known about this topic?

Silica dust and coal dust are the main occupational hazards in coal-fired thermal power plants, which mainly exist in coal transportation workplaces, combustion milling workplaces, and ash removal workplaces.

What is added by this report?

The overall environmental and personal dust exposure levels decrease with an increase in the capacity of coal-fired thermal power plants, the overall dust hazard risk level of the workforce in coal-fired is Medium.

What are the implications for public health practice?

Dust management should be conducted in the coal-fired thermal power plant in 300 million watt units because it has the highest dust exposure level, and ash removal workplaces and combustion milling workplaces are key control points for dust hazards.

In China, the dominant position of coal-fired power plants in energy production will not change in the short term. The thermal power installed capacity accounts for about 70% of the total installed capacity (*1*). In 2020, the thermal power generation equipment capacity was 1,245.17 million kilowatts (kW), a cumulative increase of 4.7% and accounting for 56.6% of the total power generation capacity (*2*). By the end of 2020, the installed power generation capacity of overpower plants rated at 6,000 kW or greater was 1,996.01 million kW, and the installed thermal power generation capacity was 1,225.62 million kW, accounting for 61.4% of the total power generation in China (*3*). Silica dust and coal dust are the main occupational hazards in coal-fired thermal power plants, which could cause pneumoconiosis, silicosis, lung cancer, tuberculosis, and other adverse health effects. The prevalence of occupational lung diseases such as pneumoconiosis and silicosis and its annual increase rates are still high in China (*4*). According to the latest report in China, there were 15,898 new cases of pneumoconiosis, accounting for 81.8% of the total cases of occupational diseases reported in 2019 (*5*). Some studies have estimated that a total number of 1.37 million standardized incident cases of lung cancer will be attributed to occupational exposure in coal-fired power by 2025 (*6*). The thermal power plants have gradually changed from 300 million watt (MW) units to 600 MW and 1,000 MW units with technological advancements, while dust hazards are still present and difficult to control effectively. This study aimed to investigate occupational exposure levels of respirable dust and evaluated the occupational health risk levels of key dust-exposed position in six coal-fired thermal power plants of different sizes and regions, providing information that can be used by other researchers in the future in solving dust exposure problems in the working environment.

A field survey was carried out in 6 coal-fired thermal power plants, including a total of 12 units which included two 2×300 MW units, two 2×600 MW units, and two 2×1,000 MW units. Considering the regional and climate impacts, the power plants we selected are located in Zhejiang, Shanxi, Hebei, Shandong, and Fujian. Overall, 291 respirable dust samples (195 environmental and 96 personal samples) were measured. Safety and health practitioners in each thermal power plant were interviewed and gave information about the production process, positions, and number of workers exposed to dust, and the inspection routes for each position were collected. This study measured the environmental and personal dust exposure levels based on workplaces that produce dust hazards, such as coal transportation, combustion milling, and ash removal. Methods of sampling and respirable dust measurement were determined according to the relevant guidelines GBZ 159–2004 and GBZ/T 192.2–2007. The peak exposures of respirable dust in workplaces were measured by AKFC-92A type mine dust sampler with a flow rate of 20 L/min. The sampling time was 15 minutes at the personal breathing zone of workers during a normal work shift. Individual dust samples were collected using AKFC-92G type individual dust sampler with a flow rate of 2 L/min. For each work position, 1–2 people were selected for three shifts, and the average value was calculated.

Bulk samples were also collected from each plant site and subjected to free silica analysis. The content of free silica in dust was determined by GBZ/T 192.4–2007, the free SiO_2 of coal dust is 5.33%–6.70%, and the free SiO_2 of silica dust is 14.44%–27.62%. Considering GBZ 2.1–2019, the time weighted average concentration (C_{TWA}) of respirable coal dust (free SiO_2<10%) being greater or equal to 2.5 mg/m^3 and the C_{TWA} of respirable silica dust (10%≤free SiO_2≤50%) being not less than 0.7 mg/m^3 were considered to exceed the personal dust exposure standard.

The occupational hazard risk index method (*7*) was used to evaluate the occupational health risk levels of the capacity and the selected position by comprehensively considering the exposure level, the severity of the hazard, the number of exposed workers, and protective measures, combined with national health standards to give weights and evaluate grades. The risk index was divided into 5 levels, namely no hazard (0–6), light hazard (7–11), moderate hazard (12–23), high hazard (24–80), and extreme hazard (>80). The risk index = $2^{\text{Health effect grade}} \times 2^{\text{Exposure ratio}} \times$ working condition grade, where the health effect grade was divided according to the content of free silica in the dust, exposure ratio = average measured value/occupational exposure limit, working condition grade = [exposure time value × value of the exposed workers number × value of engineering protection measure × value of personal protective equipment (PPE) usage rate]$^{1/4}$. The classification standards of the health effect grade and working condition grades were described in Table 1. Relevant information was obtained from occupational health surveys and measurements conducted for each thermal power plant.

