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The Efficiencies of different Dust Collectors and Characteristics of $PM_{2.5}$ Water-soluble Ions in Industrial Fluidized Bed Boilers

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Abstract. $PM_{2.5}$ were collected before and after dust collectors of five industrial fluidized bed boilers by $PM_{2.5}$ sampler. The ELPI was used to monitored the number and mass concentrations of $PM_{2.5}$ before and after the dust collectors, and the dust removal efficiencies of different dust collectors was analyzed. The efficiencies of electrostatic and bag filter dust collectors are high, and the efficiency of mechanical dust collector is low. NH_4^+, K^+, Mg^{2+}, Ca^{2+} cations, and F^-, Cl^-, NO_3^- , SO_4^{2-} anions were analyzed by ion chromatography. It was found that the contents of Ca^{2+} and SO_4^{2-} were higher in $PM_{2.5}$ samples, and the contents of Ca^{2+} and SO_4^{2-} were different among different boilers, The content of Mg^{2+} in cations is relatively low, the content of F^- in anions is relatively low, and $NO_3^-$is not detected in many samples.

1 Introduction

The industrial boiler is an important thermal power equipment in China, which plays an important role in industrial and residential heating. There are a large number of industrial boilers in China. Although the implementation of policies such as "coal to gas" and "large-scale demolition and small-scale" have reduced the number of coal-fired boilers, the number of coal-fired industrial boilers still accounts for an essential proportion of the total number of boilers, and fluidized-bed boilers have been widely promoted in China relying on the advantages of high combustion efficiency and low pollutant emission [2]. The smoke and dust emitted from industrial boilers are essential sources of $PM_{2.5}$, and the particulate matter emitted by the increasing number of fluidized bed boilers has become an essential source of $PM_{2.5}$[3].

Due to its large specific surface area and strong fluidity with airflow, $PM_{2.5}$ has strong scattering, and enction ability can attach therapeutic bacteria, which is easy to cause respiratory diseases and other diseases in the human body [4-6]. $PM_{2.5}$ is composed of water-soluble ions, heavy metal elements, carbon-containing components, et al., and water-soluble ions account for a large proportion of $PM_{2.5}$, which is considered to be an important chemical composition causing haze and other composite pollution [7-9]. The concentration of water-soluble ions presents seasonal characteristics, with the highest value in winter, which may be related to the increase of coal-fired and biomass combustion activities in winter [10]. The removal efficiencies of dust collectors are different, which resulted in different degrees of air pollution[11]. Therefore, it is of great significance to carry out water-soluble ion analysis for studying the chemical characteristics and traceability of $PM_{2.5}$ particles.

2 Test object

In this paper, five industrial fluidized bed boilers with different capacity and dust removal equipment were selected to collect $PM_{2.5}$ particle samples on the quartz membrane before and after the dust collector by $PM_{2.5}$ sampler. NH_4^+, K^+, Mg^{2+}, Ca^{2+} cations and F^-, Cl^-, NO_3^-, SO_4^{2-} ions in the samples were analyzed by ion chromatography. The samples were extracted by ultrasonic vibration, and no heating in the ultrasonic extraction processing, due to the NH_4^+ will volatilize if the samples were heated. Ion Chromatography（IC）was used for the measurement，the Dionex-600 produced by Diane company was selected for experimental analysis. The sampling point's layout of this experiment is shown in figure1.The capacity of industrial fluidized bed boilers and the type of dust collector are shown in Table 1.

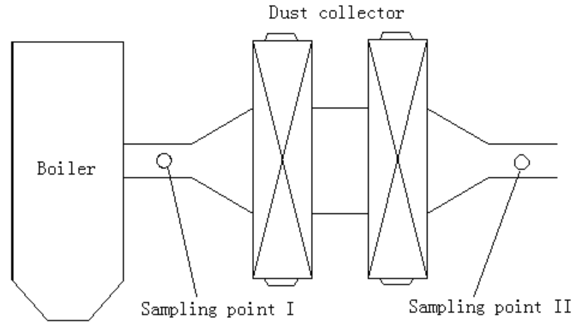

Fig 1. Schematic of the industrial fluidized bed boilers

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Table 1. The capacity of boilers and the type of dust collectors

Boilers	the test load （%）	rated load	dust collector
1#	95	73t	electrostatic
2#	98	20t	bag filter
3#	90	20t	bag filter
4#	100	40t	bag filter
5#	90	35t	water film

3 Test results and discussion

3.1 The dust removal efficiencies of dust collectors

The dust number and mass concentrations removal efficiencies of different boiler dust collectors are shown in figure 2 and figure3.

