Research on the Harm Degree of PM2.5 Atmospheric Particulate Pollution to Human Health

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Abstract. Today's haze weather, as an atmospheric environmental pollution that seriously endangers human health, plagues most cities and regions in my country, and fine particulate matter in the air (especially PM$_{2.5}$) is an important pathogen that poses a serious threat to human health. The toxic and harmful (allergic) substances contained in PM$_{2.5}$ and pathogenic microorganisms such as bacteria and viruses can induce and aggravate human respiratory diseases, cardiovascular diseases, cancers and metabolic diseases, and increase the incidence and death of these diseases Rate; PM$_{2.5}$ enters the lung tissue through the respiratory tract, and then enters the blood circulation through the capillaries, through direct damage to the human body, inflammatory damage, stimulating the human body to produce oxidative stress, damaging the human body’s immune system, and mutating human DNA And other effects, causing harm to human health. This article takes PM$_{2.5}$ as an example to summarize the research status of PM pathogenicity, in order to attract the attention of pathology research field.

Keywords: PM$_{2.5}$, atmospheric particulate matter, haze, human health, hazards, pathogenicity.

1. Introduction

In daily pathological diagnosis work, some black granular substances-dust particles can often be seen in the dust cells and interstitial of lungs, lymph nodes, spleen and some organ slices. Some people call them "carbon powder" particles. It is not pathogenic to humans. Current research believes that “toner” dust particles in lungs and other organs are actually solid and liquid particulate matter (PM) suspended in the atmosphere that is swallowed by dust cells. Every year, 2.7 million people in the world die from air pollution. PM is the main pollutant. A large number of studies have also shown that PM is an independent risk factor for the morbidity and mortality of cardiovascular and respiratory diseases. It can affect multiple systems and provide new hypotheses for some diseases of unknown etiology, which has gradually attracted people's attention [1]. The physical and chemical properties of PM are complex and are generally classified by their aerodynamic diameter (AD). Among them, air fine particles (AD≤2.5μm, PM$_{2.5}$) are the most harmful to human health. Medical experts believe that the haze caused by fine particles in the air (mostly PM$_{2.5}$) is harmful to human health, and can induce and aggravate human respiratory diseases, cardiovascular diseases, metabolic diseases and cancers. It is closely related to the morbidity and mortality of these diseases. Haze weather has caused people to worry and worry about health problems. In order to illustrate the impact of fine particulate matter
(mostly PM$_{2.5}$) in the air on human health during haze weather, this article now focuses on fine particulate matter (mostly PM$_{2.5}$). The health hazards and prevention of various human systems are summarized as follows.

2. **Source and composition of PM$_{2.5}$**

2.1. **Sources of primary particle emissions**
Among the primary particles, dusty particles mainly come from dust from roads, construction and agriculture; carbon black particles mainly come from diesel-engine cars, boilers, waste incineration, open-air barbecues, open-air burning of straw, and firewood by residents. Among the various sources of primary particles, the proportion of PM$_{2.5}$ is quite different. Road dust and construction dust are mainly coarse particles, and the particles produced by combustion are mainly PM$_{2.5}$.

2.2. **Sources of secondary particle emissions**
The precursor SO$_2$ of ammonium sulphate and ammonium nitrate mainly comes from coal-fired boilers and oil-fired boilers, NO$_x$ mainly comes from boilers and motor vehicles, and NH$_3$ mainly comes from fertilizer production, animal manure, coke production, refrigeration workshops and boilers that control NO$_x$. The precursors of secondary organic aerosols, VOCs, mainly come from spraying, printing, plywood, furniture, home decoration, etc. During the formation of secondary particles, relative humidity is not only an important condition that determines the formation and low-altitude accumulation of secondary particles, but also the primary condition that determines the increase in the size of the secondary particles and the change in scattering rate, which plays a very important role.

2.3. **The chemical composition of PM$_{2.5}$**
The components of PM$_{2.5}$ have a certain degree of complexity. Its main components include elemental carbon, salts and organic carbon compounds. Heavy metals are common components and pollute the ecological environment to a large extent. The heavy metals in PM$_{2.5}$ mainly come from two types of components, including natural sources and anthropogenic sources: natural sources include very large amounts of sodium, magnesium, calcium, aluminium, iron, etc. in the earth’s crust; anthropogenic sources include stationary sources and mobile sources [2]. There are two sources. Stationary sources are mainly left over after chemical combustion of fossil fuels, while mobile sources are mostly exhaust gas emitted by vehicles in the process of using fuel. Figure 1 shows the chemical composition of PM$_{2.5}$.