In this study, we measured 195 respirable dust samples in workplaces among coal-fired power plants of different sizes (Table 2). Coal transportation workplaces were exposed to coal dust, and the average peak exposure was 2.02±1.45 mg/m^3. In combustion milling workplaces, the average peak exposure of coal dust was 1.27±1.32 mg/m^3 and that of silica dust was 0.86±0.60 mg/m^3. The average peak exposure of silica dust measured in ash removal workplaces was 0.93±0.52 mg/m^3. With an increase in capacity, the average peak exposure for each workplace decreases gradually.

TABLE 1. The classification standard of health effect grade and working condition grades in occupational hazard risk index method.

Value	Health effect grade	Working condition grade			
	The content of free silica	Exposure time (h/shift)	No. of exposed workers	Engineering protection measure	PPE usage rate (%)*
5	NA	>12	>50	None	≤20
4	NA	–12	26–50	Overall control	21–50
3	≥70%	–8	16–25	Partial control, operation but uncertain effect	51–80
2	40%–70%	–5	6–15	Partial control, clear effect	81–90
1	10%–40%	–2	–5	Confined facility	≥90
0	≤10%	NA	NA	NA	NA

Abberviations: NA=not applicable; PPE=personal protective equipment.
* PPE usage rate: number of workers using protective equipment/number of workers exposed to dust×100%.

TABLE 2. The peak exposures of respirable dust from coal-fired thermal power plants of different capacities in China, 2017–2019.

Unit	Type of dust	Overall		300 MW		600 MW		1,000 MW	
		No. of samples	Mean±SD (mg/m^3)	No. of samples	Mean±SD (mg/m^3)	No. of samples	Mean±SD (mg/m^3)	No. of samples	Mean±SD (mg/m^3)
Coal transportation	Coal	73	2.02±1.45	18	2.36±1.73	28	2.11±1.57	27	1.71±1.07
Combustion milling	Coal	37	1.27±1.32	13	1.89±2.0	10	0.85±0.48	14	1.00±0.61
	Silicon	48	0.86±0.60	17	1.03±0.91	19	0.86±0.34	12	0.63±0.17
Ash removal	Silicon	37	0.93±0.52	11	1.26±0.65	14	0.82±0.30	12	0.76±0.50
Total		195	1.39±1.23	59	1.67±1.51	71	1.34±1.18	65	1.18±0.89

The operators mainly engaged in inspection work, with each inspection time being about 2–3 hours and each workplace being inspected twice per shift. A total of 96 personal breathing zone respirable dust samples were collected. Table 3 listed the C_{TWA} of respirable dust for each position of different capacities and the pass rate. The C_{TWA} of coal transportation operators all met the requirements of the GBZ 2.1–2019 guidelines, and other positions had different degrees of excess. Especially for ash removal operators in 300 MW unit, C_{TWA} exceed the permissible limit seriously.

From Table 4, occupational health risk assessment results showed that the overall occupational health risk level was medium, most positions had light or negligible hazards, and the risk level of ash removal and combustion milling operators in 300 MW unit and combustion milling operators in 1,000 MW unit were medium*.

DISCUSSION

There were about 1,000 coal-fired thermal power stations in China, and the dust hazards of thermal power plants have always been a focus of occupational health. The effective implementation of the "National Occupational Disease Prevention and Control Plan (2016–2020)" and the Pneumoconiosis Prevention and Control Action in 2019 by the National Health Commission of the People's Republic of China have enabled the dust exposure level of thermal power plants to be controlled to a certain extent. The study showed that the personal dust concentration of coal transportation workplaces of different capacities were lower than national standards, indicating that the dust prevention measures adopted by the enterprise for the coal transportation workplaces are feasible and can meet the purpose of protecting the health of workers. However, the pass rate of C_{TWA} in the ash removal workplaces was 74%, mainly due to the C_{TWA} of ash removal workers in 300 MW unit exceeding the allowable limit. This study also found that the environmental and personal respirable dust exposure among coal-fired thermal power plants had decreased with an increase of capacity, and the C_{TWA} of respirable dust in 300 MW unit was higher than those among plants with bigger capacities. This was due to the increasing of the capacity is accompanied by technical improvements. Compared with the thermal power plants of 300 MW and 600 MW units, the 1,000 MW thermal power plants were built in recent years with advanced technology, the levels of containment and automation of machines was higher, and the effect of dust proof equipment on preventing dust from escaping was better. However, the expansion of the unit size will lead to more inspection personnel and prolonged inspection time, which will also increase the risk of dust exposure.

