The Global Burden of Air Pollution: Respiratory and Cardiovascular Impacts

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Abstract

Air pollution is one of the major worldwide issues that causes almost 7 million premature deaths every year from respiratory and cardiovascular conditions. Dangerous pollutants, which include nitrogen oxides (NO), carbon dioxide (CO), sulfur oxides (SO), and particulate matter ($PM_{2.5}$ and PM_{10}), affect the health of humans by causing oxidative stress, immune system impairment, and systemic inflammation. Longer exposure to $PM_{2.5}$ highly increases lung cancer, high blood pressure, heart diseases, and chronic pulmonary obstructive disease, putting vulnerable groups such as children, the elderly, and those people with lower incomes at high risk. Industrialization and modernization, which have increased air pollution, especially in developing countries, are mostly linked to emissions from transportation, manufacturing, and energy production. The Agreement of Paris and the China Renewable Air Action Plan demonstrate projects that illustrate the ability of technologies and legislation, such as electric vehicles and energy from renewable resources, to minimize pollution levels. However, the execution of such programs is prevented by the limitation of resources in low-income countries. In addition, a change causes an increase in air pollution, emphasizing the value of immediate action and international efforts to limit its effects. A thorough approach to combat air pollution is essential to better air quality, minimize health risks, and secure future generations.

Keywords: Air pollution, public health, Climate change, Particulate matter, Chronic disease

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Introduction

Air pollution has recently emerged an essential global health problem, endangering the health of the public and well-being. In contrast to destroying quality of life, it mainly increases the chances of premature death and respiratory diseases. According to the reports of the World Health Organization (WHO), 98% of the world population lives in areas where air quality does not reach recommended safety standards, which causes roughly 4.3 million premature deaths because of air pollution-related disease (Rom, 2023). The quality of air has been immensely affected because of rapid industrialization and urbanization in developing countries, which makes cardiovascular and respiratory diseases more common and increases the mortality rate (Jiang et al., 2023).

Pollution is an important environmental issue because it involves the presence of harmful elements that affect the health of humans and their well-being. Among all pollutants listed above, the Nitrogen dioxides (NO_2), sulfur dioxides (SO_2), Carbon Monoxides (CO), Particulate Matter ($PM_{2.5}$ and PM_{10}), and Ground-level ozone (O_3) are most common and have maximized adverse effects on humans (Zayakhanov, 2023). Ambient air particulate matter, including particulate matter with sizes less than 2.5 micrometers ($PM_{2.5}$) and about 10 micrometers (PM_{10}), has direct adverse effects on humans because it can be inhaled into the respiratory system. Exposure to $PM_{2.5}$ has also been found to increase people's risks of developing cardiovascular diseases, respiratory diseases, and death (Chin et al., 2019).

NO2 is a reddish-brown type of gas that is chiefly accountable for the pollution, which is very dangerous to the lungs and results in asthma and other related ailments. SO_2 is a large amount of atmospheric pollutant that forms acid rain that has harmful effects on the health of humans, soil, and waters (Khreis et al., 2022). In metropolitan areas with heavy vehicular emissions, CO is dangerous because it competes with hemoglobin in the blood to carry oxygen to the body's organs and could cause poisoning or death. O_3 is not directly emitted; rather, it forms when other pollutants, such as VOCs and NO_2, react with sunlight (Rana, 2019).

Air pollution can be mainly attributed to industrial emissions, especially in urban areas that are known to be hubs of energy production and industrial activities. The pollutants emitted by various industries, such as thermal power plants, steel manufacturing, and cement production are particulate matters (PM), sulphur dioxide (SO_2), and nitrogenous oxides (NO_x) (Wang & Huang, 2014). Though there have been endeavors to minimize their emissions, they still have adverse health impacts of cardiovascular and respiratory diseases (Acciai et al., 2017). Also, these emissions intensify their impacts with the influences of topography and climate, and therefore, the rate of build-up of pollutants in

the atmosphere may go higher (Ferrante et al., 2015)

The main goal of this investigation is to measure global air pollution effects on public health. The research identifies the main air pollutants; at the same time, it explores how these pollutants cause oxidative stress and damage immune function.