![Figure 1. The chemical composition of PM2.5](image-url)
3. The impact of PM$_{2.5}$ on atmospheric visibility

PM$_{2.5}$ is the culprit leading to the haze weather. The haze that enters the atmosphere reduces the visibility of the atmosphere and poses a huge threat to ground traffic safety and aircraft take-off and landing. Atmospheric visibility (visibility) usually refers to the maximum distance that a person with standard vision can distinguish a black target object (appropriate size) from the sky background in the horizontal direction under the prevailing weather conditions. Visibility in a broad sense includes atmospheric visibility in meteorological observations, light visibility to identify distant light signals at night, and visibility of ground targets observed from the air in satellite measurement technology [3]. At first, the visibility was divided into 10 levels, which were represented by numbers 0-9. For example, in a foggy weather condition, the visibility is level 2, which means that the visibility distance is 0.2km-0.5km. Visibility is closely related to meteorological conditions and atmospheric pollution. In theory, the visibility of dry air can reach 300km. The visibility in the polluted air is only 10km or even lower. The decrease in atmospheric visibility is mainly caused by the absorption and scattering of light by particles. The wavelength of visible light radiation is 0.40μm-0.76μm, and the maximum intensity is around 0.52μm. Therefore, solid or liquid particles with a particle size of 0.1μm-1.0μm have the greatest impact on visibility. The particle size of sulphate particles in the atmosphere is mostly between 0.2 μm and 0.9 μm. Therefore, their impact on atmospheric visibility is particularly significant. Among particulate particles, the extinction effect of particles with a particle size of <2.5μm is much greater than that of particles with a particle size of 2.5μm or more. Among particles <2.5μm, PM$_{2.5}$ has the strongest extinction effect for visible light (with a wavelength in the range of 0.40μm-0.76μm). Therefore, PM$_{2.5}$ is the most important factor for reduced visibility. Assuming that the particles of the particulate matter are spheres of the same size and uniformly distributed, the visibility can be calculated according to the formula (1):

$$L_v = \frac{2.6 \rho_p d_p}{Kr}$$

In the formula: $\rho$ is the concentration of particles in the line of sight, mg/m$^3$; $\rho_p$ is the density of particles, kg/m$^3$; $d_p$ is the diameter of the particles, μm; K is the scattering rate, that is, the wave affected by the particles the ratio of the front area to the particle area. According to Van der Helst’s research, the K value generally varies between 1.7 and 2.5.

The physical meaning of the above visibility formula is that the visibility of the atmosphere ($L_v$) is proportional to the material density ($\rho / \rho$) of the particulate matter and the particle diameter ($d_p$) of the particulate matter, and is proportional to the concentration ($\rho$) of the particulate matter in the direction of the line of sight. The scattering rate (K) is inversely proportional [4]. The smaller the particle size ($d_p$), the lower the visibility ($L_v$). Therefore, it can be explained theoretically that the impact of fine particles PM$_{2.5}$ on the reduction of atmospheric visibility should be more significant than that of coarse particles (PM10).

4. Pathogenicity of PM$_{2.5}$

Through the statistics of the number of deaths from respiratory diseases, circulatory diseases and non-accidental deaths in city T, see Table 1 and Figure 2.
Table 1. Daily particulate matter concentration, air quality index, death toll and meteorological parameters in city T