Occupational health risk assessment results showed the risk level of ash removal operators in 300 MW unit and combustion milling operators of different capacities were relatively high. Workers in combustion milling workplaces and ash removal workplaces were mainly exposed to silica dust in thermal power plants. Many studies have shown that there was a strong epidemiological evidence for the association between occupational silica dust exposure and several diseases (*8*). Some research found workers engaged in ash removal suffered the highest health risk (*9*). The dust generated in the combustion process of the boiler escaped relatively easily, and the concentration of silica dust was likely to exceed standards when the ash removal device was not properly closed, especially in small power plants. This was also shown by a study on three coal-fired power plants of different capacities, which suggested that the silica dust concentration of the ash removal workplaces and combustion milling workplaces among the three power plants exceeded the permissible limit to varying degrees (*10*). Therefore, the ash removal workplaces and the combustion milling workplaces were the key control points for dust hazards in coal-fired thermal power plants.

During site investigations, the main reasons for dust exceeding in coal-fired thermal power plants were imperfect design and installation of dust protection facilities, untimely maintenance, and unscheduled dust removal onsite. Optimally, work processes should be isolated and enclosed and adequate ventilation should be provided. The plants need to strengthen maintenance and upkeep of dust prevention facilities and encourage personal protective equipment use among workers during possible dust exposure. Even

* Operations with no hazard risk can be regarded as acceptable operations. Operations with light hazard risks should be further evaluated. Operations with medium hazard risks should be risk controlled based on further evaluation, such as strengthening protection or reducing exposure time. For operations with high hazard risks, measures must be taken to reduce the risk of occupational hazards. Operations with extreme hazard risks should be stopped, and comprehensive measures such as finding new methods or reforming the process flow or strengthening engineering control should be adopted to reduce the hazard risk.

TABLE 3. C_{TWA} of respirable dust and pass rate for positions from coal-fired thermal power plants of different capacities in China, 2017–2019.

Position	Type of dust	Overall				300 MW				600 MW				1,000 MW			
		No. of samples	No. of passes	Passrate (%)	Mean±SD (mg/m³)	No. of samples	No. of passes	Passrate (%)	Mean±SD (mg/m³)	No. of samples	No. of passes	Passrate (%)	Mean±SD (mg/m³)	No. of samples	No. of passes	Passrate (%)	Mean±SD (mg/m³)
Coal transportation operators	Coal	38	38	100	0.59±0.55	19	19	100	0.84±0.58	11	11	100	0.43±0.48	8	8	100	0.22±0.09
Combustion milling operators	Silicon	39	32	82	0.49±0.63	13	11	85	0.48±0.47	16	14	88	0.42±0.67	10	7	70	0.61±0.76
Ash removal operators	Silicon	19	14	74	0.46±0.39	7	2	29	0.83±0.39	6	6	100	0.23±0.23	6	6	100	0.26±0.10
Total		96	84	88	0.53±0.55	39	32	82	0.72±0.54	33	31	94	0.39±0.55	24	21	88	0.39±0.51

TABLE 4. Occupational hazard risk index method assessment results from coal-fired thermal power plants of different capacities in China, 2017–2019.

Capacity	Position	Type of dust	Health effect grade	Exposure ratio*	Working condition grade								Grade †	Risk index §	Risk level
					Exposed workers		Exposure time		Engineering control measure		PPE usage rate				
					No.	Value	h/shift	Value		Value	%	value			
300 MW	Coal transportation operators	Coal	0	0.34	110	5	4	2	Partial control, operation but uncertain effect	3	60	4	3.31	4	None
	Combustion milling operators	Silicon	1	0.69	99		6	3					3.66	12	Medium
	Ash removal operators	Silicon	1	1.19	69		4	2					3.31	15	Medium
600 MW	Coal transportation operators	Coal	0	0.17	148	5	6	3	Partial control, operation but uncertain effect	3	60	4	3.66	4	None
	Combustion milling operators	Silicon	1	0.60	134		6	3					3.66	11	Light
	Ash removal operators	Silicon	1	0.31	50		4	2					3.31	8	Light
1,000 MW	Coal transportation operators	Coal	0	0.08	82	5	6	3	Partial control, clear effect	2	75	4	3.31	4	None
	Combustion milling operators	Silicon	1	0.87	176		6	3					3.31	12	Medium
	Ash removal operators	Silicon	1	0.37	62		6	3					3.31	9	Light
Total		Silicon	1	0.76	930	5	6	3	Partial control, operation but uncertain effect	3	60	4	3.66	12	Medium

Abbreviation: PPE=personal protective equipment.

* Exposure ratio=average measured value/occupational exposure limit, the coal dust limit=2.5 mg/m^3, the silica dust limit=0.7 mg/m^3.

† Working condition grade=(exposure time value×exposure number value×value of engineering protection measure×value of PPE usage rate)$^{1/4}$.

