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The Impact of Atmospheric Haze on Human Health

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Abstract: Atmospheric haze, a complex air pollution phenomenon comprising particulate matter and gaseous pollutants, has emerged as a critical threat to human health amid rapid industrialization and urbanization. This paper examines the composition, sources, and health impacts of haze, highlighting PM2.5 as the primary toxic component. PM2.5 penetrates deep into the respiratory system, carrying heavy metals and toxic organic substances, which induce oxidative stress, gene mutations, and organ damage. Prolonged exposure is linked to respiratory diseases, cardiovascular disorders, immune suppression, and reproductive issues. Epidemiological studies confirm PM2.5's carcinogenicity, with mechanisms involving DNA damage. Control strategies include source reduction and personal protection. Addressing haze requires collaborative efforts from governments, industries, and individuals to mitigate its far-reaching health consequences.

1. Introduction

Atmospheric haze, a complex air pollution phenomenon of various pollutants, has drawn growing attention recently. With rapid industrialization and urbanization, the haze problem has become severe and poses a significant threat to human health.

The issue of haze first came to the fore in the middle of the 20th century. Across numerous Western industrialized nations, large - scale environmental contamination, such as the well - known "Maas Valley Smog Incident" and "Donora Incident", sparked broad - based concerns regarding atmospheric haze[1].In China, since the 21st century, haze has become a significant aspect of environmental challenges. For example, the haze pollution in January 2013 affected an area of approximately 1.3 million square kilometers and around 800 million individuals. According to the World Health Organization's 2018 list of the top ten threats to human health, air pollution claimed the top spot. Evidently, haze is a problem that demands attention[2].To develop strategies to alleviate the adverse effects of atmospheric haze on human well - being, we put forward and consolidate the concept of Atmospheric Haze.

2. The impact of Atmospheric Haze

2.1 Components and causes of atmospheric haze

Atmospheric pollutants mainly include particulate matter and gaseous pollutants. Particulate matter is categorized by size into TSP, PM10, and PM2.5, while gaseous pollutants consist of SO_2, NO$_x$, CO, VOC, O_3, Hg, etc[3]. Among them, PM2.5, with its small size and large specific surface area, can adsorb numerous harmful substances and penetrate deep into the human respiratory system, posing a great threat to health. Below is a brief description of haze components in different regions of China(Figure 1).

The sources of atmospheric aerosols can be both natural and man-made. Natural sources include weather phenomena such as sandstorms, dust raised in the soil, sea salt particles formed in the ocean, and pollen spread by plants, while man-made pollution sources are also numerous. Among them are pollutants emitted during industrial production processes, the volatilization of various chemicals used in agricultural production, exhaust gases emitted by transportation vehicles, dust raised during construction projects, and waste gases released from the combustion of household fuels. These anthropogenic pollution sources are the main causes of the current severe air pollution situation.

