The characterization of PM2.5 composition in flue gasses discharged into the air from selected coal-fueled power plants in Jilin Province, China

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Abstract. According to the installed capacity, coal type and the kinds of environmental protection facilities of coal-fired power plants in Jilin Province in China, five typical coal-fired units were chosen. PM2.5 from final stack outlet of five typical units was gain by Dekati PM2.5(Finland). The characteristics of PM2.5 composition in flue gasses discharged into the air from selected coal-fueled power plants are analyzed in this paper.

1. Introduction
China’s sustained time long wave and large range of haze weather is better, but the PM2.5 pollution problem has not been[1]. Previous studies have shown that fire coal is one of the three major sources of PM2.5 pollution. Coal is still the most important energy in Jilin Province, and the total operation capacity of coal fired power plant is 14589MW, accounting for 70.19%. Researchers analyze the composition of PM2.5 in the Jilin Province, the hazy is caused by coal using[2,3]. Coal-fueled power plant is the bigger consumer in Jilin Province, about 318 million tons. PM2.5 research in Jilin Province is just in beginning. For providing energy and environmental policies to relevant departments, the composition of coal-fueled power plants flue gas outlet PM2.5 characteristics are still the first problem to solve.

From the perspective of environmental pollution and harm to human beings, the heavy metals and environmental risk elements of PM2.5 were analyzed. At the same time, the characteristics of soluble ions were analyzed. Element analysis includes Al, Ag, Au, As, B, Ba, Be, Bi, Ca, Cd, Co, Cr, Cu, Fe, Ga, Hg, Mg, Mn, Mo, Ni, P, Pb, Pt, Sb, Se, Si, Sn, Sr, Ti, Tl, W, V, Zn, a total of 33 elements. Soluble ions include NH4+, Li+, Na+, K+, Ca2+, Mg2+, F-, Cl-, NO2-, SO32-, SO42-, NO3-, a total of 12 ions.

2. Experiment process and results

2.1. The information of select coal-fueled power plants
There are five coal-fueled power plants with 200MW units, eleven coal-fueled power plants with 200MW units and three coal-fueled power plants with 600MW units.

Azabache form Inner Mongolia, bituminous coal from Heilongjiang and local coal from Jilin province are mainly used in Jilin Province coal-fueled power plants. Bituminous coal from
Heilongjiang is used by three coal-fueled power plants, accounting for 15.59%. Only two coal-fueled power plants used local coal from Jilin province, accounting for 10.53%. Most of them use Azabache form inner Mongolia.

Electrostatic precipitator is mostly used Jilin Province, nine coal-fired power plants using electrostatic precipitator, accounting for 47.36%. The using proportion of bag filter and electrostatic fabric filter is same, 26.32%.

Denitrification device is partly used in Jilin Province coal-fired power plants. Three coal-fueled power plants which are installed denitrification device, only one coal-fired power plant is using SNCR and all the other is using SCR.

Due to the new emission standard, the coal-fired power plants which installed DFGD change DFGD to FGD. Now all the coal-fired power plants are using FDG.

According to the installed capacity, coal type and the kinds of environmental protection facilities of coal-fired power plants in Jilin Province in China, one coal-fired power plant with 200MW units, three coal-fueled power plants with 300MW units and one coal-fired power plant with 600MW units was selected. The detail information is in the table 1.

| Code | Area       | Type of Coal              | Install Capacity | Dust collector | Denitrification device | Desulfurization device |
|------|------------|---------------------------|------------------|----------------|------------------------|------------------------|
| A    | Jilin City | Bituminous coal from Heilongjiang | 200MW            | Electrostatic fabric filter | ----       | FGD                    |
| B    | Changchun  | Azabache from Inner Mongolia | 300MW            | Bag filter     | SCR                    | FGD                    |
| C    | Changchun  | Azabache from Inner Mongolia | 300MW            | Electrostatic precipitator | SCR        | FGD                    |
| D    | Baishan    | Coal from Jilin           | 300MW            | Electrostatic fabric filter | SCR        | FGD                    |
| E    | Jiutai     | Azabache from Inner Mongolia | 600MW            | Electrostatic | SCR                    | FGD                    |

2.2. Sample collection
Gas through dehumidification tube which Nafion is put in, in the tube’s outter layer, using dry air remove the water. Summing the characterization of all of coal power plants flue gas particulate matter by electron microscope, 30L/min is the best flow speed for drying dehumidification tube, impostor cutting effect is achieved. Dehumidification tubes within insulation layer eliminate moisture condensation. According to different dust collector, the collection of samples is not same, ESP 2 hours, others 3 or 4 hours.

2.3. Analysis of elementals
Samples were dissolved by aqua regia and analysis by ICP (IC-1100, Thermofisher, USA)

2.4. Analysis of soluble ions
The samples were dissolved by ultrapure water and analysis by IC-1100 (Thermofisher, USA) and DX-600 (DIONEX, USA.).