§ Risk index = $2^{\text{Health effect grade}} \times 2^{\text{Exposure ratio}}$ × working condition grade.

with such measures, the exposure levels still exceeded the guidelines in some areas, especially in areas where dust or ash accumulations were present. Consequently, it was clear that continued efforts are needed to train and supervise workers to promote worker safety in terms of dust exposure and to reduce the adverse impact from dust exposure on the health of workers.

The findings in this report were subject to at least three limitations. First, the survey included only 6 coal-fired thermal power plants, and the generalizability of the findings are limited. Second, the occupational risk index method was subjective in the process of evaluating the various grades of the operation and therefore subject to biases. Third, data only included the environmental and individual exposure levels, and the related health data that could be affected by dust among the workers were not studied. Further studies should expand the sample sizes and study the relationship between dust exposure and related health consequences among coal-fired thermal power stations of different capacities and combine this with occupational health to provide a realistic basis for improving the assessment method.

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Corresponding author: Meng Ye, Yemeng@niohp.chinacdc.cn.

[1] National Institute of Occupational Health and Poison Control, Chinese Center for Disease Control and Prevention, Beijing, China.

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Vital Surveillances

Surveillance of Noise Exposure Level in the Manufacturing Industry — China, 2020

Jinnan Zheng[1]; Siyu Zhang[1]; Hongfei Wang[1]; Yue Yu[1]; Weijiang Hu[1,#]

ABSTRACT

Introduction: Occupational noise exposure is a widespread issue in the manufacturing industry in China. Since 2019, the National Surveillance System for Occupational Hazards in the workplace was established to understand different occupational hazards, especially occupational noise, in workplaces in China.

Methods: Both environmental and individual noise exposure levels were measured for 19,378 enterprises according to the *Work Plan for Surveillance of Occupational Hazards in the Workplace (2020)* issued by National Health Commission of the People's Republic of China. Median and interquartile range (IQR) were calculated to describe the distribution of the noise exposure level by industry classification, enterprise-scale, and ownership type of the enterprise.

Results: Overall, 25.14% of the individual noise exposure samples exceeded the Chinese national standard among the selected enterprises. The overall median of environmental noise exposure level was 82.8 dB(A) in selected enterprises, while the median of individual noise exposure level was 81.3 dB(A). The individual noise exposure level in the manufacture of metal products, manufacture of motor vehicles, mini-sized enterprises, collective enterprises and private enterprises was relatively high.

Conclusion: Occupational noise is still one of the occupational hazards that cannot be ignored in the manufacturing industry, especially in mini-sized and private enterprises. The risk of noise exposure in the target industry is still high and will pose a threat to the health of workers.

INTRODUCTION

Noise has been one of the most prevalent occupational hazards in many industries both in China and worldwide, which affects more than 10 million Chinese workers' health (*1–2*). With an annual growth of incidence of 24.2% from 2014, occupational noise-induced deafness has been the second leading occupational disease after pneumoconiosis in China (*3*). Since China's reform and opening-up, China's manufacturing industry has developed rapidly. In 2018, the number of enterprises exceeded 3 million, accounting for 15% of the total number of enterprises, with more than 100 million workers (*4*). Meanwhile, 67.56% of the diagnosed cases of occupational otolaryngological and stommatological diseases in China were from the manufacturing industry in 2020, which was reported from the National Surveillance System of Key Occupational Diseases. Studies reported that the noise exposure level in many workplaces exceeded 85 dB(A) among several manufacturing industries such as the wood furniture manufacturing industry, the transportation equipment manufacturing industry, and the automotive industry (*3,5–6*). Therefore, it is necessary to understand the noise exposure level in the workplace in the overall manufacturing industry from different dimensions and provide evidence for measures to reduce the noise exposure level and protect workers' health.

METHODS

In order to estimate the noise exposure level among the overall manufacturing industry on a national scale, 19,378 enterprises were selected from the database of National Surveillance System for Occupational Hazards in the workplace in 2020. The surveillance was conducted according to the *Work Plan for Surveillance of Occupational Hazards in the Workplace (2020)* issued by the National Health Commission of the People's Republic of China. Based on the plan's requirement, the average number of enterprises included in the surveillance in each county should not be less than 20, and a minimum total number of 55,890 enterprises should be monitored. Furthermore, all the enterprises included in the surveillance should be exposed to major occupational hazards selected according to the epidemiological trends of occupational disease in China. The surveillance was conducted mostly by Occupational Disease Prevention and Control Institutes at the county level and occupational health technical service institutions. Quality control of the surveillance was conducted by provincial and municipal Occupational Disease Prevention and Control Institutes. The selected enterprises in this study were from 31 provincial-level administrative divisions (PLADs) and the Xinjiang Production and Construction Corps in China and were categorized according to their industrial classification, enterprise-scale, ownership type of the enterprise (*7–9*).