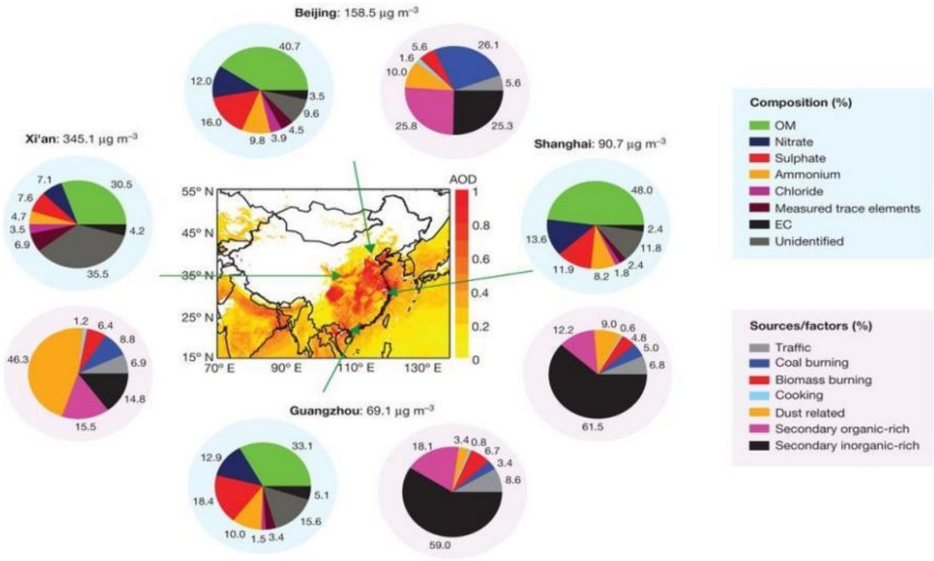

Figure 1 The composition and sources of Haze of China

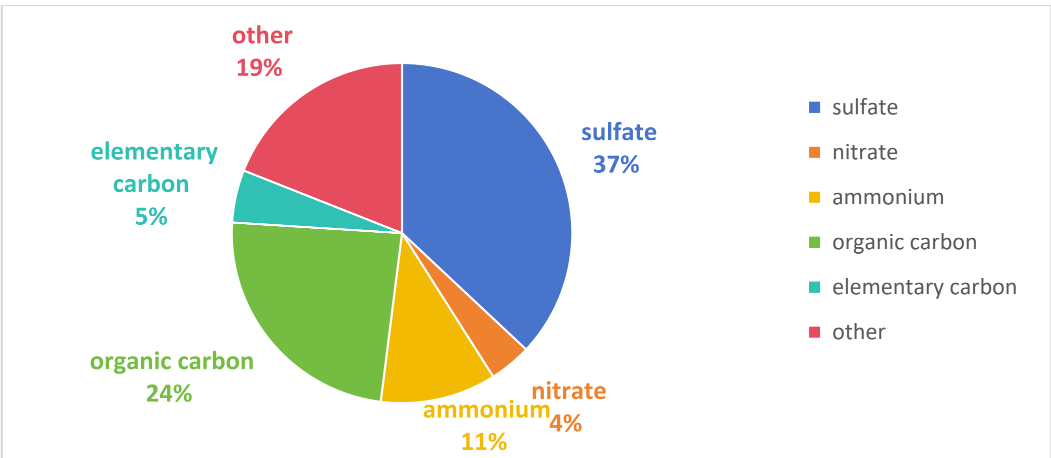

Figure 2 Typical composition of fine continental aerosol adapted

Based on their generation relationship, aerosol particles are divided into primary and secondary ones. Primary particles are directly emitted into the atmosphere, while secondary particles form through atmospheric reactions, like the oxidation of inorganic sulfides and photochemical reactions generating photochemical smog[4]. Under stable atmospheric circulation, low wind speed, high humidity, these particles can accumulate, triggering hazy weather. The inversion in some urban areas worsens pollutant accumulation near the ground, intensifying haze. The following graph shows the typical composition of fine continental aerosol(Figure 2).

2.2 Impact of atmospheric haze on human health

2.2.1 Toxic substances in haze particles and their toxicity

PM2.5 is the main toxic component in haze, with heavy metal elements and toxic organic matter adsorbed on it being the primary sources of its toxicity[5].

Harmful heavy metals, including mercury (Hg), cadmium (Cd), lead (Pb), chromium (Cr), and arsenic (As), are non - decomposable in nature. These metals display distinct toxicity towards living organisms and have the ability to increase in concentration and build up as they move through the food chain. Once they enter the human body, they vigorously interact with biological molecules like proteins and enzymes. This interaction results in the deactivation of these biomolecules. Moreover, these heavy metals can amass in human organs, which may give rise to chronic poisoning, toxicity in the reproductive system, and in severe cases, even cause birth defects and cancer.

Harmful organic substances, such as polycyclic aromatic hydrocarbons (PAHs) and nitro - polycyclic aromatic hydrocarbons (NPHs), can cause irritation to the eyes and the respiratory system. This irritation may lead to symptoms like tiredness, light - headedness, or even intoxication. Aromatic hydrocarbons have the potential to impair the human body's hematopoietic capabilities. Moreover, a large number of them are known to be carcinogenic. Among these, PAHs are particularly hazardous, exhibiting substantial "tri - lethal" impacts. In summary, all these toxic compounds present threats to human well - being.

2.2.2 Hazards of haze on major human systems

Atmospheric haze poses a significant threat to human health, particularly to the respiratory system(Table 1). PM2.5 particles bypass the nasal hairs' filtration and penetrate deep into the respiratory tract, settling in the bronchi, lungs, and even the alveoli. From there, they enter the body fluids and circulate throughout the body. These particles erode the alveolar walls, compromise the respiratory defense barrier, and impair lung function, triggering inflammatory reactions[6].

Prolonged exposure to haze can lead to chronic rhinitis, pharyngitis, bronchitis, and other respiratory diseases. For asthmatics, haze pollutants can exacerbate symptoms like breathlessness and wheezing. Additionally, long - term exposure reduces lung ventilation and gas exchange. The carcinogenic substances in haze, such as PAHs and heavy metals, can cause gene mutations in respiratory epithelial cells, increasing the risk of lung cancer. Studies have shown that high - level PM2.5 exposure significantly reduces lung function indicators like FVC and FEV[7].