2.5. Experiment result
The tables show the result of analysis of elementals and soluble ions.
Table 2. The element percentage of coal power plants flue gas outlet PM2.5.

| Elements | A   | B   | C   | D   | E   |
|----------|-----|-----|-----|-----|-----|
| Al (%)   | 4.12| 4.58| 3.22| 4.67| 4.19|
| B (%)    | 0.18| 0.36| 0.58| 0.39| 0.76|
| Ba (%)   | 0.09| 0.09| 1.00| 0.30| 1.30|
| Ca (%)   | 0.51| 1.28| 1.78| 0.85| 2.32|
| Cr (%)   | 0.26| 0.31| 2.93| 1.78| 1.21|
| Cu (%)   | ----| ----| 1.72| ----| 1.24|
| Fe (%)   | 3.42| 1.85| 7.78| 5.85| 4.11|
| Ga (%)   | 0.06| 0.07| 0.08| 0.08| 0.13|
| Hg (%)   | ----| ----| ----| ----| 0.56|
| Mg (%)   | 0.47| 7.56| 1.55| 1.16| 2.01|
| Mn (%)   | 0.15| 0.11| 0.51| 0.30| 0.67|
| Mo (%)   | 0.46| 0.53| 0.38| 0.27| 0.50|
| Ni (%)   | ----| ----| 0.62| 0.01| 1.11|
| P (%)    | 0.42| 0.21| 0.24| 0.57| 0.33|
| Se (%)   | 4.88| 4.96| 2.88| 2.29| 3.74|
| Sr (%)   | 11.85| 4.32| 3.34| 5.77| 4.34|
| Sn (%)   | 0.39| 0.27| 0.18| 0.75| 0.24|
| Zn (%)   | 0.09| 0.15| 0.67| 1.40| 0.87|

Ag, As, Au, Be, Bi, Cd, Co, Pb, Pt, Sb, Sr, Ti, Tl, V, W, Zn is not detected

3. Results and discussion

Table 2 shows that the trend of elements and the content of each element of PM2.5 the coal and flue gasses discharged into the air from selected coal-fueled power plants are similar, and the percentage of Si, Al and Fe is the highest. Due to the stable physical and chemical of SiO₂, Si as silicate or SiO₂ in coal keep stable at high temperature. After high temperature burning, most of Si is removed by dust collector as fly ash, and the other comes into the desulfurization tower with flue gas. Crystalline SiO₂ melt or adhere to be larger specific surface fine particulate silicon compounds as the skeleton of SiO₂. Fine crystalline SiO₂ can lead to pulmonary fibrosis and silicosis. Because of the large specific surface area of fine particles, toxic and harmful substances in the flue gas attached to particles easily, forming more toxic compound pollutants.

Table 3. The soluble ions percentage of coal power plants flue gas outlet PM2.5.

|          | Na⁺(%) | NH₄⁺(%) | K⁺(%) | Mg²⁺(%) | Ca²⁺(%) | F⁻ | Cl⁻ | NO₂⁻(%) | SO₄²⁻(%) |
|----------|--------|---------|-------|---------|---------|----|-----|---------|---------|
| A        | 4.85   | 2.85    | 1.94  | 0.31    | 0.29    | 0.22| 0.71| 8.62    | 24.31   |
| B        | 2.13   | 4.45    | 1.97  | 4.94    | 0.72    | 0.35| 0.68| 10.74   | 23.11   |
| C        | 1.68   | 8.26    | 1.20  | 1.01    | 1.00    | 0.33| 0.55| 9.67    | 19.15   |
| D        | 1.88   | 6.31    | 1.77  | 0.76    | 0.48    | 1.33| 1.17| 13.81   | 17.32   |
| E        | 1.73   | 6.79    | 1.61  | 1.32    | 1.30    | 0.34| 0.87| 12.85   | 18.31   |
Figure 1. Ion chromatography of negative ions in coal power plant flue gas outlet PM2.5.

Arsenic is considered to be the symbol of coal pollution. The percent of As in the range of 0.24 ~ 70.83g/t coal in China[4]. Most of As is in organic form in coal, partly in the inorganic form of FeS₂As or As₅S₃. As is an reduction element[4], after combustion the valence of As trivalent risen. In PM2.5 from coal-fueled power plants flue gas outlet, As was not detected, but the coal contained arsenic trace, so it can be concluded that after the coal burning As was reduced to arsenic oxides and removed by dust collector.

In addition to the above elements, Ba, Be, Bi, Ga, Mo, P, Sb, Se, Sn were also detected. The total percentage of these elements in PM2.5 is low, less than 5%.

From the figure 1, there is no characteristic peak of SO₃²⁻ and NO₃⁻. Therefore, PM2.5 in flue gases, nitrogen oxide mainly exists as NO₂⁻; sulfur oxide mainly exists as SO₄²⁻. Table 3 shows The soluble ions percentage of coal power plants flue gas outlet PM2.5.

PM2.5 in flue gases discharged into the air from selected coal-fueled power plants in Jilin Province is mainly composed of the fly ash which as the coal after burning and doesn’t remove by the dust, adsorbing lots of gas molecules, such as NOx and SO₃. Soluble inorganic ions take the most part of PM2.5, SO₄²⁻ comes the first, NO₂⁻ second. The content of fluoride and chloride is very low.

Reference
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