Both environmental and individual noise exposure levels were measured for each enterprise, the specific measurement guidelines were as follows: 1) at least 20 noise exposure areas should be measured in the workplace in large and medium-sized enterprises, and all of the noise exposure areas should be measured in the workplace in small and mini-sized enterprises; 2) the level of environmental noise onsite should be measured in each noise exposure area, and individual noise exposure measurements should be conducted for at least four operating posts in each enterprise; individual noise exposure measurements should be conducted for all operating posts if operating posts comprise less than four units; and 3) the sampling method and noise measure method for both environmental and individual noise exposure were determined according to the *Measurement of Physical Agents in the Workplace Part 8: Noise (GBZ/T 189.8–2007)*.

Statistical analysis was performed using SPSS (version 22.0, SPSS Inc, Chicago, IL, USA). The median and interquartile range (IQR) were calculated to describe the distribution of the noise exposure by industry classification, enterprise-scale, and ownership type of the enterprise. Kruskal-Wallis H test was used to compare noise exposure levels among different dimensions. The significance level of tests was $P<0.05$.

RESULTS

In this study, 19,378 enterprises from 10 major divisions of the manufacturing industry were included, and more than 530,000 workers were found exposed to occupational noise. As shown in Table 1, a total number of 111,858 environmental noise samples and 97,419 individual noise samples were detected. Overall, 25.14% of the individual noise exposure samples exceeded the Chinese national standard among the selected enterprises. The proportions of individual noise exposure levels equal to or above 85 dB(A) were much higher in the manufacturing of other non-metallic mineral products, which was 32.08%.

TABLE 1. Distribution of noise exposure levels among the manufacturing industry in different divisions — China, 2020.

Division*	Total number of enterprises	Total number of workers	Environmental noise exposure level [dB(A)]		Individual noise exposure level $L_{Ex,8h}/L_{Ex,40h}$ † [dB(A)]		The proportion of individual noise exposure levels ≥85 dB(A) (%)
			Number of samples	Median (*IQR*)	Number of samples	Median (*IQR*)	
Manufacture of furniture	2,430	45,826	15,750	83.2 (80.2–86.5)	13,955	81.7 (77.4–84.8)	24.01
Printing and reproduction of recorded media	2,148	39,730	9,457	81.1 (78.0–83.8)	9,022	80.5 (76.3–83.4)	15.21
Manufacture of coke and refined petroleum products	359	27,552	3,470	82.9 (78.8–87.1)	2,196	78.3 (73.8–82.0)	9.39
Manufacture of chemicals and chemical products	1,401	40,121	8,354	80.1 (75.9–83.5)	6,439	77.4 (72.7–81.0)	7.59
Manufacture of other non-metallic mineral products	8,228	166,938	41,471	83.8 (80.3–88.9)	36,066	82.0 (77.3–86.9)	32.08
Casting of iron and steel	808	44,022	6,821	82.6 (78.7–86.8)	5,615	80.5 (76.4–84.2)	21.52
Casting of non-ferrous metals	1,001	55,640	7,733	82.2 (78.6–85.8)	6,202	80.5 (76.3–84.2)	20.39
Manufacture of metal products	1,368	35,715	7,688	83.2 (80.2–87.1)	7,224	82.2 (78.8–85.9)	29.01
Manufacture of motor vehicles	1,533	70,246	10,278	82.8 (79.7–86.7)	9,917	82.2 (78.7–85.6)	27.76
Manufacture of electrical equipment	102	7,928	836	82.4 (79.8–85.5)	783	81.8 (78.4–84.9)	24.58
Total	19,378	533,718	111,858	82.8 (79.3–87.0)	97,419	81.3 (76.9–85.0)	25.14

* $P<0.001$.

† $L_{Ex,8h}$: Normalization of equivalent continuous A-weighted sound pressure level to a nominal 8 hours working day. $L_{Ex,40h}$: Normalization of equivalent continuous A-weighted sound pressure level to a nominal 40 hours working week.

The surveillance results showed that all the medians of both environmental and individual noise exposure levels were below 85 dB(A). The overall median of environmental noise exposure level was 82.8 dB(A) in selected enterprises, while the median of individual noise exposure level was 81.3 dB(A). The medians of individual noise exposure levels in the categories of manufacturing of metal products, manufacturing of motor vehicles, and manufacturing of other non-metallic mineral products were higher compared to other divisions, and their upper quartiles showed that more than 25% of the operating posts were exposed to a noise level of 85 dB(A). The occupational noise exposure level was relatively high in the workplace among divisions of manufacturing of other non-metallic mineral products, manufacturing of furniture, and manufacturing of metal products, as shown by the median and their IQR, which were 83.8 (80.3–88.9), 83.2 (80.2–86.5), and 83.2 (80.2–87.1), respectively. The difference between the medians of environmental and individual noise exposure level in the manufacture of coke and refined petroleum products was 4.6 dB(A) (H=697.894, P<0.001), which was larger compared to other divisions.

