



Air pollution in recent years: Causes, health impacts, and legal measures worldwide

Abdullah Al Masum*

Jagannath University, Dhaka, Bangladesh

Abstract

Air pollution has emerged as a serious global challenge in recent years, with concentrations of particulate matter (PM_{2.5}, PM₁₀), nitrogen oxides, sulfur dioxide, carbon monoxide, and other pollutants rising abruptly due to rapid industrialization, increased transport emissions, household fuel use, and fossil fuel-based energy production. This environmental crisis contributes to approximately seven million premature deaths annually, disproportionately affecting children, the elderly, and low-income communities, while also weakening chronic respiratory, cardiovascular, and neurological conditions.

In response, countries worldwide have developed legal and regulatory frameworks to reduce air pollution, ranging from international agreements such as the UNECE Long-Range Transboundary Air Pollution Convention and WHO air quality guidelines to binding national laws, including the EU Ambient Air Quality Directives, the U.S. Clean Air Act, and evolving South Asian policies targeting industrial emissions, vehicular pollution, and urban air quality. Despite these measures, enforcement remains uneven, and challenges persist in transboundary coordination and implementation.

This article employs a doctrinal and comparative methodology to examine the causes, health impacts, and legal responses to air pollution globally, with a focus on Asia and developing countries.

Keywords: Air pollution, environmental law, public health, climate change, air quality regulation, fossil fuel emissions, industrial pollution

Introduction

Approximately 7 million premature deaths occur each year due to air pollution, a serious and rapidly escalating global issue that affects 90% of the population. Through the burning of fossil fuels, it contributes significantly to the development of neurological, respiratory, and cardiovascular disorders as well as climate change. This "silent killer" costs the world economy more than \$8 trillion and disproportionately affects low- and middle-income nations, especially those with young people and the elderly.^[1] Air pollution also connects environmental damage to the breaking of basic human rights, especially the right to life.^[2] In this context, law plays a crucial role in preventing pollution, regulating emission sources, and ensuring accountability through effective enforcement mechanisms. Strong legal frameworks are thus essential to protect public health and environmental integrity. This article examines air pollution in recent years by analyzing its major causes, associated health impacts, and the legal measures adopted worldwide to address the problem. The article is structured to first review relevant literature, followed by an analysis of causes and health impacts, an examination of global and national legal frameworks and concluding with recommendations for strengthening air pollution governance.

Literature Review

1. Scientific and Public Health Literature

Scientific literature has firmly established air pollution as a leading global health risk. The World Health Organization (WHO) estimates that ambient and home-based air pollution together cause approximately 7 million early deaths per annum, primarily through cardiovascular and respiratory diseases.^[3] The Global Burden of Disease project similarly identifies fine particulate matter (PM_{2.5}) as a major reason for shortened life expectancy worldwide.^[4] Empirical studies further link long-term exposure to PM_{2.5} and nitrogen

dioxide (NO₂) with neurological disorders and increased mortality.^[5] Regional research highlights stark inequalities: South Asia consistently records some of the highest pollution-related health burdens, while Europe and North America show comparatively lower mortality due to stronger regulatory frameworks.^[6] Despite their methodological care, these studies largely remain within the domain of public health and provide limited insight into legal accountability or regulatory effectiveness.

2. Environmental and Legal Scholarship

Legal scholarship on air pollution focuses mainly on regulatory frameworks and governance mechanisms. At the international level, scholars analyse soft-law instruments such as the WHO Air Quality Guidelines and the Sustainable Development Goals, acknowledging their normative value but criticising their non-binding character and weak enforcement capacity. At the domestic level, comparative studies often highlight the effectiveness of binding regimes within the European Union and the enforcement-oriented approach of the United States under the Clean Air Act.^[7] In contrast, research on developing countries such as south Asian countries like India, Bangladesh & Pakistan frequently identifies legislative gaps, weak institutions, and inadequate monitoring and enforcement mechanisms.

