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 was lower than national standards, indicating that the dust prevention measures adopted by enterprises 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 were 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 was 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 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/m³, the silica dust limit=0.7 mg/m³.

† 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 is 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.

Funding: The National Natural Science Foundation of China (81472956, 30972449) and the Occupational Health Risk Assessment and National Occupational Health Standard Setting Project (131031109000150003) of the National Institute of Occupational Health and Poison Control, Chinese Center for Disease Control and Prevention.

Conflicts of Interest: No conflicts of interest reported.

doi: 10.46234/ccdcw2021.221

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.

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

REFERENCES

1. Yuan HD, Guo XJ, Cao Y, He LS, Wang JG, Xi BD, et al. Case study on incentive mechanism of energy efficiency retrofit in coal-fueled power plant in China. Sci World J 2012;2012:841636. http://dx.doi.org/10.1100/2012/841636.
2. National Energy Administration. 2020 national energy industry statistics published by national energy administration. 2021. http://www.nea.gov.cn/2021-01/20/c_139683739.htm. [2021-1-20]. (In Chinese).
3. National Energy Administration. National energy industry statistics from January to November published by the national energy administration. 2020. http://www.nea.gov.cn/2020-12/18/c_139600798.htm. [2020-12-18]. (In Chinese).
4. Han S, Chen H, Harvey MA, Stemn E, Cliff D. Focusing on coal workers' lung diseases: a comparative analysis of China, Australia, and the United States. Int J Environ Res Public Health 2018;15(11): 2565. https://www.mdpi.com/1660-4601/15/11/2565.
5. National Health Commission of the People's Republic of China. China statistical bulletin of medical and health development in 2019. 2020. http://www.nhc.gov.cn/guihuaxxs/s10748/202006/ebfe31f24cc145b198dd730603ec4442.shtml. [2020-6-6]. (In Chinese).
6. Lin CK, Lin RT, Chen T, Zigler C, Wei YG, Christiani DC. A global perspective on coal-fired power plants and burden of lung cancer. Environ Health 2019;18:9. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6350330/.
7. Lin SH, Wang ZM, Tang WJ, Wang JZ, Lan YJ, Wang PX. A methodological study on occupational hazard risk index. Chin J Ind Hyg Occup Dis 2006;24(12):769–71. https://kns.cnki.net/kcms/detail/detail.aspx?dbcode=CJFD&dbname=CJFD2006&filename=ZHLD200612028&v=2TKYoK16seMgafOfhlgRyceyDJJtRlvma2sglAkT3HegwAV4Lox24ua%25mmd2FGxJA3epC. (In Chinese).
8. Barnes H, Goh NSL, Leong TL, Hoy R. Silica‐associated lung disease: an old‐world exposure in modern industries. Respirology 2019; 24(12):1165 – 75. http://dx.doi.org/10.1111/resp.13695.
9. Tong RP, Liu JF, Ma XF, Yang YY, Shao GH, Li JF, et al. Occupational exposure to respirable dust from the coal-fired power generation process: sources, concentration, and health risk assessment. Arch Environ Occup Health 2020;75(5):260 – 73. http://dx.doi.org/10.1080/19338244.2019.1626330?journalCode=vaeh20.
10. Tang SH, Zhang H, Zhang JW, Ling WJ, Xu SX, Chen PX, et al. Occupational hazards and critical control factors in coal-fired power plants. Occup Health Emerg Rescue 2017;35(4): 369-72. https://kns.cnki.net/KCMS/detail/detail.aspx?dbcode=CJFQ&dbname=CJFDLAST2017&filename=ZYWS201704023&uid=WEEvREcwSlJHSldRa1FhcTdnTnhYaCswaVJaVEg2VDdUNmgxZnlXd3RRVT0=$9A4hF_YAuvQ5obgVAqNKPCYcEjKensW4IQMovwHtwkF4VYPoHbKxJw!!&v=MTMyMzVUcldNMUZyQ1VSN3FmWStkb0Z5emdXN3ZJUHpUY2ZiRzRIOWJNcTQ5SFo0UjhlWDFMdXhZUzdEaDFUM3E=. (In Chinese).