

WHAT IS THE ROLE OF CHEMISTRY IN AIR POLLUTION?

Abstract

The World Health Organisation (WHO)¹ reported that air pollution is among the top three global risk factors for disease. Global warming, induced by the release of greenhouse gases, particularly carbon dioxide (CO₂), has emerged as a significant apprehension in recent times. The escalating carbon emissions can be attributed to the collective efforts of almost all nations. The surge in CO₂ emissions is directly linked to the amplification of heat levels. Consequently, the survival of living beings is becoming increasingly challenging due to the combustion of fossil fuels. Moreover, mankind's activities are causing substantial harm to the air, water, and soil. The overall condition of our global atmosphere is severely compromised.² Air pollution is undeniably one of the most pressing problems of our time, with far-reaching consequences for both the environment and human health. The presence of pollutants in the air has a profound impact on our well-being, leading to the development of various diseases and posing serious health risks. One of the immediate effects of air pollution is the creation of smog and acid rain. Smog is a visible manifestation of high levels of pollutants in the air, causing a haze that obscures visibility and poses significant health risks. Acid rain, on the other hand, occurs when pollutants in the atmosphere combine with water vapor, forming acidic compounds that fall back to Earth. This not only damages buildings and infrastructure but also harms plants, animals, and aquatic life.³ In this chapter, the causes, and impacts of air pollution and its management have been discussed which results in sustainable development.

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I. INTRODUCTION

Air pollution is one of the significant societal challenges for mankind not only in the present time but also a matter of great concern in the upcoming decades. A relevant and recent example that received a great deal of national and international attention is the extremely poor air quality in Delhi, India, particularly during winter times. Several studies have been carried out to understand the interaction between human beings and their physical environment because we know that human actions show greater influence on their surroundings⁴. Pollutants are dangerous substances of solids, liquids, and gases that are made in high quantities as compared to their normal ranges and show harmful effects on the surroundings. The behaviour of human activities shows adverse influences on the surroundings after drinking the polluted water and through the air or the land in which the cultivation of plants occurs. One of the biggest international health issues is environmental contamination globally. Important factors involved in this problem include legislative, economic, and social. Anthropogenic activities are the chief difficulty related to air pollution.⁵⁻⁷

It also has terrible effects on human health. When a person is exposed for a short time it causes problems like breath problems, respiratory illness, cough, chronic obstructive pulmonary illness, asthma, and hospitalization rates high. Long-duration exposure to air pollutants increases the chances of cardiovascular system problems, insufficiency of lungs, asthma, and diabetes as well.

It has been estimated that more than six million deaths occur annually due to the combined effect of household and ambient air pollution.⁸⁻⁹ Emission, chemistry, and meteorological conditions are the three prime factors that influence air pollution. This short review aims to explore the role of chemistry in air pollution. Tropospheric ozone (O₃), and particulate matter (PM) are the two most important chemical entities that cause poor air quality globally.⁷⁻⁸ Other chemicals that contribute to air pollution include carbon monoxide (CO), nitrogen dioxide (NO₂), sulfur dioxide (SO₂), and ammonia (NH₃) to name but a few. In this review, the chemistry behind the formation of tropospheric ozone (O₃) and secondary organic aerosol (SOA), a major constituent of the atmospheric particulate matter (PM) is thoroughly discussed.

Air pollution is a pressing environmental issue that affects the quality of air we breathe. It encompasses a wide range of pollutants, including gases, particles, and volatile organic compounds, which can have detrimental effects on human health and the environment. Chemistry plays a critical role in understanding, analyzing, and addressing air pollution. This document aims to explore the role of chemistry in air pollution and its implications for society.

1. Chemical Reactions and Air Pollutants: Chemical reactions are at the core of air pollution. The release of pollutants into the atmosphere from various sources triggers complex chemical reactions that lead to the formation of harmful compounds. For example, the burning of fossil fuels in power plants and vehicles releases carbon dioxide (CO₂), a greenhouse gas that contributes to global warming. Additionally, the incomplete combustion of fossil fuels produces nitrogen oxides (NO_x) and sulfur dioxide (SO₂), which can lead to the formation of acid rain.

- 2. Photochemical Smog Formation:** Chemistry also plays a significant role in the formation of photochemical smog, which occurs primarily in urban areas with high levels of air pollution. Photochemical smog is formed when sunlight reacts with nitrogen oxides (NO_x) and volatile organic compounds (VOCs) emitted from vehicle exhausts, industrial processes, and other sources. These reactions result in the formation of ground-level ozone (O₃) and other harmful secondary pollutants. Ground-level ozone irritates the respiratory system and can cause breathing difficulties, especially for individuals with pre-existing respiratory conditions.
- 3. Chemical Monitoring and Analysis:** Chemistry provides the tools and techniques necessary for monitoring and analyzing air pollutants. Scientists use sophisticated instruments to measure the concentration of various pollutants in the atmosphere. These measurements help in understanding the sources, transport, and transformation of pollutants. Chemical analysis is crucial for identifying the types and quantities of pollutants present in the air, allowing policymakers to develop effective strategies for pollution control and mitigation.
- 4. Air Quality Management:** Chemistry plays a pivotal role in air quality management. By understanding the chemical processes involved in air pollution, scientists and policymakers can develop strategies to reduce pollutant emissions and improve air quality. This involves implementing stricter emission standards for industries and vehicles, promoting the use of cleaner fuels, and investing in renewable energy sources. Chemistry also contributes to the development of advanced air pollution control technologies, such as catalytic converters, which help reduce harmful emissions from vehicles.

