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SOURCES OF AIR POLLUTION IN RELATION TO THE PUBLIC HEALTH AND ENVOIRONMENT

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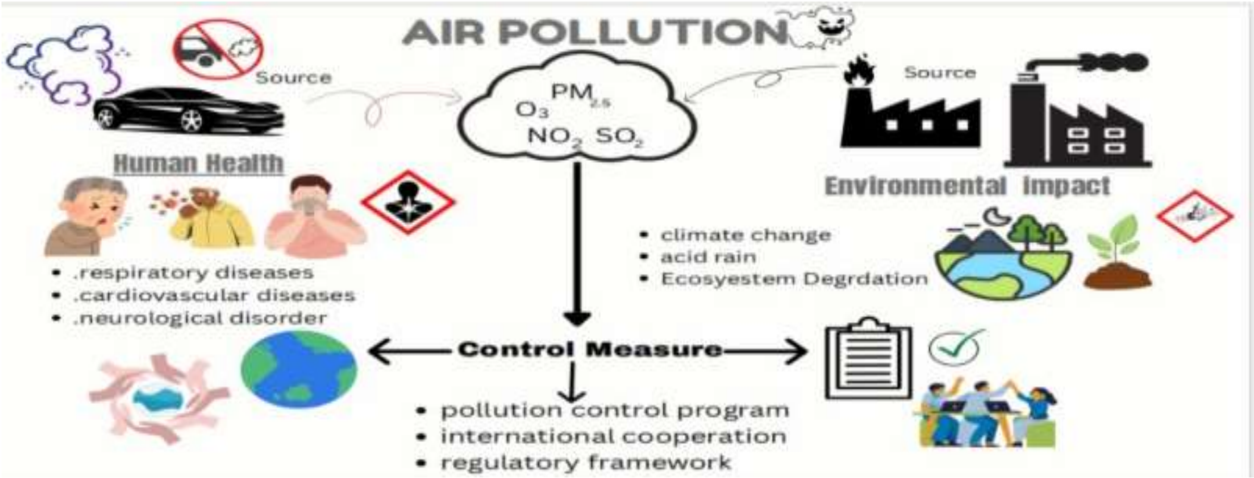
Article Info

Abstract

Air pollution has emerged as a critical global threat to public health and the environment. Major pollutants like PM2.5, O3, NO2, and SO2 contribute to respiratory, cardiovascular, and metabolic diseases, affecting over 92% of the world's population. Children are especially vulnerable, with pollution linked to increased morbidity and mortality worldwide. Anthropogenic activities such as vehicle emissions, power plants, and industrial processes are the major sources of air pollution, releasing harmful pollutants that impact human health and the environment. Both indoor and outdoor pollution contribute to respiratory and cardiovascular diseases, especially among vulnerable populations like children and workers. Long-term exposure to fine particles significantly increases the risk of chronic respiratory diseases like COPD and cardiovascular conditions such as ischemic heart disease. Air pollution causes climate change, acid rain, ecosystem degradation, ozone depletion, and biodiversity loss by damaging air, water, soil, and living organisms. These impacts threaten ecosystem services and global environmental health, necessitating urgent pollution control measures. Maximizing success in addressing atmospheric change and environmental degradation requires increasing public awareness, training, and engagement. A global preventative program and sustainable development strategies are essential to counteract anthropogenic air pollution and manage its health impacts. International cooperation in policy, administration, monitoring, and research is crucial, alongside advancing and synchronizing air pollution laws. Focusing on local frameworks to promote knowledge and practice can support the creation of effective global regulations for sustainable ecosystem management.

Keywords: *Environmental health, Gas emission, Toxicity, Policy , Air pollution, Public health.*