PM2.5 enters the body via the respiratory system, crossing alveolar walls into the bloodstream and impacting the cardiovascular system. Epidemiological data links PM2.5 to the morbidity and mortality of cardiovascular diseases, including ischemic heart disease, congestive heart failure, and arrhythmias. By altering heart rate, heart rate variability, and blood viscosity, PM2.5 increases the risk of sudden myocardial infarction.

Atmospheric haze affects the cardiovascular system in multiple ways. Short - term exposure to PM2.5 can elevate blood pressure; for instance, in Shanghai, a 1.0 $\mu g/m^3$ increase in PM2.5 concentration correlated with a 2.3% rise in systolic and 0.3% in diastolic blood pressure. Long - term exposure may lead to hypertension. Additionally, haze can cause metabolic disorders, atherosclerosis, platelet aggregation, and thrombosis, increasing arrhythmia risks and destabilizing atherosclerotic plaques. Prolonged exposure can even trigger heart failure by promoting blood clot formation.

Table 1 Respiratory Penetration vs. Particle Size (source:Spengler et al.1996)

Particle size (range)	Penetration of particles
11 µm	and up particles do not penetrate
7-11 µm	and up particles penetrate nasal passages
4.7-7µm	particles penetrate pharynx
3.3-4.7µm	particles penetrate trachea and primary bronchi
2.1-3.3 µm	particles penetrate secondary bronchi
1.1-2.1 µm	particles penetrate terminal bronchi
0.65-1.1µm	particles penetrate bronchioli
0.43-0.65 µm	particles penetrate alveoli

Moreover, atmospheric haze damages the immune system, reducing immune cell activity and increasing the risk of infectious and allergic diseases. It also affects the nervous system, with pollutants reaching the brain via blood circulation, causing symptoms like headaches, dizziness, and mood disorders, and increasing the risk of mental illnesses. Thus, we must take the impact of atmospheric haze on human health seriously and actively protect ourselves from its harm.

2.2.3 Carcinogenicity and other health hazards of haze pollutants

Atmospheric haze pollutants are closely associated with cancer. PM2.5, for instance, raises lung cancer incidence upon entering the body due to its carcinogenic components like heavy metals and polycyclic aromatic hydrocarbons. It also heightens cancer risk via mechanisms such as promoting tumor neovascularization.

Epidemiologic studies confirm PM2.5's carcinogenicity. A 26-year Canadian study on 188,699 nonsmokers found 1,100 lung cancer deaths correlated with PM2.5 exposure. PM2.5 poses greater lung cancer risks to elderly patients with lung diseases, and the risk varies by season and PM2.5 composition—summer haze increases risk, and PAH in PM2.5 correlates with lung cancer prevalence. Analyzing PM2.5 components helps develop targeted anti-pollution measures[8].

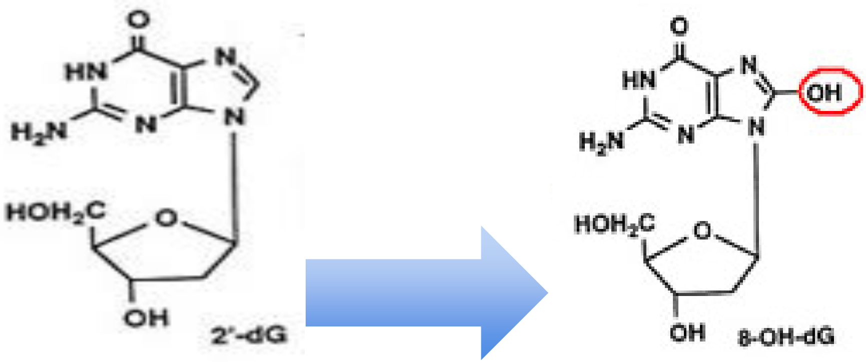

Figure 3 Formation of 8hycroxy-2-deoxyguanosne (8-OHdc) by oxgen radicails. H Kasai: Environmental Mutagen Research,Vol.10, p73-78(1988)

Regarding the carcinogenic mechanisms of PM2.5(Figure 3), especially for lung cancer, research is hampered by its physical and chemical complexity. Hypotheses include oxidative stress, gene mutation, and others. In oxidative stress, PM2.5's soluble metals trigger reactive oxygen species production; even without these metals, remaining components still induce oxidative stress. Gene mutation occurs when hydroxyl radicals, produced by PM2.5, damage DNA. 8-hydroxy-2-deoxyguanosine is a key biomarker for such DNA damage[8][9].

