Study on the Hazards and Treatment Methods of PM2.5

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Abstract: PM2.5 is a particulate matter in the atmosphere that can enter the lungs with a diameter of less than or equal to 2.5 microns. This article discusses the harm of PM2.5 to the human body and the environment and comprehensively introduces the source and mode of PM2.5. Studies have shown that the sources of PM2.5 are divided into natural causes (volcanic ash, pollen ash) and human causes (transportation, agriculture, industry, etc.). This paper reveals that PM2.5 can affect visual visibility and contribute to climate change, exacerbate the greenhouse effect, and cause cardiovascular diseases and negative effects on overall human health. This paper also proposes the treatment methods of PM2.5 in each period from the source, process, and end. Research shows that the treatment technology for PM2.5 is becoming more mature, but there is still room for improvement, such as achieving high efficiency and energy saving of treatment materials, and the integration of existing technologies. People should use a variety of methods to effectively reduce PM2.5 concentration, protect the atmospheric environment, and maintain human public health.

Keywords: PM2.5, hazards, treatment methods, human health, gaseous particulate matter.

1. Introduction

Particulate matter is a variety of solid or liquid particles that are uniformly dispersed in an aerosol system. Pollution sources can emit particulate matter directly into the environment, or emit substances such as sulfur dioxide, nitrogen dioxide, and volatile organic compounds. These substances are converted into particulate matter by atmospheric chemistry. Particles are generally divided into PM50, PM10, PM2.5, and PM0.1 according to size. Particulate pollution is a burden of global pollution, with smaller particles having greater health impacts [1]. PM2.5 refers to particulate matter in the atmosphere with a diameter of less than or equal to 2.5 microns that can enter the lungs, which can be suspended in the atmosphere for a long time, thus causing haze weather. Smog is an environmental pollution that people are very likely to come into contact within their daily lives, so people's attention to PM2.5 has also increased. The World Health Organization (WHO) reports that air pollution killed 4.2 million people in 2016.

Particulate matter, as the main component of outdoor air pollution, is classified as a Group 1 human carcinogen by the International Agency for Research on Cancer. PM2.5 can have important effects on multiple systems, and increased PM2.5 exposure is positively associated with CVD morbidity and mortality [2]. During 2000~2021, the spatial changes of PM2.5 exposure risk in urban agglomerations in China were significant. The high-risk areas of PM2.5 population exposure are concentrated in the Beijing-Tianjin-Hebei urban agglomeration, the Yangtze River Delta urban agglomeration, and the central Shanxi urban agglomeration, and the low-risk areas are concentrated in the urban agglomeration on the northern slope of the Tianshan Mountains, the Lanxi urban agglomeration and the Yanhuang urban agglomeration in Ningxia. In addition, there is a significant positive correlation in the risk of PM2.5 population exposure in China's urban agglomerations, and the characteristics of spatial agglomeration are obvious [3]. The high aerosol concentration in China is closely related to the large emissions from anthropogenic pollution sources caused by the large population and rapid economic development [4]. Especially in the rapidly developing Yangtze River Delta and the Beijing-Tianjin-Hebei region, high aerosol concentrations and high population densities can cause significant haze weather. It not only affects the aesthetics of the local city's image, but also causes health problems for residents that cannot be ignored. In the long run, it will bring a lot of blows to the vitality of social and economic development, have a serious impact on the ecological environment, and bring

great pressure to local hospitals. Therefore, rapid action is needed to combat PM2.5. The following article will introduce the hazards of PM2.5 and how to deal with it in detail.

2. The Harm Caused by PM2.5

2.1. The Source of PM2.5

(1) Natural causes: Natural sources refer to particulate matter released to the environment due to natural causes, such as dust from the ground, salt particles splashed by seawater, volcanic eruptions, forest fires, weathering of soil rocks, and pollen, spores, and bacteria from plants [5]. Some groups have pointed out that PM2.5 caused by natural causes is negligible, but this is not the case. The 2023 Canadian wildfires seriously threaten the air quality in the surrounding areas. The smoke from wildfire spread to many major cities in North America. In early June, air quality alerts were issued on the East Coast and Midwest of the United States. At the end of June, Montreal, Quebec, Canada, was surrounded by smoke and dust, making it the worst city in the world for the day. At the same time, more than 20 states in the United States have issued air quality alerts again, and some areas have issued severe pollution alerts, putting about 100 million people in the United States at risk of potential health threats [6]. It can be seen that particulate matter caused by natural causes can still have a huge negative impact on human life, exacerbate the greenhouse effect, and damage the ecological environment.