GRAPHICAL ABSTRACT



1. Introduction:

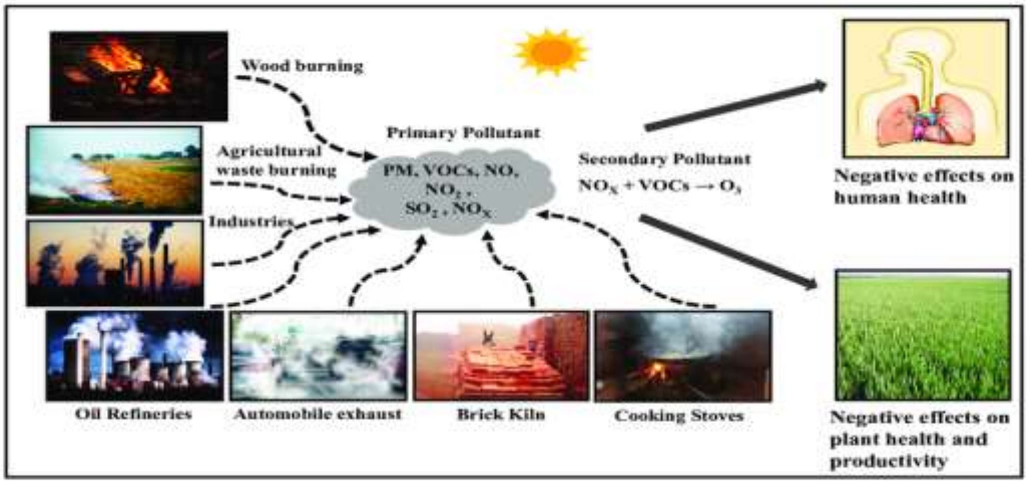
Since the release of Silent Spring, environmental pollution's threat to the ecology and public health has gained more attention worldwide. Because the environmental problem is so complex, the risks that pollution constitutes to public health are still an open question. Due to the growing problem of air, soil water, pollution, the world's population continues to face previously unrecognized health issues. As an illustration, airborne PMs raise threat of lung cancer, chronic respiratory illnesses, heart disease, acute and stroke diseases (Organization, 2025). The problem of air pollution is worldwide. Statistics from the World Health Organization (WHO) show that more than 92% of people live in areas with contaminated air . This has had a major effect on both the natural environment and human life. It is noteworthy that 93% of children over 15 breathe contaminated air globally, mostly from indoor sources (Le et al., 2024).Climatic alterations and the outcomes of global warming have a significant effect on numerous ecosystems, leading to problems such as animal extinction, food safety, ice and iceberg melting, and plant damage (Karl et al., 2009; Marlon et al., 2019). Air pollution has numerous health consequences even with little air pollution, the health of sensitive people can suffer. Short-term contact to air pollutants has been caused pulmonary insufficiency, asthma, cough, shortness of breath, respiratory disease. Chronic asthma, cardiovascular disease, as well as cardiovascular mortality are some of the long-term effects of air pollution. Swedish cohort research reveals that , long-term exposure to air pollution appears to produce diabetes (Eze et al., 2014).When smoke, dust, vapor's, or foreign gases are released into the atmosphere, the composition of the air is significantly altered, resulting in strange smells, decreased visibility, and climatic change. This is known as air pollution. The health of people, animals, and plants on Earth is directly impacted by these contaminants. The primary causes of air pollution are PM, O3, NO2, and SO2. Among these, the largest percentage of PM2.5 emissions came from the burning of agricultural waste (40%), followed by road traffic (13%), residential cooking (17%), forest fires (12.7%), industrial operations (11%), and thermal power plants (3.3%). Together, the remaining sectors provided roughly 3% of the nation's emissions, especially PM2.5. There is a substantial and rising disease burden linked to both indoor and outdoor air pollution exposure. Approximately 7 million people die from it every year, making it a serious hazard to human health. The morbidity and mortality rates from non-communicable respiratory and cardiovascular diseases are raised by air pollution. Additionally, the main factor contributing to the rise in the illness burden from lower respiratory tract infections, preterm deliveries, and other causes of pediatric mortality is declining air quality. In addition, air pollution continues to be a major contributor to the burden of disease in low- and middle-income nations (Organization, 2021). In 2019, common causes like obesity, low birth weight, or an unhealthy diet were outweighed by the effects of indoor as well as outdoor air pollution on mortality (Kumar et al., 2023). Furthermore, according to data from Europe, a 10% sample mean rise in PM2.5 concentration, or 1 µg/m3, causes a 0.8% drop in real GDP in the same year (Shen et al., 2022). Air pollution not only has a negative health impact but also has financial consequences due to its effects on crops, infrastructure, and buildings. Degradation of the environment and air pollution also support to the costs of climate change (Organization, 2021).Both acute and long-term exposure to air pollution, particularly coarse and fine particles, has been shown to increase mortality and morbidity in the population . According to the WHO, exposure to outdoor air pollution causes an estimated 4.2 million deaths annually, making it the most important risk factor for death globally Living in large cities, where traffic emissions are the primary cause of air quality degradation, is where people are most affected by air pollution. There is also a risk of industrial mishaps, in which the local population may perish as a poisonous cloud spreads. Wind and atmospheric stability are two of the many factors that affect how pollutants spread (Organization, 2021).Urban areas are leading the way in vehicle pollution, which has significantly increased over the past few decades due to a number of factors, including heavy traffic, biological and non-biological waste decomposition, vehicle engine combustion. The release of VOC into the environment is caused by industrial activities, among other things. VOC emissions in urban areas are significantly increased by large-scale construction projects, building painting operations, dry cleaning methods, coal-fired power stations, and petrochemical manufacturing facilities (Jin et al., 2022). Furthermore, a lot more volatile organic compounds are released during the synthesis, transportation, use, and manufacture of fossil fuels(Fairburn et al., 2019). In determining the cause of stubborn human diseases, environmental pollution deserves greater attention. Environmental variables, including dangerous chemical ,biological and physical elements in the environment, are thought to be responsible for 23% of deaths and 24% of the world's illness burden ("Preventing disease through healthy environments," 2006; de Araujo Scattolin et al., 2022). Environmental biohazard elements are categorized as conventional environmental risks (de Araujo Scattolin et al., 2022). A correlation between pollution and mortality was documented based on outdoor pollution monitoring in six major US cities (Semczuk-Kaczmarek et al., 2022). Mortality appeared to be highly correlated with fine, inhalable, sulfur dioxide, and levels in each instance, more so than nitrogen dioxide, or total particulate pollution levels ,aerosol acidity (Semczuk-Kaczmarek et al., 2022). Moreover, reports of extremely high pollution levels include Ankara, Melbourne, Mexico city and Rio de Janeiro first, Tokyo, and Moscow(Dar et al., 2024). Problematic locations must be identified by comparing these criteria to the emissions inventory standards using causal analysis and dispersion modeling (Sah et al., 2023). In order to control air quality, WHO as well as EPA created regulations and guidelines for the various contaminants(Nawaz et al., 2024). Causation analysis and dispersion modeling must be used to identify problematic locations (Sah et al., 2023).Normally, a mixture of direct measurements and emissions modeling utilized to create profiles (Semczuk-Kaczmarek et al., 2022; Sah et al., 2023).Using cars' catalytic converters as an example, we outline the source-level control measures here. These are machines that use redox reactions and catalysis to turn the harmful gases and pollutants from combustion engines into less harmful ones (Akhtar et al., 2021).Tracking private vehicles' license plates was implemented in Greece to limit their use and ease rush-hour traffic (Akhtar et al., 2021).

In terms of industrial emissions, closed systems and collectors can decrease air pollution to the established ranges (Manisalidis et al., 2020).The economic value of the advantages based on suggested programs must be evaluated in order to execute current air quality improvement initiatives. Public authorities have developed these projects and given directions with guidelines that should be obeyed. The National Ambient Air Quality Standards, set the national air quality standard values in the United States (Manisalidis et al., 2020). The decrease of overall emissions and related environmental and health impacts has been accomplished with considerable success, while the fact that rules and regulations are based on different methods (Manisalidis et al., 2020). Children experienced the same health problems as adults, and the major finding was that VOCs had an impact on the youth at any age, which truly alarming. In particular, The important outcomes has been that VOCs target the young population, which was very alarming and children faced the same health concerns like adults (Sonne et al., 2022; Vandenberg et al., 2023). These results have given some link for their susceptibility towards lung infections including bronchitis as their schooling environment is surrounded by a typically high pollution rate because of high traffic exhaust pollution and household heating activities, etc. were found to be more strongly impacted than elementary and secondary school students (Sonne et al., 2022; Vandenberg et al., 2023).In this review, we emphasize on the sources of Air pollution in relation to public health and environment and also give some solutions and interferences that may be interest to environmental legislation as well as decision makers.