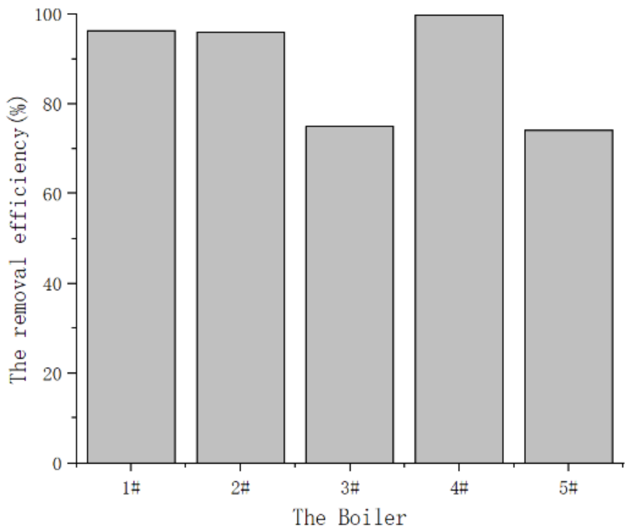

Fig 2. The removal efficiency of number concentrations

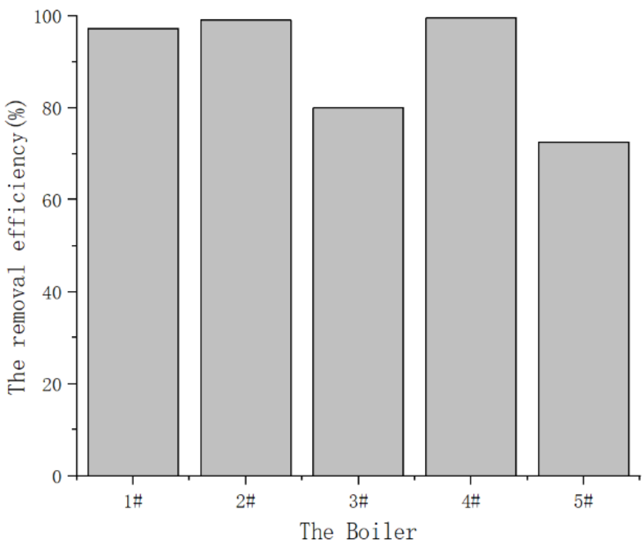

Fig 3. The removal efficiency of mass concentrations

The electrostatic dust collectore is used in the boiler 1#, the bag filter dust collectors are used in the boilers from 2# to 4#, and the old mechanical dust collector is used in the boiler 5#. It can be seen from Figure 2 and Figure 3 that different dust collectors have different dust removal efficiencies for $PM_{2.5}$. The removal efficiency of $PM_{2.5}$ in boiler 1#,2# and 4# is higher than others, due to the electrostatic or bag filter are used for dust removal. The highest removal efficiencies of $PM_{2.5}$ are more than 99% in some boiler dust collectors. The removal efficiency of $PM_{2.5}$ is about 75%, though the bag filter dust collector is used in the boiler 3#, maybe the bags in the dust collector are broken. In addition, a large number of particles are discharged from the dust collector with the flue gas when the bag is pilse back blowing, which reduces the dust removal efficiency[12]. The lowest dust removal efficiency is about 74% in the boiler 5#, which equipped the water film dust collector based on old mechanical dust removal principle.

3.2 The water-soluble ion contents of $PM_{2.5}$

The water-soluble ion content of $PM_{2.5}$ particles before and after dust removal in different industrial fluidized bed boilers are shown in Table2 to Table5.