(2) Anthropogenic causes: As can be seen in Figure 1, natural sources account for only a small part of the total PM2.5 generation sources in Guangzhou. And the proportion of each source in the three years of 2020~2022 has not fluctuated much. This shows that in today's cities, the impact of anthropogenic air pollutants is far greater than that of natural causes.

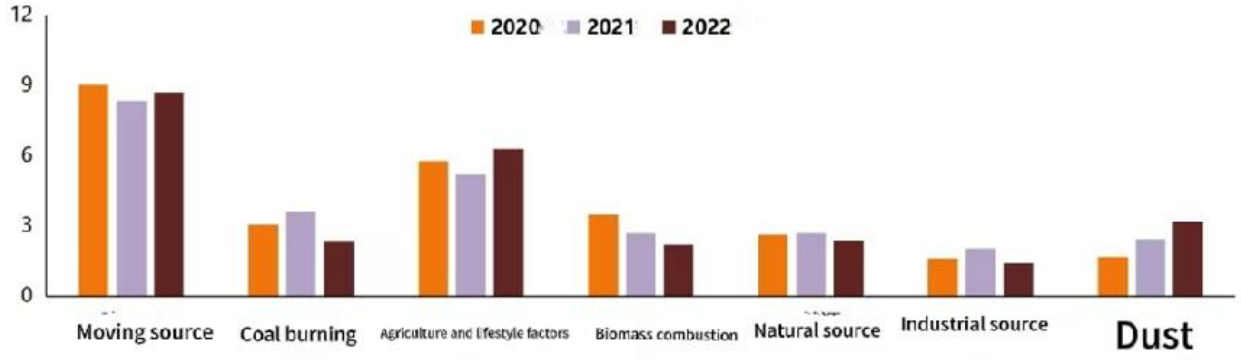

Fig. 1 PM2.5 sources in Guangzhou, China, 2020~2022 [7]

In human influence, the transportation industry, as a basic industry and service industry for national economic and social development, is also the carrier of logistics and passenger flow in social and economic activities and plays an important role in the country's economic and social development. At the same time, transportation is a key sector for oil consumption and is one of the important sources of greenhouse gas and air pollution emissions [8]. At the same time, the emissions caused by the combustion process can be said to be the main cause of PM2.5, which produces a large amount of sulfur dioxide, ammonia, nitrogen oxides, and many volatile organic compounds in industrial production such as chemical industry, metallurgy, electric power, and tobacco. This organic matter can drift into the atmosphere and become part of the pollutant. In agricultural production, a series of behaviors such as burning bellflower and burning fields will also produce atmospheric particulate matter, and the processing of particulate matter is more troublesome because the agricultural production site is an open environment. In addition to this, there are also reasons such as household coal burning, road construction, house demolition, and fireworks.

2.2. Harm to People

As shown in Figure 2, atmospheric particulate matter produced by human activities is dispersed in the air, and people breathe in the air carrying particulate matter. In people, nasal cilia and nasal mucus absorb and block most particulate matter, inhalable particles larger than 10 microns are kept out of the nose, and some can be excreted through sputum. Particulate matter between PM2.5 and PM10 can enter the upper respiratory tract and penetrate the lungs and affect the human body.