Air Pollution and Respiratory Health

Impact on Lungs

As research into the effect of air pollution on respiratory health progresses, researchers have discovered that a large number of pollutants have a dangerous effect on lung tissue and function in several ways. A lot of techniques involve direct harm to inflammatory reactions, pulmonary cells, and changes in the performance of the immune system (Megha et al., 2021). One of the main methods through which air pollution affects lung health is through swelling, which occurs in air airways. O_3, NO_2, and particulate matter are those pollutants that can increase the inflammatory responses in the airways, causing the innate immune system (Lee et al., 2021).

Air pollution has a serious negative effect on respiratory health, particularly when it comes as transient symptoms like wheezing, sneezing, and throat irritation. Particulate matter, nitrogen oxides, and sulfur oxides may trigger respiratory reactions. Exposure to high levels of particulate matter $PM_{2.5}$ and PM_{10} is linked with increased respiratory signs like wheezing and coughing, especially in vulnerable groups like the elderly and infants. Chronic obstructive pulmonary disease (COPD) is the result of long-term exposure to air pollution. The studies have proven that air pollution accelerates the progression of chronic obstructive pulmonary disease (COPD) and increases its symptoms (Nie et al., 2023; Gao et al., 2014).

Increased Asthma Incidence

Asthma, particularly in youngsters, is another kind of big worry. Breathing in polluted air during early childhood or pregnancy increases the risk of respiratory problems and developing asthma in later life, as revealed by the studies. Furthermore, chronic and acute bronchitis are made worse by air pollution. In cities where vehicular and industrial emissions are common, high concentration of air pollutants, have been connected with chronic bronchitis (Dondi et al., 2023; Wang, 2023).

Lung Cancer

Lung cancer has been linked to long-term exposure to $PM_{2.5}$ through a variety of pathophysiological pathways. Chemicals carried by microscopic particles cause chronic inflammation and damage to lung tissue (Olesiejuk & Chałubiński, 2023).

Air Pollution and Cardiovascular Health

Impact on Heart and Circulatory System

Since numerous pollutants can enter the bloodstream and impair cardiovascular function, it is widely known that air pollution dramatically increases the risk of cardiovascular disease. Air pollution can affect cardiovascular health in several ways, like systemic inflammation, inhalation. and changes in vascular function.

Oxidative stress and systemic inflammation are both results of exposure to pollutants like particulate matter, as suggested by the evidence, and both are main participants in cardiovascular injury. This indicates that the relationship between cardiovascular health and air pollution is complicated (Lee et al., 2011). A condition known as oxidative stress occurs when more reactive oxygen species (ROS) are produced by the body than its ability to neutralize them. There is cellular damage since tissues are damaged in this process. Since the rumors, there has been a correlation between this imbalance and several cardiovascular problems such as atherosclerosis and pressure (Yang et al., 2017).

Increased Risk of Heart Disease

Concerning cardiovascular health, long-term exposure to air pollutants is more sensitive than short-term exposure to the same pollutant, despite surpassing the set hazard level on some days. It has also been shown that as small as a $17\mu g/m^3$ rise in annual average $PM_{2.5}$ concentrations is also associated with increased risk of hospitalizations and risk concerning heart failure (Shah et al., 2013). This is especially the case among elderly people who already have cardiovascular disease. The amount of particulate matter inhaled increases blood pressure and the formation of vessels, and consequently heart failure (Lelieveld et al., 2019).

Stroke and Air Pollution

Cardiovascular morbidity is directly determined by the air quality because the systemic inflammation from the air pollution also enhances atherosclerosis and vascular inflammation (Shah et al., 2013). Besides that, there are grounds to associate particulate matter and nitrogen dioxide with coronary artery lesions and, therefore, to indicate the negative impact of air pollution on the heart.

Global Mortality and Morbidity

Global Statistics on Mortality

A major issue related to community health is air pollution, since this is among the main causes of diseases and deaths in the world. Current research by the WHO indicates that it contributes to about 7million deaths every year or 14% mortality of the world's population Additionally, more recent research suggests that at least 97% of global people live in areas with air quality worse than WHO recommended standards meaning that diseases that are because of air pollution are on the rise (Nataraj, 2022).

