Characteristics and Source Analysis of PM₁₀ and PM_{2.5} in Shizuishan City, Ningxia Hui Autonomous Region

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Abstract. This paper sets up monitoring points in Shizuishan City to perform characteristics and source analysis of PM_{2.5} in Shizuishan City, Ningxia Hui Autonomous Region according to the Technical Guide for Analyzing the Source of Atmospheric Particulate Matters (trial). The results show that the main ionic components in the air particulate matters of PM₁₀ and PM_{2.5} in Shizuishan are SO₄²⁻, NO₃⁻ and Ca, thereby providing a technical basis for improving the air quality in Shizuishan City.

1 Introduction

The constant increase of human industrial production leads to frequent occurrence of dust-haze in urban areas. Dust-haze contains toxic and harmful substances, which are very harmful to humans. Dust-haze is stable in nature, difficult to degrade, and can be transported further by the atmosphere [1-3]. Atmospheric particulates such as PM_{2.5} and PM₁₀ play an important role in the formation of the dust-haze [4]. Due to the excessive emissions of atmospheric pollutants from industrial production [5], the dust-haze, mainly composed of PM_{2.5} and PM₁₀, has become a serious pollution problem in China's major cities, causing great harm to human health as well as social, economic and ecological environment [6-7]. Therefore, it is of great significance to study the effects of pollution sources in specific cities on the atmospheric quality of urban centers so as to reveal the characteristics and source of PM₁₀ and PM_{2.5}.

2 Research methods and treatment

The existing research at home and abroad shows that the PM_{2.5} is mainly generated from human activities. Urban PM_{2.5} can be mainly divided into 9 types: soil wind dust, construction cement dust, coal dust, dust from diesel/heavy oil combustion, petrochemical fuel/fuel emissions, dust from metallurgical chemical industry, motor vehicle emissions, dust from biomass fuel combustion, and dust from secondary conversion source. Source characteristic identification elements of atmospheric PM₁₀ and PM_{2.5} emission are shown in Table 1.

Table 1. Characteristic identification elements of atmospheric PM₁₀ and PM_{2.5} emission sources

Emission source type	Feature identification element
Soil dust	Al, Fe, Si, Ti, Ba, Mn, Na
Building cement dust	Ca, Mg
Coal dust	As, Cu, Cd
Combustion of diesel and heavy oil	Cu
Emissions of petrochemical fuels and fuels	Ni
Metallurgy and chemical industry	Fe, Mn, Zn, Cd, Cu, Pb, Cr
Motor vehicle emissions	Zn, Cu, Pb
Biomass fuel combustion	K
Secondary transformation source	NH ₄ ⁺ , NO ₃ ⁻ , SO ₄ ²⁻

According to the statistics of national pollution source census, the industries that cause air pollution in Shizuishan City mainly include 5 categories, involving 129 large and medium-sized enterprises, accounting for 48% of the total (271), of which ferroalloy smelting and carbon products manufacturing companies account for 14% of the total. This paper sets up monitoring points for elemental analysis of PM₁₀ and PM_{2.5}, and uses SPSS 16.0 statistical software and EIAProA 2008, a professional auxiliary system for atmospheric environmental assessment, for data processing according to the Technical Guide for Analyzing the Source of Atmospheric Particulate Matter (trial).

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3 Analysis of pollutants and raw materials of enterprises in key industries

According to the statistics of national pollution source census, the industries that cause air pollution in Shizuishan City mainly include 5 categories, involving 129 large and medium-sized enterprises, accounting for 48% of the total (271), of which ferroalloy smelting and carbon products manufacturing companies account for 14% of the total.

After investigation and key monitoring, this paper selects thermal power generation, carbon and calcium carbide ferroalloy as key industries for component analysis based on the distribution characteristics of industrial enterprises in Shizuishan City. For the thermal power generation industry, the author chooses Dawukou Power Plant Co., Ltd. and Tianrui Power Plant; for the carbon industry, Yonggang Carbon (forging furnace); for the calcium carbide ferroalloy industry, Dadi Chemical No. 1 Plant (Silicon-manganese furnace) and Kunhui Gasification (Calcium carbide furnace). Monitor and take samples of the flue gas emitted by the five companies, and analyze the composition and content of its 29 main ions through the elemental spectrum analysis of waste residue and raw material products.