3. Gaps in Existing Literature and Justification

Although the literature is extensive, it often treats scientific evidence and legal analysis separately. Limited attention is paid to comparative enforcement practices and accountability mechanisms across jurisdictions. This article addresses these gaps by integrating recent health impact data with a comparative legal analysis of air pollution control measures, focusing on implementation and enforcement challenges in both developed and developing states.

Causes of Air Pollution in Recent Years

1. Industrial Emissions

Industrial emissions are a major cause of air pollution in recent years. Activities such as manufacturing, fossil fuel combustion, and energy production release large amounts of carbon monoxide, hydrocarbons, particulate matter (PM), and other harmful chemicals into the atmosphere. These processes also emit significant greenhouse gases, including carbon dioxide (CO₂), methane (CH₄), and nitrous oxide (N₂O). While greenhouse gases naturally help regulate the Earth's temperature by trapping infrared radiation, excessive human-induced emissions have intensified the greenhouse effect, contributing to climate change.

The impact of each greenhouse gas varies according to its atmospheric lifetime and global warming potential (GWP), which measures its warming effect relative to CO₂ over a specific period. Methane, for instance, has a GWP approximately 21–25 times higher than CO₂, making it a particularly potent contributor to global warming. Increased industrial emissions have therefore accelerated atmospheric warming and intensified environmental and public health risks.^[8] In addition, inadequate adoption of effective emission control technologies remains a significant cause of air pollution, particularly in rapidly urbanising and industrialising regions. Although advanced technologies have reduced emissions in some developed areas, continued expansion of industrial production, increased vehicle use, and reliance on outdated, high-emission equipment have offset these gains. The failure to implement cleaner technologies and modern pollution-control systems, therefore contributes to persistently high and often hazardous levels of air pollutants.^[9]

2. Transport and Urbanization

Transportation infrastructure and urbanization significantly contribute to environmental pollution, particularly through increased CO₂ emissions, which is a major component of air pollution.^[10] Inadequate transport planning and dependence on fossil-fuel vehicles in urban settings raise pollutant concentrations, further deteriorating air quality. Factors such as road networks, distance to major roads, traffic density, housing concentration, industrial areas, and availability of green spaces strongly influence pollution levels and people's exposure. Individual behavior, such as daily travel patterns, also affects personal exposure to pollution, access to green areas, sunlight (UV), and levels of physical activity. Environmental conditions in cities such as air pollution, noise, and extreme temperatures are linked to higher rates of illness and premature death.^[11] Many urban environmental problems can be improved through better planning and policy. Measures such as improved public transport, greener urban design, and reduced traffic congestion are often more effective and cost-efficient at the community level than focusing only on individual behavior. However, cities function as complex systems where transport, housing, environment, and public health are closely connected, making integrated planning essential.^[12]

3. Fossil Fuel Extraction and Energy Production

Fossil fuel extraction and energy production are major causes of air pollution, releasing harmful pollutants like nitrogen oxides, sulfur dioxide, and particulate matter (soot) that cause smog, acid rain, and severe respiratory diseases. The energy production through fossil fuels is a leading

contributor to air pollution globally. Burning coal, oil, and natural gas for electricity, heating, or transportation emits numerous harmful pollutants into the atmosphere, posing serious risks to public health and the environment.^[13]

"In 2024, carbon dioxide (CO₂) emissions increased due to energy production caused by higher coal and natural gas use, especially in countries such as China and India that experienced intense heatwaves. This rise, to meet cooling demands, led to a notable increase in electricity consumption and consequently, a 0.8% increase in global CO₂ emissions, reaching 37.8 billion tonnes."^[14]