2. Pathway and source of exposure:

Most environmental contaminants are released om large-scale by anthropogenically activities comprising driving cars, , power plants, using combustion engines as well as industrial machines. These activities are the main sources of air contamination due to their extensive magnitude; autos are thought to be accountable for about 80% of current pollution (Brumberg et al., 2021). Field cultivation methods, petrol stations, fuel tank heaters, also cleaning practices are some more anthropogenic activities that have a lesser impact on our environment (Osipov et al., 2022). In addition to a number of natural sources including soil along with volcanic eruptions and forest fires. The primary basis for classifying air pollutants is the sources of pollution. In accordance with the classification , it is crucial to discuss the four primary sources: major, area, mobile, and natural sources. The chemical and fertilizer industries, metallurgical ,power plants, refineries, also petrochemicals are major producers of pollution emissions, subsequently municipal incineration. Dry cleaners, printing shops, gas stations, and household cleaning tasks are examples of indoor area sources. Automobiles include, cars, railroads, airplanes, and other vehicle types are examples of mobile sources. As mentioned before, natural sources (De et al.) including forest fires, volcanic erosion, dust storms, and agricultural burning are examples of natural sources. Fast population expansion and a constantly changing economy contributed to a fast rise in energy demand. In terms of producing goods to fulfill basic requirements, human production is the main source of hazardous compounds that are hazardous to people. Every day, emissions of tobacco smoke, exhaust gases, pesticides, solvents, detergents, dust, particles, molds, fibers, and allergens are released (Diver et al., 2024; Le et al., 2024). Increased fossil fuel consumption is especially worrisome since it threatens the environment's ability to develop sustainably (Chunyu et al., 2021). The emissions of CO2, SO2, CO, NO2, and PM into the indoor atmosphere are also caused by combustion sources and cooking activity (Mansouri et al., 2022).

There is also a connection between inside and outdoor air pollution (Nandan et al., 2021; Zhao et al., 2024). There are a number of known indoor air pollutants, such as radon, PM, SO2, O3, CO, NOx, O3, and volatile as well as microbes. NOx, SO2, O3, PM, and other pollutants are prevalent both indoors and outside, and some may have their source outside (Fermo et al., 2022). The movement of outside contaminants into the indoor environment, for example, through ventilation systems, occurs as concentrations of these pollutants rise (Zhao et al., 2024).Increased cardiovascular morbidity (Fermo et al., 2022) and the development of asthma (Kim et al., 2020). have been associated to air pollution exposures in neonates and children in two recent assessments on ambient and traffic-related air contamination. PM exposure during pregnancy has also been linked to increased risks of infant mortality from respiratory and all causes (Deng et al., 2020). However, a full assessment of the research on early-life exposures to air pollution has not been conducted with regard to a wide range of prenatal and child health outcomes. Furthermore, the majority of reviews have concentrated on ambient outdoor air pollution without source attribution (Kim et al., 2020) .Risks to occupational safety and health have become a growing issue in recent years (Stahl, 2020) . Workers in industries that are primarily involved in manufacturing and agriculture may be facing hazardous substances on a short-term or long-term basis. The industry's exposure to silica dust at work serves as an example. During industrial activities such as drilling, blasting, cutting, etc., silica can be produced in both crystalline and amorphous forms (Antoniou et al., 2024). Silicosis is a distinguished fibrotic lung condition that can be hazardous if inhaled in significant quantities of crystalline silica dust (Handra et al., 2023).A common cause of cardiopulmonary disease in air pollution. Train conductors and engineers who were exposed to diesel exhaust, a mixture of burning gas also ultrafine PMs containing organic compounds, had higher rates of COPD mortality, which was linked with their length of service, according to a research of COPD cases among railroad workers in the US (Ferguson et al., 2020). Individuals with COPD experienced an increase in heart rate variability of 8.3% and 7.7%, respectively, when exposed to ambient air consisting PM 2.5 and nitrogen dioxide (Dominski et al., 2021). Figure#01. Exposure pathway of Air pollutants



Sourse:https:https://www.researchgate.net/figure/The-different-sources-of-primary-and-secondary-air-pollutants-and-their-negative-effects_fig1_363394640

Also there is evidence that the improving of residential areas has been linked to a lower rate of heart failure and acute myocardial infarction among local residents. Also, patients with cardiovascular disease (Watkins et al., 2023). many advantages from the improved air quality, which is evidenced by a lower risk of death When changes are made to the components of the environment it cause environmental pollution. Pollutants damage our environment by either introducing dangerous compounds or by raising levels above normal. The sources listed above release primary pollutants, simultaneously as secondary pollutants are produced as results of the primary pollutants. Pollutants may be artificial or naturally occurring, biodegradable, or nonbiodegradable. Being our body's outermost layer, our skin serves as a barrier against UVR and other pollutants. Pigmented spots on our skin may result from pollutants linked with traffic, including volatile organic compounds, oxides, PM also PAHs (C.-H. Huang et al., 2022).Furthermore, public areas like cafes, temples, and other construction sites boost the concentrations of airborne particles (Safo-Adu et al., 2023). Global warming, Acid rain, ozone, greenhouse effect, besides with climate change have an ecological effects on air pollution(Chauhan et al., 2024) .