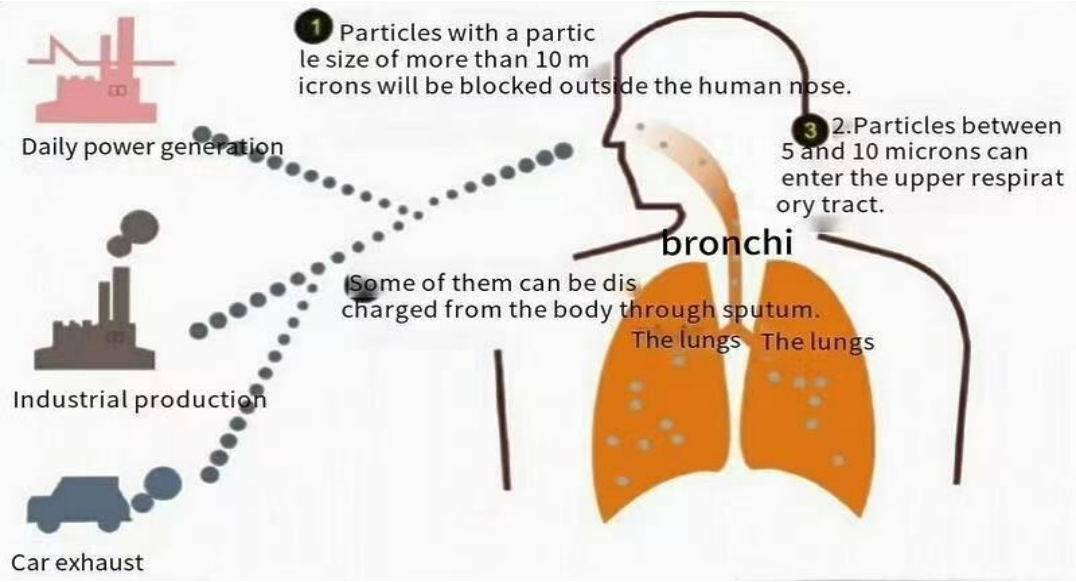

Fig. 2 Pathway of PM2.5 into the lungs [9]

Epidemiological studies over the past 20 years have shown that fine particulate matter from air pollution is significantly associated with morbidity and mortality from respiratory diseases [10]. PM2.5 can cause multiple harms to human health, and it can affect the respiratory, cardiovascular, and central nervous systems by causing pneumonia and oxidative damage, triggering systemic inflammatory responses and neuromodulatory changes [11]. PM2.5 can adsorb a wide variety of organic pollutants and heavy metals. It can be considered that the more substances adsorbed in the air, the greater the harm to the human body. PM2.5 is very easy to adsorb organic pollutants such as polycyclic aromatic hydrocarbons and heavy metals, which significantly increases the probability of carcinogenicity, teratogenicity, and mutagenicity. The elderly, children, and people with heart and lung diseases are sensitive to infection. Polycyclic aromatic hydrocarbons (PAHs) are associated with the morbidity and mortality of lung cancer in residents. Most PAHs in the air are adsorbed on the surface of the particulate matter, and the more particulate matter in the air, the more opportunities we have to come into contact with the carcinogen, PAHs [12].

2.3. Harm to the Environment

PM2.5 is the main cause of haze weather, which seriously affects the visibility of travel in the case of haze weather, and reduced visibility poses a huge threat to the safety of ground traffic and the take-off and landing of aircraft, and will also affect the ecological environment and climate change [13]. It has an indelible impact on global warming and the intensification of the greenhouse effect.

3. The Treatment Method of PM2.5

3.1. Source Control

Publicity of relevant departments: Relevant departments need to strengthen the education of the masses on PM2.5-related knowledge, and go to primary and secondary schools to carry out popular science lectures on PM2.5 prevention and control. Cultivate residents' awareness of the protection of the atmospheric environment, and take the reduction of PM2.5 content as a human consensus.

Traffic control: Promote new energy vehicles and optimize traffic flow. It is possible to reduce the number of vehicles by limiting the number of vehicles, and car manufacturers should also do a good job of optimizing the exhaust emissions of automobiles. Promote the development of the tram industry and increase the proportion of trams. From 2014 to 2017, Beijing's ambient air quality improved year by year, but there was no significant change in air quality in 2018 compared with 2017. In the past 5 years, the pollutant concentration index values on non-restricted Saturdays have always been high, and the air pollution level is worse than that on other days of the week, and the air quality on non-restricted Sundays is not significantly worse during the week compared with Saturdays, and is generally at the middle level. The air quality on restricted days is generally better during the week, but there are also cases where the air quality level on restricted days is still lower than on non-restricted Sundays. This indicates that the policy measures of traffic restriction have a certain effect on the air quality of Beijing, and the effect is more reflected in the fact that the air quality on restricted days is generally better than that on non-restricted Saturdays [14].

Industrial emission reduction: Adopt cleaner production technology and improve energy efficiency. Reduce the use of traditional fossil energy, and a large amount of dust will be generated in the process of mining traditional fossil energy, which will bring irreversible damage to the ecological environment, destroy soil nutrients and human habitation, and reduce the land available for human life. Optimizing the energy mix and carrying out technological innovations are the most important parts of the industry at present.

Reducing emissions in agriculture: Reduce the number of burning bellflowers, and release a large amount of CO2, CO, SO2, and NOx in the process of straw burning, especially CO2 and NOx, which are the main sources of greenhouse effect. In addition to releasing a large number of harmful gases, straw burning also produces a large number of inhalable particles (PM10), which seriously endanger health. For example, the open burning of straw produces a large amount of smoke and dust to form a dense fog, resulting in a decrease in visibility, which directly affects the normal operation of civil aviation, railways, and highways, and brings traffic hazards [15].