The cross-sectional and longitudinal evidence shows that many different populations are vulnerable to the health impacts of air pollution to some extent (Murray et al., 2020). The most vulnerable groups include the senior citizens and anyone with ailments, contraptions, or other

complications. Exposure results are intimately related to health results and the overall socioeconomic status of the examined population. Higher surrounding PM is a result of industrialization and urbanization, especially in developing countries with weak policies in environmental compliance. Because $PM_{2.5}$ levels have an inverted-U relationship with health outcomes, small improvements in $PM_{2.5}$ levels have large positive effects on people's health in heavily polluted areas (Murray et al., 2020).

Years of Life Lost and Disability-Adjusted Life Years (DALYs)

Air pollution, specifically airborne particulate matter, is directly related to numerous health problems such as respiratory and cardiovascular diseases and causes a major number of DALYs. According to the studies, the morbidity and mortality rates come down, life expectancy rises, and the disease burden decreases with a decrease in air pollution. This places into perspective the role of air pollution in affecting the well-being of society through real-life illustrations of some of the most polluted cities in the world, such as Beijing in China, New Delhi in India, and Mexico City in Mexico. New Delhi has been found to high exposure to $PM_{2.5}$ for a long time and has effects on cardiovascular and respiratory illnesses, and approximately 1.2 million deaths per year (Saraswat et al., 2013).

As we know, air pollution in Beijing takes away between 341,100 and 490,900 people every year, and this shows how health has suffered due to the decline in the quality of air in towns (Tang, 2019). Mexican City health and exposure study shows that reductions in PM_{10} and O_3 levels may significantly reduce illness and mortality for the population, and therefore the relevance of effective air quality management methods (Molina et al., 2019).

Vulnerable Populations

Children and the Elderly are at Greater Risk

Air pollution is a main public health danger, particularly to susceptible groups such as the elderly and children. Children's pneumonia and asthma are well known to affect respiratory health. Children's growing respiratory systems make them particularly vulnerable to the severe effects of air pollution. Research has revealed that exposure to particulate matter (PM2.5) is linked with increased rates of asthma hospitalization in children from 6 to 11 years
(Zhang, 2023). It was discovered by a complete study that exposure to air pollution from traffic in early childhood is likely to increase the risk of respiratory illness in later life. This would endorse that this exposure may result in structural changes in the lungs that produce asthma symptoms (Bowatte et al., 2014).

Socioeconomic and Geographic Disparities

Air pollution is a big issue for public health in countries with geographical and social disparities, as well as in low-income areas where air pollution is more common. The health risks that residents of these areas face are increased by the high levels of air pollution to which they are exposed, as revealed by the researcher. People living in lower-income neighborhoods are more likely to be exposed to high concentrations of air pollution, which is connected to worse health outcomes at higher exposure levels than in wealthier communities (Hajat et al., 2015). A system-level factor, for example, residential segregation and past policies such as redlining have placed polluting industries within or near impoverished global communities of color, thus worsening this difference (Lane et al., 2022).

Policy Response and Mitigation Efforts

Global Efforts to Combat Air Pollution

Activities and measures towards the protection of the environment and reduction of air-borne pollutants have been stepped up internationally and through treaties, the main goal being improving the quality of air and minimizing its effects on the health of people and the surroundings. The Paris agreement is one of the main frameworks that outlines the call for the reduction of greenhouse gases as a response to mitigate global warming. The agreement also outlines the side effects of reducing air pollution, which as improving public health and reducing expenditure on health costs occasioned by pollution-related diseases (Vandyck et al., 2018).

The WHO has published the guidelines for air quality in association with the Agreement of Paris. They are grounded on evidence and directed at the elimination of air pollution and safeguarding the well-being of people. These recommendations stress the problem of addressing the outdoor emissions and the emissions in an indoor environment, with a focus on the emissions produced by fuel fuel-consuming house (Shen et al., 2022).

National Policies for Air Quality Improvement

Europe and, to some extent, China have registered notable improvement in air quality due to the newborn countries' national programs in enhancing air quality. These projects entail technological development, regulation, and public health efforts aimed at improving the general quality of air as well as containing pollution. The Clean Air Act has been a main base step to set up the structured framework of the air quality management scheme in Europe. This legislation has opened the possibilities for systematic reductions of pollutants through the efficiency of monitoring systems and strict laws (Zheng et al., 2018).