3. Classification of Air pollutants:

Air Pollutants is the combination of dust, feasts, shadows, patches, and natural rudiments in sufficient amounts to have an impact on the terrain and mortal health is known as air pollution (Usman et al., 2023). Air adulterants are distributed into out- of- door and Inner air adulterants. The primary sources of out- of- door air pollution include Vehicular emissions, agriculture, petroleum emissions, wildfire, thermal power plants, industrial boilers, dust storms and incineration of waste. . Inner air pollution can include high attention of adulterants, annoyances, carcinogens, microorganisms, aversions, and fine inner dust (Navas-Martín et al., 2023; Le et al., 2024). According to world health association report(WHO) report, there are 6 main adulterants that are honored and studied includes Particulate matter(PM), sulphur Dioxide, Nitrogen oxides, carbon monoxide, lead and ground position ozone. Likewise, it seriously endangers living goods. In keeping with this, we are primarily take interest in this adulterants since they are associated to more crucial issues with mortal health and terrain. The effects of Acid rain, high temperature, changes in global weather pattern have diverse impact on air pollution (Wu et al., 2022). They also have serious health impacts. Also we club each contaminant.

3.1.Particulate matter and their Source

The US Environmental Protection Agency combined a term" particulate matter"(PM) to adulterants (Kant, 2021).Particulate matter(PM) is created by atmospheric chemical responses as well as direct emigrations. Vehicle exhaust, artificial operations, and the burning of biomass are some of the sources of primary PM emigrations. Environmental factors like moisture, temperature, pH have an impact on these processes (Pennington et al., 2024).Physical processes that increase flyspeck size, similar as coagulation and condensation, also aid in the generation of PM (Y. Li et al., 2023). PM pollution is made up of particulate matter that is dispersed according to specific sizes, such as patches that are 10µm or smaller PM10 also extremely fine patches that are typically 2.5 µm or smaller. Ingredients for PM 2.5 and PM10 may be biological or inorganic (Wong et al., 2021). Particulate matter (PM) is divided into four groups based on size and kind (Richard et al., 2024).

Table #01: Types of Particulate matter with diameter

Type		PM diameter [μm]
Particulate contaminants	Smog	0.01–1
	Soot	0.01–0.8
	Tobacco smoke	0.01–1
	Fly ash	1–100
	Cement Dust	8–100
Biological Contaminants	Bacteria and bacterial spores	0.7–10
	Viruses	0.01–1
	Fungi and molds	2–12
	Allergens (dogs, cats, pollen, household dust)	0.1–100
Types of Dust	Atmospheric dust	0.01–1
	Heavy dust	100–1000
	Settling dust	1–100
Gases	Different gaseous contaminants	0.0001–0.01

Source:https://www.researchgate.net/figure/Types-and-sizes-of-particulate-Matter-PM_tbl2_339383139

3.2.Sulphur Dioxide and their Source

Sulfur dioxide(SO_2) is a white , toxic gas with pungent small and odorless produced by burning of fossils and industrial processes like coal and oil , as well painting refining and substance smelting. Significant respiratory issues similar asthma, bronchitis, and other pulmonary conditions can affect from breathing in SO_2, a major air contaminant (Orellano et al., 2021). Likewise, SO_2 combines with atmospheric water vapor to induce sulfuric acid, a major element in acid rain that harms structure, soil, and ecosystems (J. Huang et al., 2023). According to Zhang, SO_2 also plays a part in formation of fine particulate matter ($PM_{2.5}$), which increases air pollution and causes major health hazards (Zheng et al., 2022). Also, although SO_2 cools the earth by reflecting sun through the creation of aerosols, its mischievous consequences on mortal health and the ecosystem greatly exceed whatever slight benefits it may have for the climate (Asare, 2024). Thus, several nations have executed laws to circumscribe SO_2 emigrations, using technologies similar scrubbers to lessen the quantum of SO_2

released into the atmosphere (M. Huang et al., 2021).

3.3. Nitrogen oxides and their Source

Nitrogen oxides is a sanguine- brown gas. The primary source of nitrogen dioxide(NO_2) is the burning of reactionary powers, particularly in buses power shops and artificial operations. It is a major contributor to air pollution, playing a significant role in the creation of fine particulate matter ($PM_{2.5}$) and ground-level ozone Formation, both of these pose serious risks to human health (S. Huang et al., 2021) . Exposure to NO_2 can aggravate the respiratory system, adding the trouble of respiratory infections and conditions like asthma and bronchitis (X. Xia et al., 2024). Along with its negative goods on health, NO_2 also helps produce acid rain, which can harm leafage, soils, and submarine homes(S. Huang et al., 2021). To make matters worse, NO_2 also reacts with changeable organic mixes(VOCs) to produce secondary pollutants like ozone and secondary organic aerosols (de Souza et al., 2025). Likewise, NO_2 has a part in the product of fine particulate matter, which is connected to lung cancer, cardiovascular conditions, and early death (S. Huang et al., 2021).For this reason, reducing NO_2 emigrations is essential to enhancing air quality and securing public health.

3.4. Carbon monoxide and their Source

Carbon monoxide is a Taintless, odorless and tasteless gas, poisonous to both people and brutes, indeed at low situations. Wood, coal, natural gas, gasoline, and other powers that contain carbon are the main sources of it (S. Huang et al., 2021). The main sources are backfires, artificial exertion, home heating, and motor vehicle emigrations(Arab et al., 2024). Kerchief hypoxia results from CO's list to hemoglobin in red blood cells to produce carboxyhemoglobin, which lowers the blood's capability to deliver oxygen (Moberg et al., 2023). Headache, nausea, flightiness, and, at elevated situations, unconsciousness or death are signs of CO poisoning (Weaver, 2024).Individualities with cardiac problems, pregnant women, and babies are more susceptible to CO exposure (Place et al., 2025). Long- term exposure to low situations can also harm cardiovascular health and cognitive function (Weaver, 2024). In deficiently raised homes with wood burners or gas heaters, inner CO exposure is a problem (Hampson, 2023).The main cause of ambient CO attention in cosmopolite's is transportation emigrations (Kangas et al., 2024). In multitudinous nations, regulations including as emigrations guidelines and catalytic mills have drastically lowered CO situations. Nonetheless, ongoing surveillance and public awareness campaigns are essential to precluding CO- related conditions and deaths.