As presented in Table 2, the proportions of individual noise exposure levels equal to or exceeding 85 dB(A) increased with the decline of the enterprise-scale. The mdian of individual noise exposure levels in mini-sized enterprises was the highest when compared to the other three enterprise scales (Table 2). The difference between the medians of environmental and individual noise exposure levels was 2.2 dB(A) in both the large and medium enterprise-scales, which were bigger than those in small and mini-sized [1.3, 1.5 dB(A)]. Table 2 also presents the distribution of the noise exposure states among the manufacturing enterprises in different ownership types. The proportions of individual noise exposure levels equal to

TABLE 2. Distribution of noise exposure levels among the manufacturing industry in different enterprise-scale and ownership type — China, 2020.

Item	Total number of enterprises	Total number of workers	Environmental noise exposure level [dB(A)]		Individual noise exposure level $L_{Ex,8h}/L_{Ex,40h}$* [dB(A)]		The proportion of individual noise exposure level ≥85 dB(A) (%)
			Number of samples	Median (*IQR*)	Number of samples	Median (*IQR*)	
Enterprise-scale							
Large	458	76,923	6,291	83.3 (80.1–87.2)	4,884	81.1 (76.6–84.5)	22.07
Medium	1,878	169,139	20,556	83.1 (79.7–87.2)	17,277	80.9 (76.1–84.6)	23.13
Small	9,926	236,325	59,901	82.5 (79.1–86.5)	52,774	81.2 (76.9–84.8)	24.00
Mini-sized	7,116	51,331	25,110	83.2 (79.3–88.1)	22,484	81.7 (77.4–86.2)	30.11
P-value				<0.001		<0.001	
Ownership type							
State-owned	683	42,526	6,405	83.4 (80.1–87.6)	4,677	80.6 (76.9–84.1)	19.53
Collective	120	1,784	461	83.0 (79.8–86.2)	434	81.6 (78.1–84.3)	20.97
Joint-equity cooperative enterprises	221	9,246	1,425	83.0 (79.2–87.2)	1,196	81.6 (77.3–85.1)	25.42
Joint-operate	31	2,285	205	81.0 (78.4–84.7)	187	80.0 (76.0–84.1)	17.65
Private	6,421	114,065	29,957	83.0 (79.3–87.5)	25,687	81.4 (77.2–85.6)	27.91
Incorporated company	527	33,265	3,995	82.2 (78.5–86.0)	3,335	81.0 (76.8–84.3)	21.71
Limited liability company	10,062	275,998	60,573	82.8 (79.3–86.7)	54,075	81.3 (76.7–84.9)	24.70
Hong Kong, Macau, and Taiwan-invested enterprises	364	19,447	2,931	82.3 (79.1–86.2)	2,709	81.0 (75.9–84.3)	22.55
Foreign	476	26,638	3,625	82.3 (78.9–85.8)	3,167	81.1 (76.9–84.5)	22.99
Others	473	8,464	2,281	83.1 (79.3–87.6)	1,952	81.7 (77.1–85.8)	28.54
P-value				<0.001		<0.001	
Total	19,378	533,718	111,858	82.8 (79.3–87.0)	97,419	81.3 (76.9–85.0)	25.14

* $L_{Ex,8h}$: Normalization of equivalent continuous A-weighted sound pressure level to a nominal 8 hours working day. $L_{Ex,40h}$: Normalization of equivalent continuous A-weighted sound pressure level to a nominal 40 hours working week.

or exceeding 85 dB(A) were the highest in private and joint-equity cooperative enterprises. Incorporated enterprises were found to have the lowest occupational noise exposure risk, as shown by the medians of both environmental and individual noise exposure levels.

Conclusions and Comment

Surveillance of occupational hazards in the workplace has been carried out by the Chinese government since 2019. Occupational noise was selected as one of the major hazards in the surveillance, and more than a quarter of enterprises were from the manufacturing industry. The proportion of individual noise exposure levels equal to or exceeding 85 dB(A) was still high in the manufacturing industry. The medians of environmental noise exposure levels of all industries exceeded 80 dB(A), and the same was true of the individual noise exposure levels in eight industries except the manufacture of petroleum coke and other refined petroleum products. Based on the *Classification of Occupational Hazards at Workplaces Part 4: Occupational Exposure to Noise* (GBZ/T 229.4–2012), more than 50% of operating posts in those 8 divisions could be classified as having exposure to noise.