China's air quality improvement plan is suitable for reference, as China has detailed plans for improving the quality of air. The Chinese government has in the past gone to the extent of taking serious steps towards enhancing air quality; in 2013, it implemented the Clean Air Action Plan with an aim of tackling emergent pollution situations. According to the reports, by 2018, this program helped reduce the $PM_{2.5}$ levels by 30%-40% in major cities (Zheng et al., 2018).

Technological Solutions and Innovations

The reliance on conventional energy, for instance, Fossil fuel power plants, greatly impacts our atmosphere owing to the emission of

various pollutant species like sulfur dioxide (SO2), nitrogen oxides (NOx), and particulate matter (PM). Recall that cleaner energy sources, electric vehicles, also control technologies in the industry have key roles to play in the mitigation of air pollution (Spyropoulos et al., 2021).

The second output is about the environmental impacts of using energy production; converting to cleaner sources such as solar, wind, and hydropower significantly cuts down on these emissions, hence promoting air quality and public health. The adoption of electric cars also adds to this change by doing away with emissions at the tailpipe, which are a major cause of blight in urban environments. Research has shown that extensive use of EVs will reduce urban air pollutants by substantial margins, especially within crowded regions (Qiu, 2024).

Future Outlook and Challenges

For air pollution control to be effective, there is a need for more than one solution, which includes clean energy sources, EVs, industry-specific emission standards, air monitoring, and public awareness programs. It was agreed that each measure is crucial for reducing pollution negative effects on health and ecosystems. From the use of fossil fuel and non-renewable resources to the use of clean energy is basic to pollution management; the use of electric cars has contributed to the achievement of noteworthy emission cuts (Qiu, 2024).

Challenges in Low-Income Countries

It was elicited that low-income nations face challenges in implementing effective air pollution control systems in that they lack infrastructure and are constrained by meager finances. These constraints severely impact their ability to tackle pollution, which poses grave health risks to their populations. Cuts in healthcare spending can significantly reduce the benefits available to poorer communities, increasing medical expenses and deepening health-related issues in areas (Placeres et al., 2023)

The Role of Climate Change

Climate change is predicted to amplify air pollution and its related health effects through various processes, posing serious threats to the public. Higher global temperatures are likely to boost the formation of ground-level O_3 and particulate matter (PM) due to atmospheric shifts that favor chemical reactions producing O_3 and impact pollution dispersion. As deteriorating air quality intensifies health risks, it becomes critical to implement robust public health regulations, an enhanced monitoring system, and government interventions to mitigate the issues (Fang et al., 2013).

Need for Global Cooperation

Managing the far-reaching impacts of air pollution requires a globally coordinated effort due to its transboundary nature. Strengthening international cooperation can help develop holistic strategies aimed at addressing both the sources and results of air pollution, ultimately improving air quality and global public health outcomes (Shaddock et al., 2020).

Conclusion

Reducing air pollution is vital to curbing the global incidence of cardiovascular and respiratory diseases. There is ample evidence linking air pollution to serious health risks. Addressing this issue requires collaboration among communities, governments, and health organizations to create and implement policies that enhance air quality and safeguard public health. Moreover, raising awareness through effective communication strategies is critical to encouraging protective measures, particularly among children, the elderly, and other vulnerable populations

References

Acciai, C., Zhang, Z., Wang, F., Zhong, Z., & Lonati, G. (2017). Characteristics and source analysis of trace elements in $PM_{2.5}$ in the urban atmosphere of Wuhan in spring. *Aerosol and Air Quality Research*, *17*, 2224-2234.

Bowatte, G., Lodge, C., Lowe, A. J., Erbas, B., Perret, J., Abramson, M. J., & Dharmage, S. C. (2015). The influence of childhood traffic-related air pollution exposure on asthma, allergy, and sensitization: a systematic review and a meta-analysis of birth cohort studies. *Allergy*, *70*(3), 245-256.

Chin, Y. S. J., De Pretto, L., Thuppil, V., & Ashfold, M. J. (2019). Public awareness and support for environmental protection. A focus on air pollution in peninsular Malaysia. *PloS one*, *14*(3), e0212206.

Dondi, A., Carbone, C., Manieri, E., Zama, D., Del Bono, C., Betti, L., & Lanari, M. (2023). Outdoor air pollution and childhood respiratory disease: the role of oxidative stress. *International Journal of Molecular Sciences*, *24*(5), 4345-4360.