3.2. Process Control

Environmental monitoring: real-time monitoring of PM2.5 concentration, timely take corresponding measures.

Electrostatic precipitator method: the dust-containing polluted air is first filtered by the filter screen, and then when it passes through the ionization section, the dust particles are positively charged by the combination of dust particles and positive ions, and then they are discharged to the cathode surface and deposited, and the dust-free air is discharged into the atmosphere after passing through the device (Fig. 3).

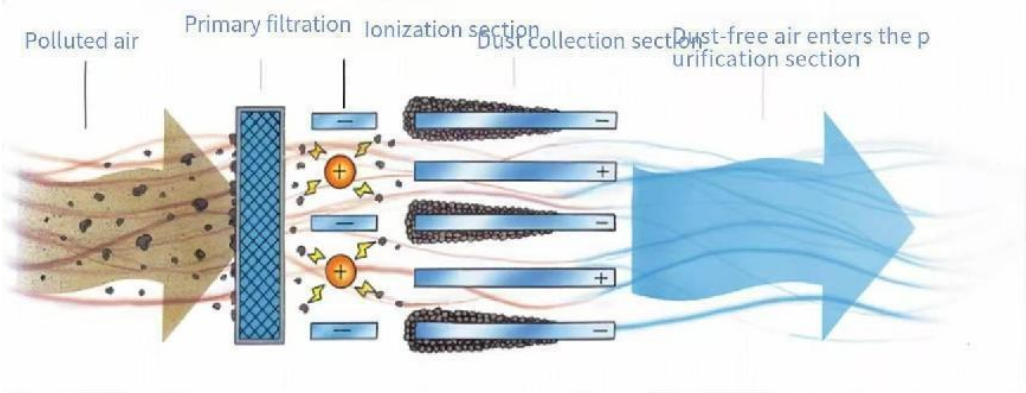

Fig. 3 Principle of electrostatic precipitation [16]

This method has high dust removal efficiency and can purify a large amount of air, and the electrostatic precipitator can also realize microcomputer control and long-distance operation. However, this method cannot purify all the dust and has a certain selectivity. The device is also complex and requires a lot of manpower and material resources for maintenance and operation.

Wet scrubber: It is a dust removal device designed and manufactured by using wet dust removal technology, in which the dust in the airflow is mainly collected by liquid (water) droplets. There are three ways to contact water with dusty air flow: water droplets, water film and bubbles, in the actual application of wet dust collectors, there may be two or three ways. There are many mechanisms for relying on droplets to capture dust particles, including gravity, inertial collision, entrapment, Brownian diffusion, electrostatic sedimentation, condensation, and sedimentation, which has the advantages of simple structure, small footprint, convenient operation and maintenance, and high purification efficiency, and can handle high temperature and high humidity airflow, and minimize the possibility of fire and explosion [17]. However, this method also has the disadvantage of high water consumption, which cannot be applied in all regions.

3.3. End Treatment

Strengthen urban greening, plant trees on both sides of the road, increase the number of green belts, and have the effect of adsorbing dust. Strengthen personal protection, use masks outdoors, and pay attention to ventilation indoors.

4. Conclusion

This article sheds light on the impact of fine particulate matter on the environment and human health. It was mentioned that the presence of PM2.5 in the atmosphere poses a significant risk to human health, including respiratory diseases, cardiovascular problems, and even premature death. The impact of PM2.5 on human health cannot be ignored, and it will also hurt the aesthetics of the environment and the greenhouse effect. The treatment methods of PM2.5 are introduced from three aspects: source control, process control, and end control, and the treatment methods are summarized and summarized. Specialized treatment technologies such as electrostatic precipitator and wet washing are introduced. In the future, the presence of PM2.5 will continue to be a major health problem, and although the way to deal with PM2.5 is nearing maturity, there are still the following areas for improvement. Combining the best of today's technologies with electrostatic precipitators and wet scrubbing. The monitoring of PM2.5 is intelligent, and technologies such as big data and the Internet of Things are used to achieve real-time monitoring and automatic control. Look for more energy-efficient materials, similar to nanofibers, to improve the efficiency of PM2.5 capture. It is necessary to insist on the development of PM2.5 treatment methods in the direction of high efficiency and intelligence. The purpose of this paper is to provide a preliminary understanding of the current situation and treatment measures of PM2.5 for all researchers interested in air pollution control and to comprehensively publicize and popularize relevant information in this regard.

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