According to the surveillance results, the median of individual noise exposure levels was 82.2 dB(A), both in the manufacture of metal products and manufacture of motor vehicles, which were higher than the other divisions. However, as shown from the National Surveillance System of Key Occupational Diseases, the incidence of occupational noise deafness among the manufacture of metal products was much higher than that of the manufacture of motor vehicles in China. This may be due to the relatively high proportion of large and medium enterprises in the manufacture of motor vehicles, with better occupation health management and stronger self-protective awareness of workers (*4*). As for the manufacture of metal products, this category mostly consisted of small and mini-sized enterprises. The poor sense of self-protection results in serious hearing loss of workers in this industry. In addition, it is worth noting that there are methylbenzene, xylene, ethylbenzene, and other ototoxic substances exist in the other three industries with lower noise exposure level. Another study showed that combined exposure of ototoxic substances and noise was more likely to cause hearing loss than noise exposure at the same exposure level (*10*).

The analysis of the noise exposure levels among different enterprise-scales shows that the noise hazard of small and mini-sized enterprises was more serious than that of large and medium enterprises. This phenomenon was mainly due to the insufficient investment in noise control and lower technical levels among small and mini-sized enterprises (*11*). Meanwhile, more than 80% of enterprises in China were small and mini-sized enterprises, so it is urgent to increase investment in the occupational disease prevention of small and mini-sized enterprises (*4*). Furthermore, the individual noise exposure levels of private enterprises were about 1 dB(A) higher than that of state-owned enterprises, which was mainly related to the decreased investment in occupational disease prevention among private enterprises.

This is the first comprehensive report presenting noise exposure levels in manufacturing industry in China based on different divisions, enterprise-scales, and ownerships based on National Surveillance for Occupational Hazards in the workplace in 2020. The risk of noise exposure in the target industry is still high and will threaten the health of a large number of the worker population. The detailed insight of the noise exposure will provide the government evidence to improve the occupational health management and develop special governance measures in the target enterprises. Meanwhile, the data will also be used for the reversions of regulations related to occupational health and the implementation of national or local projects of occupational disease prevention and control. The limitation of this study is that we did not acquire the information of workers' occupational health during the surveillance. We will improve the method in the future study.

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Corresponding author: Weijiang Hu, Huwj@niohp.chinacdc.cn.

[1] National Institute of Occupational Health and Poison Control, Chinese Center for Disease Control and Prevention, Beijing, China.

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Perspectives

Senior Research Scholars in China CDC's National Immunization Program

Miao Wang[1]; Yanmin Liu[1]; Tingting Yan[1]; Lance Rodewald[1]; Zhijie An[1]; Zundong Yin[1,#]

China CDC's National Immunization Program's Senior Research Scholars Program (NIP-SRSP) is a program created to foster the professional development of early-to-mid-career immunization experts, strengthen knowledge exchange and cooperation between national and provincial/prefectural-level CDCs, and deepen scientific and programmatic capacity of the National Immunization Program and provincial/prefectural immunization programs. Initiated in September 2019, the NIP-SRSP recruits immunization professionals for a 12-to-18-month experience in Beijing who have worked at the Vice-Senior professional level or above and are recommended by their provincial/prefectural CDC supervisor and leadership. The first cohort of National Immunization Program Senior Research Scholars successfully completed the program and were recognized by CDC Director, Academician George F. Gao at a commencement ceremony on August 25, 2021.

SELECTION PROCESS

The program selection process is designed to ensure a good match between scholars' professional development interests and the national and provincial/prefectural immunization program needs and project opportunities. Selection starts with recommendations from prospective scholars' CDC supervisors and leadership. Successful candidates have a deep affinity for their career in immunization with fulfilling working experiences, excellent interpersonal skills, and strong teamwork spirit, and they are well organized and motivated to contribute to the mission of the National Immunization Program while in Beijing and to their home CDC upon completion of the program. Scholars must be less than 45 years of age when they start the program and have good English language skills. Their work experience should include conducting and managing studies and research projects.

TRAINING METHODS

SRSP combines theory and practice into a 12-to-18-month full-time experience in Beijing that includes weekly immunization seminars; participating and teaching in conferences on infectious diseases, vaccines, epidemiology, evidence-based medicine, and pharmacovigilance; and participation in the Chinese Vaccinology Course (CNVAC), which is organized by the University of Chinese Academy of Sciences (with a curriculum that includes a global overview of vaccines, immunization strategies for prevention and control of vaccine-preventable diseases, vaccine development and preclinical research, vaccine production processes and analytics, vaccine regulation, immunization policy making, challenges of immunization and vaccinology, and communications with the public and media).