Fang, Y., Mauzerall, D. L., Liu, J., Fiore, A. M., & Horowitz, L. W. (2013). Impacts of 21st century climate change on global air pollution-related premature mortality. *Climatic Change*, *121*, 239-253.

Ferrante, M., Fiore, M., Copat, C., Morina, S., Ledda, C., Mauceri, C., & Conti, G. O. (2015). Air pollution in high-risk sites–Risk analysis and health impact. *Current air Quality Issues*, 419-442.

Gao, Y., Chan, E. Y., Li, L., Lau, P. W., & Wong, T. W. (2014). Chronic effects of ambient air pollution on respiratory morbidities among Chinese children: a cross-sectional study in Hong Kong. *BMC Public Health*, *14*, 1-11.

Gorgulu, A., Koç, Y., Yaglı, H., & Koç, A. (2018). Adsorption of nitrogen dioxide (NO_2) for different gas concentrations, temperatures and relative humidities by using activated carbon filter: An experimental study. *International Journal of advance Engineering and Research Science, 5*, 2349-2456.

Hajat, A., Hsia, C., & O'Neill, M. S. (2015). Socioeconomic disparities and air pollution exposure: a global review. *Current Environmental Health Reports*, *2*, 440-450.

Jiang, Y., Ding, D., Dong, Z., Liu, S., Chang, X., Zheng, H., & Wang, S. (2023). Extreme emission reduction requirements for china to achieve