All major fossil fuels release harmful gases and particulate matter when burned for energy. While emissions from fixed facilities such as oil and gas fields, refineries, and processing plants may be smaller in scale compared to fuel combustion, they can still cause serious local environmental and health impacts. Oil and gas activities, including exploration, production, refining, and combustion emit toxic pollutants that contribute both to air pollution and climate change. Key emissions include methane (CH₄), nitrogen oxides (NO_x), sulfur dioxide (SO₂), and volatile organic compounds (VOCs), which play a significant role in the formation of ground-level ozone and the deterioration of air quality.^[15]

4. Household and Natural Sources

Household air pollution from cooking/heating with solid fuels (biomass, coal), tobacco smoke, and cleaning chemicals, often creating toxic indoor environments. Natural sources, including wildfires, volcanoes, wind-blown dust, and pollen, release significant, uncontrollable pollutants like particulate matter into the atmosphere.^[16] Toxic pollutants including particulate matter, carbon monoxide, nitrogen dioxide, VOCs, and dioxins which pose serious health risks are released from them. It is a major environmental risk factor for disease and premature death, driven by the use of inefficient fuels and technologies in homes.

Health Impacts of Air Pollution

1. Global Mortality and Disease Burden

In 2023, air pollution contributed to 7.9 million deaths, with over 1 in 8 deaths globally linked to air pollution.^[17] 86% of air pollution-related deaths (6.8 million) are due to chronic diseases such as ischemic heart disease, stroke, chronic obstructive pulmonary disease (COPD), and lung cancer. Breathing polluted air harms the body by allowing toxins to pass from the lungs into the bloodstream, affecting the heart, brain, and other organs, and even reaching a developing fetus. It triggers inflammation and contributes to major diseases, accounting for a significant number of premature deaths. Vulnerability is uneven: people in poorer regions, young children, and older adults face the highest health risks due to greater exposure, limited healthcare access, and socioeconomic factors. While some effects appear immediately, most health impacts accumulate gradually over time, making air pollution a persistent and serious public health threat.^[18]

2. Impact on Vulnerable Groups

Air pollution disproportionately affects vulnerable populations, including children, the elderly, and low-income communities. Children are especially at risk due to their developing bodies and behaviors, with exposure to

pollutants like particulate matter (PM) and nitrogen oxides (NO_x) linked to chronic respiratory diseases, cognitive impairments, and long-term health issues.^[19] The elderly face worsening of pre-existing conditions, such as cardiovascular and pulmonary diseases, and higher risks of dementia and premature death. Low-income communities, often living near industrial zones or busy roads, experience higher pollutant exposure and limited access to healthcare and preventive measures. Additionally, air pollution during pregnancy can harm fetal development, increasing the risk of adverse childhood health outcomes. These findings highlight the intersection of environmental hazards with social and economic vulnerabilities, making air pollution both a public health and social justice issue.

International Legal and Policy Frameworks

1. Role of International Organizations

International organizations play a foundational role in shaping global responses to air pollution through norm development, institutional coordination, and policy guidance. International bodies, particularly within the United Nations system, have been instrumental in framing environmental protection as a shared global responsibility. Institutions such as the United Nations Environment Programme (UNEP) facilitate multilateral cooperation, support environmental treaty development, and provide technical assistance to member states. Similarly, the World Health Organization contributes by establishing air quality guidelines and advancing scientific standards that influence national regulatory frameworks.^[20]

2. Global Policy Instruments

Air pollution reduction is essential to the 2030 Agenda for Sustainable Development Particularly Goal 3 “Ensure healthy lives and promote well-being for all at all ages” and Goal 11 “Make cities and human settlements inclusive, safe, resilient and sustainable”. The 1979 UNECE Convention on Long-Range Transboundary Air Pollution established a regional legal framework to reduce cross-border air pollution through targeted emission control protocols. It introduced specific commitments to limit pollutants such as sulphur dioxide (SO₂), nitrogen oxides (NO_x), ammonia (NH₃), volatile organic compounds (VOCs), and particulate matter (PM_{2.5}). The 2012 amendments to the Gothenburg Protocol strengthened these obligations by setting stricter reduction targets and addressing multiple pollutants simultaneously, including black carbon as a component of particulate matter, thereby linking air quality improvement with climate benefits. Additional protocols adopted in 1998 focus on reducing emissions of heavy metals and persistent organic pollutants.^[21]