3.5.Lead and their Source

The dangerous heavy essence lead is set up naturally in the crust of the Earth, but when it's released into the air, soil, or water by mortal exertion, it cause a major harm to mortal health and the terrain. Lead contaminant is substantially caused by using prime gasoline(in nations where it's still in use), artificial operations including mining and smelting, battery product, and the declination of lead- grounded maquillages in aged structures (Ciurea et al., 2023). Prime energy use has been phased out in numerous nations, still there are still troubles associated with heritage impurity from former emigrations (Halabicky et al., 2023). The main ways that people get exposed to lead are via breathing in airborne patches or by consuming alloyed food, water, or dust (Lanphear et al., 2024). Lead poisoning can beget irrecoverable brain damage, cognitive impairments, learning challenges, and behavioral issues, making children particularly susceptible (Needleman, 2023). Habitual exposure has been linked to reproductive problems, renal failure, and hypertension in grown-ups (Lieberman-Cribbin et al., 2025). In sectors like construction and battery recycling, occupational exposure is still a problem(Münzel et al., 2022).

3.6.Ground level ozone (O_3)

A dangerous air pollutant called ground-level ozone (O_3) is created near the Earth's surface, mostly via photochemical interactions between NO_x as well as VOCs when sunlight is present (Pimlott et al., 2025). While stratospheric ozone shields the earth from damaging UV rays, ground-level ozone causes smog and is a major threat to agriculture, ecosystems, and human health (Kasdagli et al., 2024).

3.6 Formation of Ground level ozone: Formation Ozone is a secondary pollutant created by a sequence of chemical reactions rather than being immediately released at ground level.

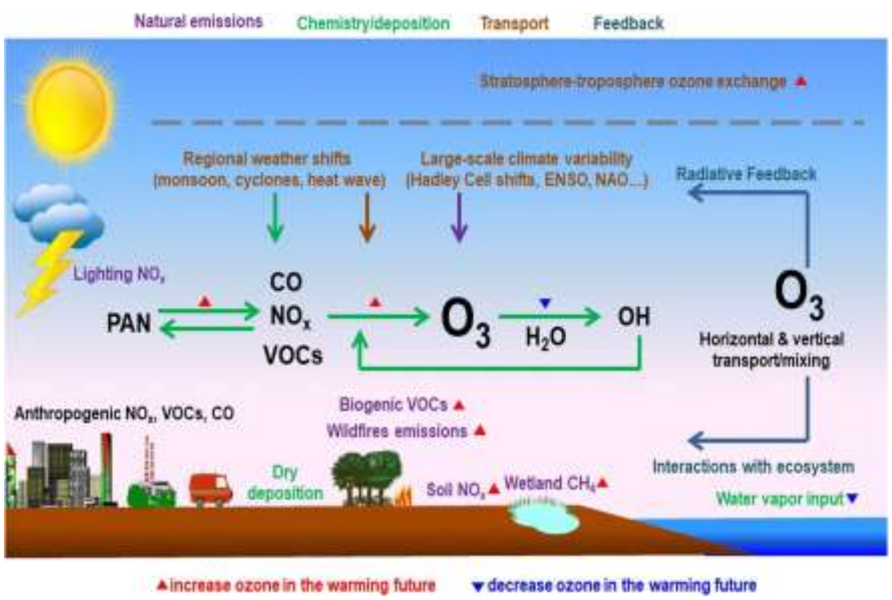


Figure #02: chemical reaction of Ground level ozone Formation (source https://link.springer.com/article/10.1007/s40726-019-00118-3

The process usually starts when photolysis of nitrogen dioxide produces nitric oxide (NO) and a free oxygen atom (O) when exposed to sunshine. Ozone is created when this oxygen atom combines with molecular oxygen (O_2).

1. NO_2+hv(Sunlight) convert to NO + O
2. O+ O_2 convert to O_3
3. O_3+NO convert to NO_2+O_2

A photo stationary condition is thus established. However, when VOCs are present, other processes take place that turn NO back into NO_2 without the need for ozone, allowing ozone levels to rise (Zhu et al., 2023). Vehicles, factories, gasoline fumes, and even plants release these volatile organic compounds (VOCs) (Zong et al., 2024).

4. Major Effects of air pollution on human health in History

4.1. Chronic Obstructive Pulmonary Disease (COPD) and Ischemic Heart Disease (IHD) – Linked to Particulate Matter (PM2.5 and PM10)

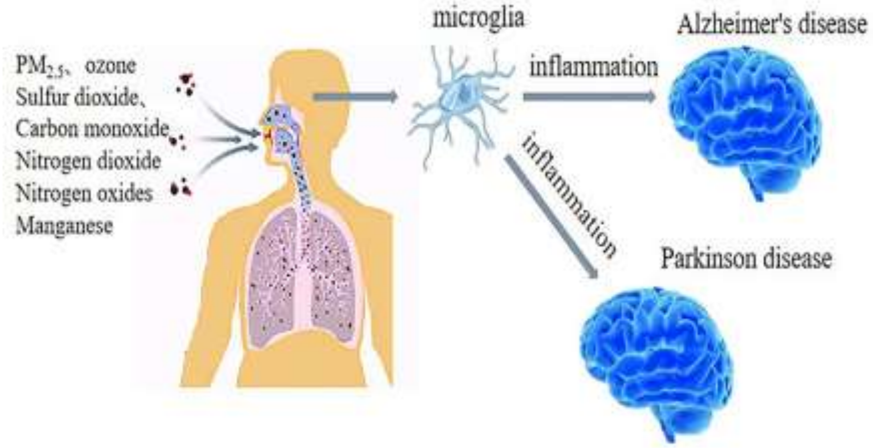
Chronic obstructive pulmonary disease (COPD) is a long-term lung disorder characterized by persistent inflammation and narrowing of the airways, leading to progressively worsening breathing difficulties. Particulate matter (PM) exposure, especially tiny particles like PM2.5 and PM10, is one of the main environmental variables that contribute to COPD. Deep penetration of the respiratory system by these particles can result in tissue injury, inflammation, and oxidative stress, all of which worsen the deterioration of lung function (Y. Hu et al., 2022). Recent studies have demonstrated that both brief surges and prolonged exposure to PM2.5 and PM10 significantly elevate the risk of developing COPD and trigger acute flare-ups in existing cases, particularly in vulnerable people such as the aged and those have pre-existing respiratory conditions. Ischemic Heart Disease (IHD) is strongly associated to long-term exposure to fine particulate matter (Berlinger et al., 2024) , which triggers inflammation and arterial damage. This exposure increases the risk of heart attacks and cardiovascular mortality.