Table 2 The cationic contents of $PM_{2.5}$ before dust removal (%)

Boiler	NH_4^+	K^+	Mg^{2+}	Ca^{2+}
1#	0.1069	0.0450	0.1210	1.9885
2#	0.5295	0.3821	0.0296	0.5763
3#	0.6163	0.2865	—	0.4009
4#	0.4185	0.7398	0.0273	0.1754
5#	0.2568	0.5990	0.0306	0.6196

Note: '- "means not detected or lower than the background value

Table 3 The anion contents of $PM_{2.5}$ before dust removal (%)

Boiler	F^-	Cl^-	NO_3^-	SO_4^{2-}
1#	0.6775	0.7777	1.6846	1.0196
2#	0.5842	0.5128	0.0049	1.1897
3#	0.2634	0.3812	—	4.5968
4#	0.6852	0.9707	0.0024	2.2374
5#	0.1670	0.4075	0.0015	2.6414

Note: '- "means not detected or lower than the background value

Table 4 The cationic contents of $PM_{2.5}$ after dust removal (%)

Boiler	NH_4^+	K^+	Mg^{2+}	Ca^{2+}
1#	2.9415	0.5226	0.9150	2.7771
2#	1.0985	0.4614	0.0187	1.4006
3#	0.6667	0.3019	0.0103	0.0470
4#	0.3338	0.2237	0.0203	0.6668
5#	0.4498	0.6630	0.0921	1.0081

Table 5 The anion contents of $PM_{2.5}$ after dust removal (%)

Boiler	F^-	Cl^-	NO_3^-	SO_4^{2-}
1#	0.4275	1.1481	1.4712	7.5746
2#	0.2608	1.6774	0.0274	3.1419
3#	0.5420	0.4872	—	2.8623
4#	0.0254	0.1665	—	—
5#	0.5404	0.7285	—	3.5986

Note: '- "means not detected or lower than the background value

In order to reduce the initial emission concentration of SO_2, the limestones are added to the coal to realize desulfurization in the bed boiler, and the adding limestones are the another source of $PM_{2.5}$ in fly ash. Terttaliisa found that a large number of limestone adsorbents were broken during coal combustion, and about 80% of the limestone adsorbents entering the furnace were dischanged in the form of fly ash[13]. It was found that a large number of fly ash particles only tooke Ca and Ca-S as the main compounds, and the adsorbent particles and fly ash particles did not aggregate together, but existed in the fly ash in the form of separate particles. The particle size of limestone adsorbent just entering the furnace is large, and the particle surface reacts with SO_2 to form a shell. With the extension of calcination process time and the release of CO_2, a large number of pores will be formed inside the absorbent particles, and SO_2 will enter the pores to react with CaO in the absorbent. The increase of particle pores makes the internal binding force decrease, some absorbent particles break and produce a large number of fine particles. The fine particles get away from the furnace and cyclone separator. The non fragile absorbent can return to the furnace through the separator to achieve higher desulfurization effect.

It can be seen from Table 2 to Table 5 that the content of Ca^{2+} in cations is relatively high, and the content of SO_4^{2-} in anions is relatively high, which is related to the desulfurization of fluidized bed boiler by adding limestone into the furnace. During the calcination process of limestone particles in the furnace, many pores will be formed, so SO_2 enters into the pores and reacts with CaO. When the absorbent particles break, many fine particles escape from the furnace and cyclone separator, resulting in relatively high contents of Ca^{2+} and SO_4^{2-} before and after the dust collector. The contents of Ca^{2+} and SO_4^{2-} in different boilers are different.

The content of Mg^{2+} in cation is relatively low, and the content of NO_3^- in anion is not detected in many samples, and the content of F^- is relatively low.

4 Summary

$PM_{2.5}$ was sampled before and after the dust collectors of five industrial fluidized bed boilers with different capacities and different dust removal equipments. The efficiencies of electrostatic and bag filter dust collectors are higher than 99% generally, and the efficiency of mechanical dust collector is low. The cations of NH_4^+, K^+, Mg^{2+}, $Ca^{2+}$and anions of F^-, Cl^-, NO_3^- and SO_4^{2-} were analyzed by ion chromatography. The contents of Ca^{2+} and SO_4^{2-} are higher in $PM_{2.5}$ samples collected. The contents of Ca^{2+} and SO_4^{2-} vary considerably among boilers due to the different proportions of limestone added to different boilers. The contents of Mg^{2+} and F^- in cations were relatively low and NO_3^- was not detected in many samples.

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