| Category                                      | Quantity | Mean ± standard deviation | P0  | P25 | P50 | P75 | P100 |
|-----------------------------------------------|----------|---------------------------|-----|-----|-----|-----|------|
| Atmospheric particulate matter concentration  |          |                           |     |     |     |     |      |
| PM$_{10}$/μg/m$^3$                            | 709      | 124±88                    | 4   | 63  | 107 | 171 | 900  |
| PM$_{coarse}$/μg/m$^3$                         | 709      | 47±56                     | 2   | 31  | 53  | 78  | 827  |
| PM$_{2.5}$/μg/m$^3$                            | 709      | 67±48                     | 2   | 32  | 55  | 93  | 334  |
| Air quality index                             | 730      | 86±48                     | 12  | 59  | 78  | 100 | 500  |
| Death toll                                    |          |                           |     |     |     |     |      |
| Respiratory diseases/people                   | 731      | 89±19                     | 53  | 76  | 87  | 102 | 154  |
| Circulatory system diseases/people            | 731      | 19±6                      | 5   | 14  | 18  | 22  | 46   |
| Non-accidental death/person                   | 731      | 179±28                    | 127 | 157 | 175 | 197 | 259  |
| Meteorological parameters                     |          |                           |     |     |     |     |      |
| Temperature/℃                                 | 730      | 14±11                     | -10 | 4   | 16  | 24  | 33   |
| Relative humidity/%                           | 723      | 44±19                     | 10  | 27  | 43  | 59  | 91   |

Figure 2. Changes in daily particulate matter concentration, air quality index, temperature, humidity, and death toll

It can be seen from Table 1 that the annual average concentration values of PM$_{10}$ and PM$_{2.5}$ far exceed the newly promulgated National Ambient Air Quality Level Two Standards (70μg/m$^3$ and 35μg/m$^3$, respectively, the number of days with daily average concentration exceeding the standard and the exceeding rate respectively It is 210 days, 29.6%, 249 days, 35.1%. More than 75% of the days have reached slight air pollution (API>100), and the highest API can reach 500. It can be seen from Figure 2 that the API index is basically consistent with the trend of particulate matter [5], indicating that air pollution, mainly particulate matter and superimposed by other pollutants, is already very serious in city T. From the hospital data, it can be seen that the daily non-accidental death toll in city T during the investigation period averaged 179 people, and deaths from respiratory and circulatory diseases the average number of people was 89 and 19. In addition, it can be seen from Figure 2 that the number of deaths of the population has a relatively obvious negative correlation with the environmental temperature and humidity (the correlation coefficient can reach -0.69).

4.1. The pathogenicity of PM2.5 to the respiratory system

Respiratory diseases related to PM$_{2.5}$ exposure include sinusitis, pulmonary insufficiency, chronic obstructive pulmonary disease, allergic diseases, sarcoidosis and lung cancer. The pathogenic
mechanism of PM$_{2.5}$ in the respiratory system is still in the exploratory stage. The currently accepted mechanisms are inflammation and oxidative damage. PM$_{2.5}$ deposited on the nasal mucosa can cause local inflammation and oxidative damage to the epithelium. Morphologically, it can be seen that epithelial destruction, basement membrane thickening, columnar epithelial squamation, decrease in the number of ciliated cells, increase in the number of goblet cells, and abnormalities in ultrastructure, such as abnormal structure of new cilia, dyskinesia, decreased inter-epithelial cell connections, and Bowman UFPs are deposited in the glands, and the appearance and degree of PM deposition are related to epithelial damage and basement membrane thickness\cite{6}. The destruction of mucosal epithelium, abnormal cilia and increased exudation lead to defects in the mucus processing mechanism, prolong the contact time of carcinogenic components in PM$_{2.5}$ with the epithelium, and increase the risk of malignant tumours such as squamous cell carcinoma. The time that PM stays in the respiratory tract is an important factor in its pathogenicity. The chronic inflammation and oxidative damage caused by PM$_{2.5}$ deposited in the lung interstitial can reduce lung function, impair lung development, increase the morbidity and mortality of asthma, and the morbidity of chronic obstructive pulmonary disease. So far, there are 6 prospective studies suggesting that long-term exposure to air pollutants may increase the risk of lung cancer, mainly related to PM$_{2.5}$ produced by combustion. However, compared with smoking, the risk is very low. For every increase of 10$\mu$g/m$^3$ in PM$_{10}$ or PM$_{2.5}$, the risk increases by 10% to 20%, but it cannot be ignored.

4.2. The pathogenicity of PM$_{2.5}$ to cardiovascular diseases

The fine particles in the air (mostly PM$_{2.5}$) enter the lung tissue through the respiratory tract, and can adhere to the respiratory mucosa and lung tissue (especially the alveolar wall). Because the particle size of PM$_{2.5}$ is small, it can penetrate the capillaries it directly enters the blood circulation and reaches all parts of the human body, causing serious harm to human health. The toxic and harmful substances contained in PM$_{2.5}$ and pathogenic microorganisms have a significant inhibitory effect on vascular endothelial cells. If people live in haze air containing too high concentrations of PM$_{2.5}$ for a long time, they can increase the incidence of cardiovascular diseases.