The elemental spectrum analysis of the five key enterprises is shown in Figure 1. It can be seen that the heavy metal with the highest content in the flue gas of the Dawukou Thermal Power Company is Ca. Its content is $411 \mu\text{g}/\text{m}^3$, accounting for 27.2% of all elements. The second highest content is Ba, with the content of $268 \mu\text{g}/\text{m}^3$, accounting for 7.7% of all elements. The third highest is Mn, with the content of $221 \mu\text{g}/\text{m}^3$, accounting for 14.6%. The soluble ion is mainly SO_4^{2-} , with the content of $72 \mu\text{g}/\text{m}^3$, accounting for 4.76%, and it is much larger than that of the chloride ion.

The heavy metals in the flue gas of Tianrui Power Plant is Ba. Its content is $602 \mu\text{g}/\text{m}^3$, accounting for 36.8% of all elements. The next highest is Ca, with the content of $597 \mu\text{g}/\text{m}^3$, accounting for 36.6%. The third highest is Fe, with the content of $222 \mu\text{g}/\text{m}^3$, accounting for 3.6%. Soluble ion mainly includes SO_4^{2-} and chloride ion.

The heavy metal of the highest content in the flue gas emitted by Dadi Chemical No. 1 Plant (silicon-manganese furnace) is Mn. Its content is $396 \mu\text{g}/\text{m}^3$, accounting for 29.9% of all elements. The next highest is Ca with the content of $379 \mu\text{g}/\text{m}^3$, accounting for 28.6%. The third highest is Ba with the content of $342 \mu\text{g}/\text{m}^3$, accounting for 25.8%. The soluble ions are mainly chloride and SO_4^{2-} .

The heavy metals of the highest content in the flue gas emitted by Yonggang Carbon (General Forging Furnace) is Ca. Its content is $11100 \mu\text{g}/\text{m}^3$, accounting for 53.6% of all elements. The second highest is Ba, with the content of $6400 \mu\text{g}/\text{m}^3$, accounting for 36.9% of all elements. The third highest is Zn with the content of $1770 \mu\text{g}/\text{m}^3$, accounting for 8.54%. The soluble ion mainly includes chloride ion, with the content of $112 \mu\text{g}/\text{m}^3$, which is much larger than that of SO_4^{2-} .

The heavy metal with the highest content in the flue gas emitted by Kunhui Gasification (calcium carbide

furnace) is Ca. Its content is $436 \mu\text{g}/\text{m}^3$, accounting for 44.3% of all elements. The second highest is Ba, with the content of $412 \mu\text{g}/\text{m}^3$, accounting for 41.9% of all elements. The third highest is Zn with the content of $48 \mu\text{g}/\text{m}^3$, accounting for 4.88%. The main soluble ions are chloride and SO_4^{2-} .

From the composition of flue gas emitted by various industries, it can be seen that the enterprises in the key industries of Shizuishan City produces the exhaust gas with different elements. The exhaust gas pollutants mainly contain 7 elements, including SO_4^{2-} , Ba, Zn, Ni, Fe, Mg, Ca, and Mn. It can be seen from their proportion that the major pollutants emitted by the major polluting enterprises in Shizuishan City are Ca, Ba, Zn, soluble ions sulfate and ammonium ions.

Fig. 1. Element spectrum analysis of 5 key companies

4 Elemental spectrum analysis of PM₁₀ and PM_{2.5}

The manual monitoring method is used to continuously collect the data of PM₁₀ and PM_{2.5} in the ambient air of the four state-controlled sites in the city for 23 days. The ICP-MS (inductively coupled plasma emission spectrometer) is used to analyze the 22 common elements and 9 anions and cations in the PM₁₀ and PM_{2.5} dust films at the Dawukou District, Huinong urban area, Hongguozu Town, and Shahu tourist area so as to preliminarily infer the source of these particulate matters.