Scholars complete one or more scientific or programmatic projects that align professional background, training needs, and goals of the scholar with the needs of the National Immunization Program. Scholars will be assigned to the appropriate branch of the immunization program for project mentorship and supervision. Currently, assignments are separated into three branches: 1) the Evidence-Based Decision-Making for Immunization Branch, which provides scientific support for the Technical Working Groups of the National Immunization Advisory Committee (NIAC) by conducting research on the methodology of evidence-based decision-making for immunization planning and providing methodological support for the formulation of technical guidelines for immunization; 2) the Vaccination and Immunization Services Branch, which conducts vaccination coverage surveillance, evaluation of vaccination service technologies, Immunization Information System development and use, programmatic policy and strategy development, technical guidelines and standards development, and school entry vaccination record check guidelines and evaluation; and 3) the Adverse Event Following Immunization (AEFI) Surveillance Branch, which conducts pharmacovigilance on all aspects of vaccine safety through a rigorous safety monitoring program jointly managed by China CDC and the National Medical Products Administration, identification and analysis of potential vaccine safety signals, formulation of vaccine safety technical guidelines, and monitoring vaccine-related public opinion.

Du Wen from Guizhou Provincial CDC and Wu Jing from Jiangxi Provincial CDC are the first graduates of this new program. Du Wen matched with the AEFI Branch to work with Dr. Li Keli, the branch chief. Ms. Du worked on the following: 1) monitoring the safety of China's new coronavirus disease 2019 (COVID-19) vaccines while they were under the Emergency Use Authorization in preparation for routine use; 2) evaluation of the National Regulatory Authority for vaccines to strengthen the capacity of AEFI surveillance and ensure that China meets or exceeds the World Health Organization's quality criteria; 3) updating the national AEFI surveillance guidelines with the most recent scientific evidence on vaccine safety monitoring; and 4) upgrading AEFI surveillance modules in Immunization Information Systems. Wu Jing matched with the Vaccination and Immunization Services Branch to work with Branch Chief Yu Wenzhou and deputy Cao Lei. Ms. Wu worked on the following: 1) a national level vaccination catch-up campaign to ensure that children who missed vaccinations due to the COVID-19 pandemic could be fully vaccinated — a campaign that immunized 94.4% of children who had missed the nearly 90 million doses of vaccines in total in the mainland of China (*1*); 2) the national COVID-19 vaccination campaign that protected frontline workers, working-age adults, older adults, and adolescents from COVID-19, providing over 1.9 billion doses of vaccine by the time that Ms. Wu graduated from the scholars program; and 3) an evaluation of COVID-19 vaccination breakthrough cases to characterize their severity and implications for effective use of COVID-19 vaccines. Upon completing the program, the two scholars returned to their home programs to bring their experiences back to their home CDCs.

EXAMINATION AND EVALUATION

Senior Research Scholars are evaluated on successful completion of their project or projects by the National Immunization Program and provincial/prefectural CDC leadership. Scholars are expected to prepare at least one manuscript for publication as first author in a core domestic or international journal level, to have participated in senior-level meetings, and to have presented at one or more national professional meetings. Upon successful completion of the Program, scholars will be awarded the Certificate of Accomplishment in the Senior Research Scholar Project of the National Immunization Program (Figure 1) and will receive an evaluation report on their work and experience. Scholars are to provide feedback to SRSP to help improve this relatively young program so that it meets the training and experience needs of early-to-mid-career professionals and helps advance their careers and the field of vaccines and immunization.

LOOKING FORWARD

The SRSP will become a mainstream program supported by the Chinese Centers for Disease Control and Prevention's National Immunization Program. SRSP supports professional development of early-to-mid-career immunization experts from provincial/prefectural level CDCs but is also designed to bring innovation and new ideas to China CDC. China's vaccine circulation law, which was enacted December 2019, requires provincial-level administrative divisions (PLADs) to implement a core immunization program, but it also allows PLADs to expand their program beyond the required core. For example, the Shanghai immunization program has discontinued the use of the live, oral poliovirus vaccine and has changed to an all inactivated poliovirus vaccination schedule in anticipation to similar changes nationally in future years; several PLADs are implementing an insurance-based vaccine injury compensation program to integrate compensation for program and non-program vaccine injuries into a

FIGURE 1. On August 25, 2021, China CDC Director George F. Gao awarded Certificates of Accomplishment to the first cohort of China CDC's National Immunization Program's Senior Research Scholar Program fellows (A) Du Wen and (B) Wu Jing.

single, evidence-based program; and several PLADs and prefecture-level cities have integrated influenza vaccine for school children into their program. Scholars will be able to bring their experience with such innovations to the national level, enriching the entire program.

The SRSP is poised to support new scholars every year into one-to-two-year programs of theory and practice. For future cohorts, all of the branches of the National Immunization Program will be available for scholars to consider. SRSP will ultimately cover all PLADs and sub-provincial cities in our country, strengthening and integrating scientific and programmatic immunization leadership to ensure success of China's vital mission to protect children, adolescents, and adults from vaccine-preventable diseases.

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Corresponding author: Yin Zundong, yinzd@chinacdc.cn.

[1] National Immunization Program, Chinese Center for Disease Control and Prevention, Beijing, China.

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