Besides its potential cancer risk, PM2.5 has numerous other harmful effects on the human body. It promotes tumor neovascularization, leading to malignant tumors, and facilitates tumor metastasis through inflammatory responses, EMT, or vascular homeostasis imbalance. Additionally, PM2.5 weakens the body's immune system by damaging mucosal tissues and killing immune cells like NK cells, T and B lymphocytes, and immunoglobulins. Recent research also shows that exposure to PM2.5 can adversely affect the female reproductive system, disrupting endocrine levels, impairing ovarian reserve function, and increasing the risk of infertility and adverse reproductive outcomes such as miscarriage, fetal growth restriction, and preterm labor[10].

Atmospheric haze exerts a wide-ranging array of effects on human health, and numerous potential perils to well-being remain undiscovered. Consequently, we shall delve into pertinent solutions and individual protective strategies to curtail the damage inflicted by atmospheric haze.

3. Control and Protection against Atmospheric Haze Pollution

The most crucial control of haze pollution lies in source control, yet it's a long-term and arduous task. PM2.5 is the main culprit for hazy weather, and its control is challenging, marking a shift from managing primary to secondary air pollution. The multi-pollutant joint control program is currently considered the most effective approach. Improving air quality by preventing and controlling secondary pollution represents a major transformation in air pollution management, achievable through formulating relevant policies and laws.

To prevent issues at their root, it is essential to target pollutants originating from coal usage, industrial activities, motor vehicles, dust, and agricultural operations(Figure 4). Heightened oversight of relevant enterprises is necessary, along with the strict implementation of emission regulations and the firm suppression of illegal emissions. Another crucial step is the optimization of the energy framework. The nation ought to boost the share of clean energy sources to curtail emissions stemming from coal combustion. Currently, the country has been taking positive steps. For instance, it has set up joint prevention mechanisms in key areas and early warning systems for severe pollution events.

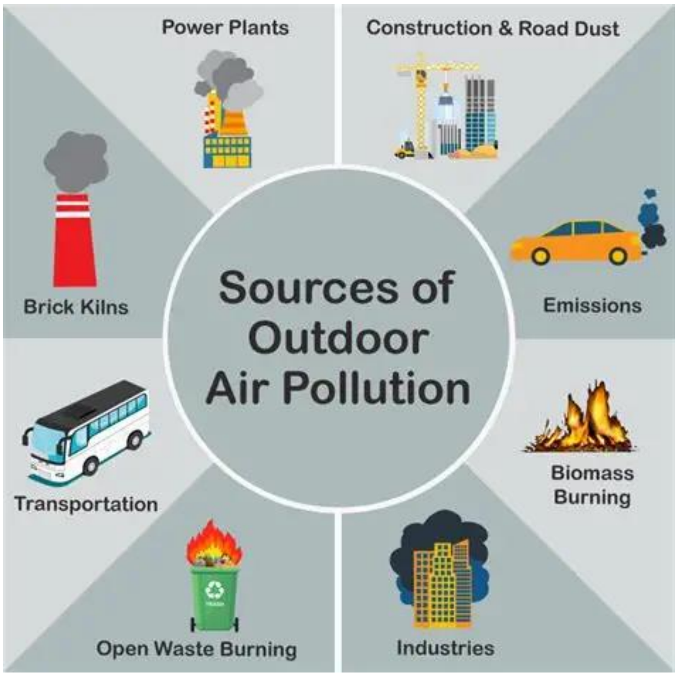

Figure 4 Source of outdoor air pollution

Specifically, the government should optimize the iron and steel industry layout, tighten vehicle emission standards, especially for diesel vehicles, improve oil quality, promote electric vehicles, and strengthen biomass combustion management. In the past five years, the atmospheric environment has improved significantly.

Regarding personal protection, understanding basic concepts helps reduce health risks. Everyone should wear high-filtration masks, minimize outdoor activities in moderate to heavy haze, and clean up promptly after going out. Also, the public should provide special protection for vulnerable groups and consider using air purifiers to lower indoor PM2.5 levels.

4. Conclusion

In this essay, we discuss together the components of atmospheric haze, the various effects of haze on human health and how to reduce haze pollution. As a very serious pollution problem, atmospheric haze has a wide and far-reaching impact on human health, and how to solve the difficult problem of atmospheric pollution has plagued mankind for a long, long time. And we believe that to effectively deal with the threat of atmospheric haze to human health requires the joint efforts of the government, society and individuals. We believe that as long as the whole society gathers together and forms a strong synergy, we can definitely reduce the occurrence of atmospheric haze, thus protecting human health and realizing sustainable and healthy social-economic development.

In the future research, each of our students can contribute to the research and development of atmospheric haze. By strengthening multidisciplinary cross-research and enhancing international cooperation and exchange, we, the whole world, can work together to cope with more environmental problems such as atmospheric pollution, and create a clean, healthy and beautiful earth home for human beings.

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