Medical experts believe that fine particles in the air (mostly PM$_{2.5}$) have the following effects on the cardiovascular system when haze occurs: (1) Change blood composition and blood viscosity. The inhalation of fine particulate matter (mostly PM$_{2.5}$) can cause changes in the lung function and blood system of a healthy body, such as activation of coagulation, inhibition of fibrinolysis, etc., and increase the formation of hypercoagulability and thrombosis of the blood. This change may be a potential risk for cardiovascular disease in the future. (2) Interfering with cardiac autonomic nerve function and heart rhythm, changing the state of cardiac function. If people inhale haze air containing PM$_{2.5}$ for a long time, it can cause unstable heart rate and blood pressure fluctuations, and heart rate instability and blood pressure fluctuations mainly rely on the regulation function of autonomic nerves, so PM$_{2.5}$ may induce autonomic nerves during haze. Dysfunction affects the cardiovascular system. In the case of pneumonia, the vague nerve in the lungs is stimulated to cause autonomic nerve dysfunction and spread to the heart; inflammatory mediators and particulate matter (mostly PM$_{2.5}$) produced by pneumonia enter the blood circulation together, directly reach the heart, and become toxic to the cardiovascular system effect. (3) The damaging effect of free radicals. Toxic substances adsorbed on fine particles (mostly PM$_{2.5}$) in the air can oxidize cardiovascular endothelial cells.

4.3. The pathogenicity of PM$_{2.5}$ to the central nervous system

Studies have shown that long-term exposure to PM$_{2.5}$ is related to central nervous system inflammation and neuronal degeneration, which can cause the deposition of $\beta$-amyloid peptide 1-42 (A$\beta$42) and $\alpha$-synuclein, which can begin to accumulate in childhood. Alzheimer's disease is characterized by the precipitation of $\beta$-amyloid (A$\beta$) outside nerve cells, forming senile plaques (SP). A$\beta$42 is an important factor in the formation of SP, and its increase is closely related to the onset of Alzheimer's disease. It can form insoluble A$\beta$ deposits in the brain tissue and gradually produce SP. Parkinson's disease (PD) is characterized by the formation of Lewy bodies (LB) in the cytoplasm of
neurons, and α-synuclein is the main component of LB and exists in the form of fibres. Under normal circumstances, α-synuclein exists in the presynaptic membrane of the central nervous system. Its abnormal metabolism in the brain is related to the occurrence of neurodegenerative diseases such as PD. The animal model of PD induced by it is currently recognized as an experimental model of sporadic PD, which can selectively damage dopaminergic neurons in the substantia nigra [7]. Therefore, exposure to PM2.5 is considered to be a risk factor for Alzheimer's disease and PD, and people with APOE4 alleles are at higher risk of PD.

5. Preventive measures
(1) Keep away from pollution sources, such as boiler rooms, large industrial areas, and automobile exhaust. (2) Residents can install air purification devices indoors to reduce exposure time in areas with heavy haze pollution. (3) Take correct and effective protective measures to prevent respiratory infections. You should choose a thicker mask with a filtering effect of 95%; avoid opening windows for ventilation, going out and participating in outdoor activities when the smog is heavy, eat more lung food, drink more water, and eat less irritating food. (4) People working outdoors with heavy pollution sources and haze should use and wear respiratory protective equipment correctly to reduce the harm of air pollutants to the human body.

6. Conclusion
The issue of air pollution in my country has attracted widespread attention at home and abroad. It is recommended to establish a national PM2.5 monitoring system, systematically carry out research on PM2.5 source analysis, and analysis of typical regional component characteristics, so as to provide information for assessing the burden of disease caused by PM2.5. Use new tools such as geographic information systems to establish air pollution (especially PM2.5) exposure models to analyse the level and characteristics of PM2.5 exposure of Chinese residents; select typical PM2.5 polluted areas to conduct large-scale prospective studies to assess atmospheric PM2.5. The exposure-response relationship between pollution and the health hazards of residents provides practical evidence for the burden of PM2.5 pollution and health loss.

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