4.2.Asthma – Exacerbated by Nitrogen Dioxide and Ozone (Yokkaichi Asthma – Historical Case of Sulfur Dioxide Pollution)

Exposure to air pollutants such as NO_2 and O_3 can significantly worsen asthma, a chronic inflammatory disease of the airways characterized by wheezing, shortness of breath, chest tightness, and coughing. When inhaled, O_3 causes inflammation and oxidative stress in the airways, which exacerbates asthma symptoms and impairs lung function. According to recent data, hospitalizations, ER visits, and asthma flare-ups can all rise with even low to moderate exposure to these pollutants (Agache et al., 2024; Walter et al., 2024). In the 1960s, a serious respiratory disease outbreak in Japan known as Yokkaichi asthma was brought on by high sulfur dioxide (SO_2) emissions from Yokkaichi City's petrochemical factories. Because of their extended exposure, residents developed chronic bronchitis, asthma, and other lung conditions. One of the biggest health disasters in Japan as a result of pollution was this instance. As a result, environmental rules became more stringent, and Japan's environmental health policies underwent a sea change. Unchecked industrial pollution poses a serious threat, as the incident makes clear (Ueda, 2021).

4.3.Neurological Disorders and Hypertension – long term Pollution exposure

Many different types of brain illnesses are associated with air pollution, particularly nitrous oxide and fine particulate matter (PM2.5). These contaminants can infiltrate the brain and cause oxidative stress and inflammation, which can lead to neurodevelopmental problems like autism and ADHD as well as diseases like multiple sclerosis (MS), Parkinson's disease, stroke, and Alzheimer's disease.(See figure #02)



Figure#02: Neurological disorder by Exposure to Pollutants (source https://www.researchgate.net/figure/Air-pollution-increases-neuroinflammation-especially-microglial-activation-which-may-be_fig1_365801369 [accessed 22 May 2025].

Air pollution also affects brain structure and neurotransmitter function, which raises the risk of mental health problems like anxiety and depression (Calderón-Garcidueñas et al., 2022; Lin et al., 2024).Because air pollution, particularly fine particulate matter (PM2.5), increases vascular dysfunction and systemic inflammation, it is associated with a higher risk of hypertension (Z. Xia et al., 2024).Cardiovascular disease rates are rising globally as a result of this4.4.Kidney Disease – Linked to Heavy Metal Exposure

The health of the kidneys is seriously threatened by heavy metals, which include cadmium ,mercury, lead and arsenic. A series of harmful effects, such as oxidative stress, mitochondrial dysfunction, inflammatory reactions, and renal cell death, are brought on by heavy metals once they enter the renal system. In the proximal tubules, for example, cadmium is particularly detrimental because it destroys the epithelial lining and interferes with energy production, resulting in proteinuria and a long-term deterioration in kidney function (Naz et al., 2023) .see figure #03.

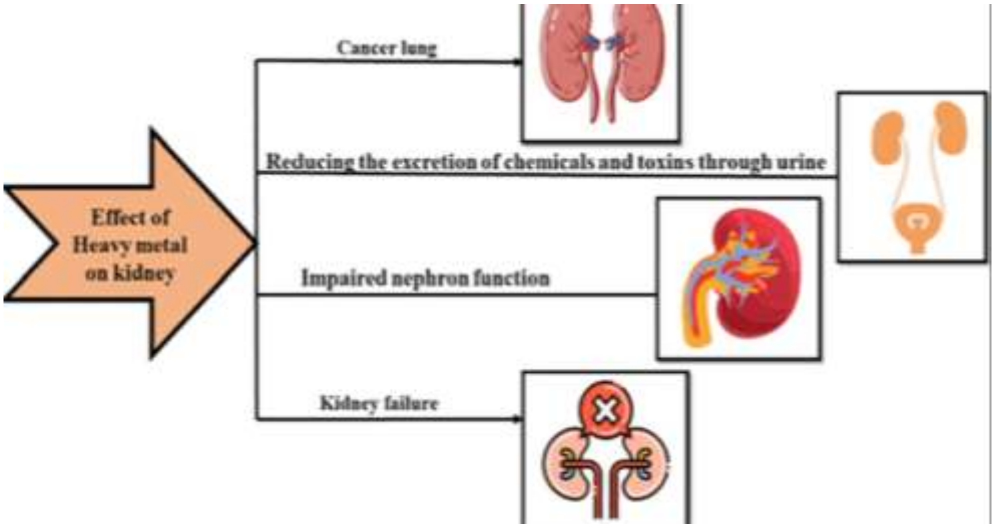


Figure #03: kidney diseases by Heavy metal Exposure (source https://www.degruyterbrill.com/document/doi/10.1515/reveh-2022-0245/html)

Another important risk that contributes to kidney disease is exposure to lead. It has been demonstrated that even modest levels of long-term exposure to lead can alter glomerular filtration rate, create interstitial fibrosis, and encourage structural damage to both glomeruli and tubules. These modifications raise the likelihood of developing chronic kidney disease (CKD), especially in urban populations and industrial workers who are exposed to high levels of lead .Arsenic is nephrotoxic and frequently found in contaminated groundwater in various areas. In societies that use arsenic-contaminated water for cooking purpose. Prolonged exposure to arsenic has been epidemiologically associated with a higher incidence of chronic kidney disease (CKD) and impairs glomerular and tubular function (W. Hu et al., 2023) .