Hence, chemistry plays a crucial role in understanding of air pollution and its impact on human health and the environment. By studying chemical reactions, monitoring pollutants, and developing effective mitigation strategies, we can strive towards cleaner and healthier air. Continued research and collaboration in the field of chemistry are essential to combat the challenges posed by air pollution and ensure a sustainable future for generations to come. Governments around the world should invest in policies and technologies that reduce air pollution and ensure access to clean air. Furthermore, public education and awareness about the dangers of air pollution is essential to create a sustainable future.

II. CAUSES OF AIR POLLUTION

Air pollution is a worldwide matter that explains vital hazards to human health and the environment. Various factors including natural and human activities are responsible for causing air pollution. It is very important to understand the causes of air pollution so that new effective strategies can be developed to mitigate its harmful effects. The majority of air pollutants are discharged as a result of human activities like car engine combustion, power stations, and industrial machinery. These activities are carried out daily on a large scale and play a main role in air pollution. Forest fires and soil erosion are two activities that have a significant impact on human health. Petrol stations, printing shops, dry cleaners, domestic actions, incineration of municipality wastes, industrial plants, metallurgical, fertilizer and chemical industry, refineries, power stations, and petrochemicals are the chief causes of air pollution. Vehicles, airways, railways, cars, and automobiles are the mobile sources. Whereas

soil erosion, forest fires, storms of dust, and agricultural burning are some natural sources causing air pollution. Other classifications are based on pollutants and these are NO, CO, CO₂, hydrocarbons, SO₂, and NO₂. Air pollution has also shown its effects on the soil environment and water. This chapter aims to provide an overview of the primary reasons of air pollution.

- 1. Industrial Emissions:** The leading reasons of air pollution is the release of harmful pollutants from industrial activities. Industries such as power plants, refineries, and manufacturing facilities emit large amounts of pollutants into the air. These pollutants include SO₂, nitrogen oxides (NO_x), and particulate matter, which add to the formation of smog and respiratory issues.
- 2. Vehicle Emissions:** The increasing number of vehicles on the road is a chief source of air pollution, particularly in urban areas. Pollutants for example CO, nitrogen oxides (NO_x), and volatile organic compounds (VOCs) discharges as a result of the combustion of fossil fuels in vehicles. These pollutants not only contribute to poor air quality but also have adverse effects on human health.
- 3. Deforestation:** Deforestation, primarily due to agricultural expansion and urbanization, is another significant cause of air pollution. Trees show a vital role in eliminating air pollutants using photosynthesis process. As forests are cut down, the capacity to absorb pollutants is reduced, leading to increased levels of air pollution.
- 4. Fossil Fuels Burning:** The fossil fuels burning, such as coal, oil, and natural gas is a major contributor to air pollution. Power plants, residential heating, and industrial processes that rely on fossil fuels release large amounts of atmospheric pollutants. These pollutants include CO₂, SO₂, NO_x, and particulate matter.
- 5. Agricultural Activities:** Certain agricultural practices contribute to air pollution. The use of fertilizers and pesticides releases nitrogen compounds into the air, which led to cause smog and acid rain formation. Additionally, the burning of agricultural waste, such as crop residues, emits pollutants and contributes to air pollution.
- 6. Waste Management:** Improper waste management, including open burning of waste and inadequate landfill practices, can release harmful pollutants into the air. The combustion of waste materials generates toxic gases and particulate matter, contributing to air pollution and posing health risks to nearby communities.
- 7. Natural Sources:** While human activities are the primary contributors to air pollution, natural sources also play a role. Volcanic eruptions, dust storms, and wildfires discharge huge quantities of atmospheric pollutants.

Hence, atmospheric pollution is a complex issue with multiple causes. Industrial emissions, vehicle emissions, deforestation, burning of fossil fuels, agricultural activities, waste management, and natural sources all contribute to the deterioration of air quality. Addressing these causes is crucial in reducing air pollution and safeguarding human health and the environment. By implementing sustainable practices and adopting cleaner technologies, we can work towards a cleaner and healthier future.