National Legal Measures: Comparative Analysis

1. European Union

The European Union regulates air quality through a three-pillar legal framework:

- 1. Ambient Air Quality Standards:** Binding limit and target values for key pollutants under Directive 2008/50/EC require Member States to maintain safe air quality levels.^[22]
- 2. National Emission Reduction Commitments (NEC):** Directive (EU) 2016/2284 sets legally binding national

emission ceilings for major pollutants, ensuring gradual reduction across Member States.^[23]

- 3. Source-Specific Regulation:** Sectoral controls address emissions from transport (Euro standards), industry (Industrial Emissions Directive), and energy production.^[24]

2. United States

The Clean Air Act^[25] is the principal federal law governing air pollution control in the United States. Enacted in 1970, it authorized the United States Environmental Protection Agency (EPA) to establish National Ambient Air Quality Standards (NAAQS) to protect public health and the environment, while requiring states to develop State Implementation Plans (SIPs) to accomplish compliance. The 1977 amendments strengthened controls in non-attainment areas and introduced the Prevention of Significant Deterioration (PSD) program to protect cleaner regions. The 1990 amendments expanded the Act to address acid rain, ground-level ozone, stratospheric ozone depletion, air toxics, and visibility impairment. The Act regulates major pollutants including NO_x, SO₂, particulate matter (PM₁₀ and PM_{2.5}), CO, VOCs, ozone, and lead.

3. Asia and Developing Countries

In Asia and other developing regions, governments are increasingly adopting coordinated strategies to combat air pollution and strengthen compliance with national air quality standards. The South Asian region faces severe air pollution, often 20 times higher than WHO-recommended levels. Legislation is evolving towards a “35 by 35” goal (35 for annual PM_{2.5} concentrations by 2035).^[26] These countries are strengthening legal frameworks to address increasing air pollution through statutory reforms, regulatory enforcement, and regional cooperation.

Bangladesh relies on the Environment Conservation Act 1995 and the Air Pollution Control Rules 2022, targeting emissions from industries, vehicles, brick kilns, and construction. The National Air Quality Management Plan (2024–2030) seeks a 15% nationwide and 30% Dhaka-based reduction in PM_{2.5} levels. Judicial directives and proposed carbon taxation further reinforce enforcement.

India operates under the Air (Prevention and Control of Pollution) Act 1981. The National Clean Air Programme (NCAP) aims for a 40% reduction in PM₁₀ in non-attainment cities. The Commission for Air Quality Management Act 2021, Bharat Stage VI standards, and emergency response mechanisms strengthen regulatory oversight.

Pakistan, under the Pakistan Environmental Protection Act 1997, implements provincial smog control plans, vehicle emission monitoring, and judicial enforcement, though outdated penalties limit deterrence.

Regionally, initiatives such as the “Kathmandu Roadmap” reflect growing recognition that air pollution is transboundary and requires coordinated, airshed-based governance.

Conclusion

Air pollution continues to pose a severe global health threat, contributing to millions of premature deaths and widespread morbidity, particularly among vulnerable populations. While numerous legal frameworks exist ranging from

international conventions to national statutes in developed and developing countries their impact is often limited by irregular enforcement, weak institutional capacity, and gaps in monitoring and compliance.

To address these challenges, national air quality laws must be strengthened with clear standards, strong enforcement mechanisms, and measurable targets. Transparent data and public access are important to ensure accountability and empower communities to contribute in pollution control efforts. At the same time, international and regional cooperation is critical, particularly in transboundary pollution where coordinated action can produce greater health and environmental benefits.

In short, air pollution is a shared global legal responsibility that demands integrated, enforceable, and science-based strategies that connect national action with international commitments to safeguard human health and the environment.

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