4.6. Autoimmune Diseases – Triggered by Air Pollution

In the onset and aggravation of autoimmune illnesses, air pollution has been recognized as a major environmental component. Chronic inflammation and oxidative stress brought on by exposure to NO_2 ,O_3, and PM2.5 can impair normal immunological functions (R.-D. Zhang et al., 2023). Diseases like rheumatoid arthritis, lupus, and multiple sclerosis may develop as a result of these pollutants' aberrant stimulation of dendritic cells and T-lymphocytes, which can impair immunological tolerance (G. Li et al., 2025).Epidemiological research has indicated that regions with higher air pollution levels had higher prevalence of autoimmune diseases. According to Rodriguez-Cotto PM2.5 in particular has the ability to enter the bloodstream and lungs deeply, where it modifies gene expression linked to immune control (B. Zhang et al., 2021).

4.7.Low Birth Weight – Resulting from Prenatal Pollution Exposure

LBW defined as a birth weight of less than 2,500 grams, is a significant public health concern that is directly linked to infant exposure to air pollution during pregnancy. Fo etal growth may be hindered by pollutants such as sulfur dioxide (SO_2), nitrogen dioxide (NO_2), and fine particulate matter (PM2.5) that can cross the placental barrier by producing oxidative stress, systemic inflammation, and placental dysfunction (Liu et al., 2023).These disruptions can impact the fetus's capacity to get oxygen and nutrition, eventually leading to decreased birth weight and intrauterine growth restriction IUGR (Arenas et al., 2024). High pollution exposure during the second and third trimesters of pregnancy, which are crucial for baby weight increase, puts pregnant women at special risk. Urban people are disproportionately impacted, especially in industrial locations where air quality problems persist. Higher LBW prevalence has been linked to ongoing exposure to traffic-related pollutants, highlighting the necessity of more stringent environmental and maternal health laws (Sun et al., 2022).

5. Environmental impact of air pollution

The environmental effects of air pollution include eutrophication, acid rains, biodiversity loss, ecosystem degradation, and changes in climatic patterns. Therefore, pollution from a variety of air pollutants emitted from both natural and man-made sources, including transportation, industry, agriculture, and energy production, can damage the air, water, soil, and animals, causing ecosystem disruption and environmental degradation. The effects of air pollution on biodiversity, soil, water, and other natural resources can be significant. The ecosystem in which we live (Husain Tahir et al., 2021) is being harmed by air pollution in addition to human health. The following are the main environmental consequences climate Change Because it releases greenhouse gases like CO_2, CH_4, and black carbon, air pollution is a major contributor to the acceleration of climate change (Lelieveld et al., 2023). Global temperatures rise and hydrological cycles change as a result of these pollutants' intensification of the greenhouse effect (Lelieveld et al., 2023) . According to (Dewan et al., 2022), nitrogen oxides and volatile organic compounds produce ground-level ozone, which damages plants and causes global warming. According to (Lyu et al., 2023), air pollution-induced warming makes sea level rise, ocean acidification, and glacier retreat worse. Particulate matter, like as sulfate aerosols, also disrupts regional climate systems by influencing precipitation and cloud formation (Skea et al., 2021) . Emissions of sulfur and nitrogen cause acid rain, which harms freshwater habitats and forests. Another major effect of habitat changes is the loss of biodiversity. Changes in rainfall patterns and the deposition of harmful substances in the air cause soil degradation to worsen. Ocean warming and acidification brought on by pollution exacerbate coral bleaching. Ecosystem services that are necessary for life on Earth are in danger due to these combined effects. Acid rain as precipitation that contains hazardous levels of sulfuric and nitric acids and can be either dry (particulates and gas) or wet (rain, fog, and snow). The burning of fossil fuels releases atmospheric pollutants like sulfur dioxide (SO2) and nitrogen oxides (Nox), which are the main source of acid rain, a severe environmental issue (Schwartz et al., 2021). When these gases combine with water vapor, sulfuric and nitric acids are produced, which causes acidic precipitation (Bhuvanesh Kumar et al., 2023).These acidic pollutants produce fine particulate matter, which has an indirect negative impact on human health by raising respiratory risks (Kalogiannidis et al., 2023).They can erode trees and plantations, harm buildings and outside statues, artworks, and building materials, and they can lower the soil pH and removing vital nutrients (Shaheryar et al., 2025). It also has an impact on the adaptability of the ecosystem as a whole and leads to the loss of sensitive species (Ren et al., 2024). Despite the fact that worldwide initiatives have decreased emissions in industrialized regions, industrial expansion and weak environmental laws continue to pose serious problems for many emerging nations (Thakur et al., 2023). Global collaboration and united efforts in emission control technology are atill essential to reducing acid rains' long term consequences (Fu et al., 2024).Ecosystem degradation Because it disturbs biological processes and reduces biodiversity, air pollution is a serious danger to both terrestrial and aquatic ecosystems. Animals and plant species may become extinct as a result of acid deposition, which is caused by the deposition of SO2 and NOx and can acidify soils and surface waters (Rosseland, 2021). Furthermore, contaminants like O3 and PMs can harm plants, preventing photosynthesis and lowering agricultural production (Perring et al., 2022). Air pollution has long- term effects on ecosystem services, making forests, wetlands, and other natural ecosystems more vulnerable (Kaylor et al., 2024). Nitrogen deposition damages fish and invertebrate populations in aquatic habitats by causing eutrophication and lowering oxygen levels (Msibi et al., 2025). By causing localized smog to emerge, urban air pollution intensifies these consequences by decreasing sunlight penetration and changing ecosystem energy balances (Khan et al., 2023). Industrial emissions cause heavy metals deposition, which contaminates soil and water, reaches the food chain, and endangers wildlife (Kumar et al., 2022). Climate change and air pollution work together to make habitats more prone to stress (Hadei et al., 2025). The cumulative effect of air pollutants interferes with biological processes such as seed distribution, pollination and predator- prey relationships (Plutino et al., 2022). Therefore, preventing air pollution is essential to preserving ecosystem services and biodiversity. Ozone depletion The primary cause of ozone depletion are air pollutants from automobiles, industry and other human activities, such as nitrogen oxides, halons and chlorofluorocarbons (CFCs). These substances enter the stratosphere, the upper most layer of the atmosphere, and degrade ozone molecules, weakening the ozone layer that shields the planet from dangerous ultraviolet -B (UV-B) radiation (Newman et al., 2024).The thinning of this protective stratospheric ozone layer allow UV radiation to reach earth, which can have detrimental impacts on agriculture Tevini, 2023) and human health (Madronich et al., 2021) , including skin cancer. The stomata in plants close when ozone penetrates, preventing CO2 transport and lowering photosynthesis (Mishra et al., 2025).Since both are impacted by the same pollutants and work together to exacerbate global warming and alter weather patterns, ozone depletion and climate change are closely related (Karagodin-Doyennel et al., 2023). Ground -level ozone, a dangerous gas that degrades air quality and indirectly impacts the ozone layer, is also increased by pollutants such as NO2, VOCs (X. Wang et al., 2022). Some prohibited compounds such as CFC-11, are still being illegally emitted, which hinders the rebuilding of the ozone layer even though the Montreal Protocol helped cut many hazardous gases. Ozone harm is worse in colder places like the arctic because of certain weather patterns (Mishra et al., 2025). Thus, preserving ozone layer and reducing air pollution are both crucial for preserving life on Earth (Chipperfield et al., 2024). Air pollution can lead to water and soil contamination due to the deposition of airborne pollutants such as Nox, SO2 ,heavy metals and particulate matter. These pollutants travel through the atmosphere and are deposited both wetly and dryly onto aquatic and terrestrial ecosystems (Chipperfield et al., 2024) . As a result of SO2 and Nox emissions, acid rain mobilizes harmful elements like lead and aluminum, changes the PH balance and acidifies soils (J. Li et al., 2022). This acidification damages freshwater biodiversity and lowers drinking water quality in aquatic systems (Ramadan et al., 2024). Additionally, heavy metals and persistent organic pollutants (POPs) including lead, mercury, cadmium, and arsenic can accumulate on soils and water bodies, contaminating soils and groundwater, and having harmful impacts on people, animals, and plants (Uddin et al., 2023). Air pollution-induced heavy metal contamination can bioaccumulate in the food chain, posing threats to human health and the ecosystem (S. Wang et al., 2025). Air pollution can also degrade soil, lowering soil productivity, hindering plant growth, and compromising ecosystem resilience. This can lead to erosion, desertification, and the loss of arable land (Weng et al., 2023).Biodiversity loss Air pollution damages ecosystems, interferes with biological processes, and has harmful impacts on plants and animals, all of which greatly contribute to the loss of biodiversity (Driscoll et al., 2024). Sensitive environments and endangered species are especially vulnerable, which could have an impact on ecosystem stability along with biodiversity conservation initiatives. Air pollution can also worsen already- existing risks to biodiversity, like habitat loss and climate change, which raises the possibility of species extinction (Ukwu et al., 2022; Ogwu et al., 2025). Air pollution such as Sulfur dioxide , nitrogen oxides, ozone (O3), and particulate matter are among the pollutants that harm vegetation, lowering plant variety and changing ecosystem's competitive dynamics . Airborne Anthropogenic chemicals impact a variety of species and ecological functions, which leads to a decline in biodiversity. Despite being underrepresented in biodiversity studies, these consequences are becoming more widely acknowledged for their importance (Sigmund et al., 2023).