The proportion of metal elements and anions and cations of PM_{2.5} is shown in Figure 2, and that in PM₁₀ is shown in Figure 3. From the monitoring results, it can be seen that the main elements of PM_{2.5} in Dawukou District are SO_4^{2-} , Ca, NO_3^- , NH_4^+ and K^+ , accounting for 32%, 18%, 16%, 9.6% and 5%, respectively. The main elements in PM₁₀ are SO_4^{2-} , NO_3^- , Ca, NH_4^+ and K^+ , accounting for 34%, 19%, 14%, 8.9% and 4.1%, respectively.

In Huinong urban area, the main elements of PM_{2.5} are SO_4^{2-} , Ca, NO_3^- , NH_4^+ , and Na^+ , accounting for 32%, 20%, 19%, 11%, and 4.7%, respectively. The main elements in PM₁₀ are SO_4^{2-} , NO_3^- , Ca, NH_4^+ and Na^+ , accounting for

29%, 20%, 11%, 8.5% and 4.8%, respectively.

Fig. 2. Proportion of metal elements and anions and cations in PM_{2.5}

In Hongguozi Town, the main elements of PM_{2.5} are SO₄²⁻, NO₃⁻, Ca, NH₄⁺, and Na⁺, accounting for 39%, 15%, 14%, 10%, and 3%, respectively. The main elements in PM₁₀ are SO₄²⁻, NO₃⁻, Ca, NH₄⁺ and Na⁺, accounting for 28%, 21%, 19%, 8.4% and 3.8%, respectively.

In Shahu tourist area, the main elements of PM_{2.5} are SO₄²⁻, NO₃⁻, Ca, NH₄⁺ and Na⁺, accounting for 34%, 13%, 12%, 9.8% and 4.3%, respectively. The main elements in PM₁₀ are SO₄²⁻, NO₃⁻, Ca, NH₄⁺ and Na⁺, accounting for 38%, 16%, 11%, 8.5% and 3.1%, respectively.

The proportion of each element of PM_{2.5} in Shizuishan City is: SO₄²⁻(35%) > Ca(16%) > NO₃⁻(15%) > NH₄⁺(10%) > K⁺(4.2%) > Na⁺(3.7%) > Ba(0.14%). The proportion of each element of PM₁₀ in Shizuishan City is: SO₄²⁻(33%) > Ca(13%) > NO₃⁻(19%) > NH₄⁺(8.6%) > K⁺(3.3%) > Na⁺(3.7%) > Mg(1.2%) > Ba(0.10%)..

Fig. 3. Proportion of metal elements and anions and cations in PM₁₀

5 Conclusion

In Shizuishan city, the coal-fired power plants emit calcium carbide and ferroalloys. In the flue gas, the heavy metal elements are mainly calcium, barium, and magnesium, while the main water-soluble ions are sulfate ions (SO₄²⁻) and nitrate ions (NO₃⁻). By analyzing the composition of the filter membranes of PM₁₀ and PM_{2.5} at each site, this paper finds out that the smoke emitted by industrial enterprises leads to higher concentrations of Ca and sulfate in PM₁₀ and PM_{2.5}. The SO₂ emissions in Huinong urban area are relatively large, and the SO₂ exceeding standard rate in the ambient air is high.

The main ionic components of PM₁₀ and PM_{2.5} in the ambient air of Shizuishan City are SO₄²⁻, NO₃⁻ and Ca. In Dawukou urban area, the main elements of PM_{2.5} is SO₄²⁻ and NO₃⁻, accounting for 32% and 16% of all elements, respectively; In Huinong District, SO₄²⁻ and Ca, accounting for 32% and 20%; in Hongguozi Town, SO₄²⁻ and Ca, accounting for 39% and 14%; In Shahu tourist district, SO₄²⁻ and NO₃⁻, accounting for 34% and 13%, respectively. The main ionic components in PM₁₀ and PM_{2.5} are basically the same as the components of pollutants and flue gas emitted by the key enterprises.

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