world health organization global air quality guidelines. *Environmental Science & Technology*, *57*(11), 4424-4433.
Khreis, H., Johnson, J., Jack, K., Dadashova, B., & Park, E. S. (2022). Evaluating the performance of low-cost air quality monitors in Dallas, Texas. *International Journal of Environmental Research and Public Health*, *19*(3), 1647.
Lane, H. M., Morello-Frosch, R., Marshall, J. D., & Apte, J. S. (2022). Historical redlining is associated with present-day air pollution disparities in US cities. *Environmental Science & Technology Letters*, *9*(4), 345-350.
Lee, S., Park, Y., Zuidema, M. Y., Hannink, M., & Zhang, C. (2011). Effects of interventions on oxidative stress and inflammation of cardiovascular diseases. *World Journal of Cardiology*, *3*(1), 18.
Lee, Y. G., Lee, P. H., Choi, S. M., An, M. H., & Jang, A. S. (2021). Effects of air pollutants on airway diseases. *International Journal of Environmental Research and Public Health*, *18*(18), 9905.
Lelieveld, J., Klingmuller, K., Pozzer, A., Poschl, U., Fnais, M., Daiber, A., & Munzel, T. (2019). Cardiovascular disease burden from ambient air pollution in Europe reassessed using novel hazard ratio functions. *European Heart Journal*, *40*(20), 1590-1596.
Mai, K. (2024). Influence of Air Quality on Respiratory Health in Urban Areas in Japan. *Global Journal of Health Sciences*, *9*(2), 49-58.
Megha, K. B., Joseph, X., Akhil, V., & Mohanan, P. V. (2021). Cascade of immune mechanisms and consequences of inflammatory disorders. *Phytomedicine*, *91*, 153712.
Molina, L. T., Velasco, E., Retama, A., & Zavala, M. (2019). Experience from integrated air quality management in the Mexico City Metropolitan Area and Singapore. *Atmosphere*, *10*(9), 512.
Murray, C. J., Aravkin, A. Y., Zheng, P., Abbafati, C., Abbas, K. M., Abbasi-Kangevari, M., & Borzouei, S. (2020). Global burden of 87 risk factors in 204 countries and territories, 1990–2019: a systematic analysis for the Global Burden of Disease Study 2019. *The Lancet*, *396*(10258), 1223-1249.
Nataraj, R. (2022). Application of machine learning on air quality. *Journal of Student Research*, *11*(4).
Nie, T., Chen, J., Ji, Y., Lin, T., & Wang, J. (2023). Impact of Air Pollution on Respiratory Diseases in Typical Industrial City in the North China Plain. *Sustainability*, *15*(14), 11198-11226.
Olesiejuk, K., & Chałubiński, M. (2023). How does particulate air pollution affect barrier functions and inflammatory activity of lung vascular endothelium? *Allergy*, *78*(3), 629-638.
Placeres, A. F., de Almeida Soares, D., Delpino, F. M., Moura, H. S. D., Scholze, A. R., Dos Santos, M. S., & Fronteira, I. (2023). Epidemiology of TB in prisoners: a metanalysis of the prevalence of active and latent TB. *BMC Infectious Diseases*, *23*(1), 20-35.
Rana, A. D., Parvez, S., Ul-Haq, Z., Batool, S. A., Chaudhary, M. N., Mahmood, K., & Tariq, S. (2019). Anthropogenic, biogenic and pyrogenic emission sources and atmospheric formaldehyde (hcho) and nitrogen dioxide (NO_2) columns over different landuse/landcovers of south asia. *Applied Ecology & Environmental Research*, *17*(5).
Rom, W. N. (2023). Annals of Education: Teaching Climate Change and Global Public Health. *International Journal of Environmental Research and Public Health*, *21*(1), 41.
Saraswat, A., Apte, J. S., Kandlikar, M., Brauer, M., Henderson, S. B., & Marshall, J. D. (2013). Spatiotemporal land use regression models of fine, ultrafine, and black carbon particulate matter in New Delhi, India. *Environmental Science & Technology*, *47*(22), 12903-12911.
Shaddick, G., Thomas, M. L., Mudu, P., Ruggeri, G., & Gumy, S. (2020). Half the world's population are exposed to increasing air pollution. *NPJ Climate and Atmospheric Science*, *3*(1), 1-5.
Shah, A. S., Langrish, J. P., Nair, H., McAllister, D. A., Hunter, A. L., Donaldson, K., & Mills, N. L. (2013). Global association of air pollution and heart failure: a systematic review and meta-analysis. *The Lancet*, *382*(9897), 1039-1048.
Shen, G., Xiong, R., Tian, Y., Luo, Z., Jiangtulu, B., Meng, W., & Tao, S. (2022). Substantial transition to clean household energy mix in rural China. *National Science Review*, *9*(7), nwac050.
Spyropoulos, G. C., Nastos, P. T., & Moustris, K. P. (2021). Performance of aether low-cost sensor device for air pollution measurements in urban environments. Accuracy evaluation applying the air quality index (aqi). *Atmosphere*, *12*(10), 1246.
Tang, D. (2019). A Comparison of Control Methods of Air Pollution in London and Beijing. *International journal of Environmental Sciences and Development*, *10*, 141-150.
Vandyck, T., Keramidas, K., Kitous, A., Spadaro, J. V., Van Dingenen, R., Holland, M., & Saveyn, B. (2018). Air quality co-benefits for human health and agriculture counterbalance costs to meet Paris Agreement pledges. *Nature Communications*, *9*(1), 4939.
Wang, D., Wang, Y., Liu, Q., Sun, W., Wei, L., Ye, C., & Zhu, R. (2023). Association of Air Pollution with the Number of Common Respiratory Visits in Children in a Heavily Polluted Central City, China. *Toxics*, *11*(10), 815-829.
Wang, X., & Huang, G. (2014). Impacts assessment of air emissions from point sources in Saskatchewan, Canada—a spatial analysis approach. *Environmental Progress & Sustainable Energy*, *34*(1), 304-313.
Yang, X., Li, Y., Li, Y., Ren, X., Zhang, X., Hu, D., & Shang, H. (2017). Oxidative stress-mediated atherosclerosis: mechanisms and therapies. *Frontiers in Physiology*, *8*, 600.
Zayakhanov, A. S., Zhamsueva, G. S., Tcydypov, V. V., Dementeva, A. L., Balzhanov, T. S., & Starikov, A. V. (2023). Results of measurements of the aerosol and gaseous composition of the atmosphere at the monitoring station of the Baikal natural territory Boyarsky. In *29th International Symposium on Atmospheric & Ocean Optics: Atmospheric Physics*, *12780*, 1166-1170.
Zhang, Y., Yin, X., & Zheng, X. (2023). The relationship between $PM_{2.5}$ and the onset and exacerbation of childhood asthma: a short communication. *Frontiers in Pediatrics*, *11*, 1191852.
Zheng, B., Tong, D., Li, M., Liu, F., Hong, C., Geng, G., & Zhang, Q. (2018). Trends in China's anthropogenic emissions since 2010 as the consequence of clean air actions. *Atmospheric Chemistry and Physics*, *18*(19), 14095-14111