6. Discussion:

The WHO's General Director, Defined to air contamination as "the new tobacco" also a "silent public health emergency" at the first WHO Global Conference in 2018 (Pandey et al., 2021). Children are definitely more exposed to air pollution, while they are still developing. Our lives are badly impacted by air pollution in a different of ways. Due to missed job and educational opportunities, diseases linked to air pollution have an important social impact in addition to an economic one. The ecosystem and human health are affected by air pollution in short-, medium-, and long-term ways. There have been several studies on the direct health impacts of exposure to air pollution. An effective solution to the problem of anthropogenic environmental pollution may need close coordination between authorities, bodies, and medical professionals in order to normalize the situation, despite the challenge of doing so. To effectively limit the rise of these challenges, governments should educate the public, provide enough information, and engage specialists. It is imperative that technologies be developed and used in all sectors and power plants to minimize air pollution at its source. Reducing GHG emissions to less than 5% by 2012 was a key goal of the 1997 Kyoto Protocol (Västermark, 2021; Naser et al., 2022). China was one of the first nations to embrace this crucial guideline for the global "health" of the environment and climate (Ofremu et al., 2024). Since China's economy is believed to be growing quickly, its GDP is estimated to reach extremely high levels by 2050, the year the protocol for decrease gas emissions is supposed to dissolve.

The 2015 Paris accord, which was released by the United Nations Climate Change Committee is a more trending international Consensus that is highly cruciform environmental change. Numerous nations of the European Union and the United Nations (UN) accepted this most recent accord (Höhne et al., 2021) . In keeping with this, parties ought to advocate for policies and initiatives that improve a variety of factors related to the topic. Some pertinent measures to maximize the chances of reaching the targets and goals on the important issue of atmospheric change and environmental degradation include increasing public awareness, training, as well as public engagement (Höhne et al., 2021). Without a question, technology elevation make our lives easier. Although it appears to be challenging to minimize the adverse effects of petrol emissions, we could bound their use by looking for trustworthy methods. In summary, a global preventative program should be developed to counteract anthropogenic air pollution in addition to appropriately managing the harmful health effects of air pollution. The application of sustainable development strategies and research findings is necessary to properly address the issue. Currently, pollution management depends on international cooperation in administration, policy, monitoring, research besides with development. Air pollution laws need to be advanced and synchronized, along with legislators could suggest creating an important tool for protect the public health and environment. Thus, the primary suggestion of this essay is that we should concentrate on creating local frameworks to encourage knowledge and practice, which we can then apply globally by creating efficient regulations for the sustainable management of ecosystems.

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