III. CLIMATE CHANGE DUE TO AIR POLLUTION

Long-term shifts in temperature and weather patterns on Earth, resulting in significant and long lasting impacts on the environment and human societies. This refers to climate change. One major contributor to climate change is air pollution. The release of greenhouse gases, such as CO₂, CH₄, and N₂O, from various human activities, including fossil fuels burning, industrial processes, and deforestation, is a major cause of air pollution. Due to trapping of heat by these gases, temperature of atmosphere increases hugely causing greenhouse effect and subsequent global warming. This led to rise in Earth's average temperature causing drastic changes in the melting of polar ice caps, weather patterns, sea level rise.

Air pollution also contributes to the formation of smog, which is characterized by a combination of smoke and fog. Smog can have severe consequences for human health, particularly for persons suffering from asthma or chronic obstructive pulmonary disease (COPD). Prolonged exposure to smog results in respiratory disorders, cardiovascular diseases which even may lead to premature death.

Furthermore, air pollution affects ecosystems and biodiversity. Acid rain can have devastating effects on forests, lakes, and aquatic life. It damages plant life, reduces soil fertility, and alters the pH levels of water bodies, making them uninhabitable for many species.

The consequences of climate change due to air pollution are far-reaching and require urgent action. Governments, industries, and individuals must work together to reduce air pollution and mitigate its effects on the climate promoting sustainable practices.

In conclusion, climate change resulting from air pollution is a pressing issue that requires immediate attention. The release of greenhouse gases and the formation of smog have significant impacts on the environment, human health, and biodiversity. It is crucial to take proactive measures to reduce air pollution and combat climate change for the well-being of our planet and future generations.

Climate change is one of the important factors which show their influence on the earth's quality.¹⁰⁻¹² The number of pollutants presents include aerosol, tropospheric ozone, methane, and carbon black One of the major problems which arise due to climate change includes air pollution.

As per the WHO, there are mainly six significant air pollutants present in the atmosphere which include lead, oxides of nitrogen, oxides of sulphur, oxides of carbon, ozone ground level and particle pollution. Air, water and soil are hugely effected due to these pollutants. These pollutants have different hazardous impact on human health, climate changes, greenhouse effects and global warming¹³⁻¹⁴.

IV. ENVIRONMENT FRIENDLY PROCESSES TO CONTROL AIR POLLUTION

Air pollution is a significant global issue that poses serious threats to human health and the environment. To combat this problem, it is crucial to adopt environment-friendly processes that can effectively control and reduce air pollution levels. This document explores

various sustainable techniques and practices that can be implemented to mitigate air pollution and promote a healthier and cleaner environment.¹⁵

- 1. Transition to Renewable Energy Sources:** Prime suppliers to air pollution are the burning of fossil fuels for different purposes. To curb this problem, transitioning to renewable energy sources such as solar, wind, and hydropower is essential. These sources are unpolluted, and abundant, and prevent the release of harmful pollutants into the atmosphere, making them an excellent substitute for regular fossil fuels.
- 2. Promote Energy Efficiency:** Another effective way to control air pollution is by promoting energy efficiency in all sectors, including residential, commercial, and industrial. Implementing energy-saving approaches such as using energy-efficient machines, improving insulation, and adopting smart technologies can significantly reduce energy consumption and consequently decrease air pollution emissions.
- 3. Encourage Sustainable Transportation:** The transportation sector is a major contributor to air pollution, primarily due to the burning of fossil fuels in vehicles. Encouraging the use of sustainable transportation options can help minimize emissions and improve air quality. Promoting public transportation, carpooling, cycling, and walking not only reduces air pollution but also helps alleviate traffic congestion and promote a healthier lifestyle.
- 4. Implement Strict Emission Standards:** Enforcing strict emission standards for industries and vehicles is crucial in controlling air pollution. Governments and regulatory bodies should establish and monitor emission limits, ensuring that industries and vehicles comply with these standards. Regular inspections, emission testing, and penalties for non-compliance are essential to achieve cleaner air.
- 5. Support Afforestation and Green Spaces:** Trees and green spaces play a vital role in improving air quality. Supporting afforestation initiatives and creating more green spaces in urban areas can help combat air pollution. Trees absorb CO₂ and discharge oxygen, filtering harmful pollutants from the air. Additionally, green spaces act as natural buffers, reducing the impact of pollutants and enhancing overall air quality.
- 6. Implement Waste Management Strategies:** Improper waste management practices contribute to air pollution through the release of harmful gases and pollutants. Implementing effective waste management strategies such as recycling, composting, and proper disposal of hazardous materials can help minimize air pollution. Additionally, investing in waste-to-energy technologies can convert waste into renewable energy sources, further reducing air pollution.

V. CONCLUSION

Air pollution has adverse effects on human health as well as on the environment. However, by adopting environment-friendly processes, we can effectively control and reduce air pollution levels. Transitioning to renewable energy sources, encouraging energy efficiency, boosting sustainable transportation, enforcing strict emission standards, supporting afforestation and green spaces, and implementing waste management strategies

are some of the key measures that can be taken to combat air pollution. Hence a healthy environment can be made by executing these practices for upcoming generations.

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