



AIR POLLUTION, CLIMATE CHANGE AND MITIGATION STRATEGIES: A REVIEW

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ABSTRACT

Air pollution is the addition of unwanted component of gases and particles into the atmosphere by human activities like burning of fossil fuels, industrial pollution etc and natural phenomenon like volcanic eruptions, forest fires, etc. All these activities release harmful gaseous and particulate components like CO₂, CH₄, CO, N₂O, SO₂, dust, soot etc into the atmosphere. The major gaseous components of CO₂, CH₄, N₂O, etc contribute to the phenomenon called as Greenhouse effect, leading to Global warming. The global warming leads to rising temperatures, melting ice caps, climatic variability contributing to Climate change. This review basically deals with air pollution, its causes, types, air pollution as major cause of climate change, its impacts and mitigation strategies to reduce air pollution and simultaneous climate change.

Key words: Air pollution, climate change, greenhouse gases, global warming, mitigation strategies.



INTRODUCTION

Atmosphere is a complex system of gases and suspended particles. However, the composition of the atmosphere keeps on changing and hence, its structure is variable in time and space. The atmosphere is mainly composed of gases like nitrogen (N_2) (78.8%), oxygen (O_2) (20.95%), argon (0.93%), and other trace gases like carbon dioxide (CO_2) (387ppm), methane (CH_4) (2ppm), nitrous oxide (N_2O) (0.3ppm), water vapour etc. Pollution is the presence of undesirable substance in any segment of the environment, primarily due to human activity discharging by products, waste products or harmful secondary products, which are harmful to man and other organisms. Air pollution is the addition of unwanted component of gases and particles into the atmosphere by human activities like burning of fossil fuels, industrial pollution etc. and also some natural phenomenon like volcanic eruptions, forest fires, etc (1). All these activities release harmful gaseous and particulate components like CO_2 , CH_4 , CO , N_2O , SO_2 , dust, soot etc. into the atmosphere hence polluting it. The changes that are occurring now have their origin in the industrial revolution.

Air pollution results due to both natural as well as anthropogenic causes. **Natural causes** like volcanic eruptions, dust from dust storms, wild forest fires and pollens released by the plants, spores of the fungi, bacteria and viruses suspended in the atmosphere and death and decomposition of organic matter. **Anthropogenic causes** include the activities of the man like deforestation, modern agricultural practices, industrial activities etc (27).

Types of air pollution

Air pollution can be of various types on the basis of their sources.



1. Vehicular air pollution: The internal combustion engine contributes to the air pollution by exhaust like carbon monoxide, unburnt hydrocarbons, nitrogen oxides, sulphur oxides, lead compounds, smoke, particulates and odour. Baumert et al. (2005) in their global survey of the emissions from the transportation have estimated that GHG emissions from the transport sector account for 14% of total GHG emissions, with domestic and international road transport contributing 72%, domestic and international air transport 11%, international marine transport 8% and others 8% (4).

2. Industrial air pollution: Among the various categories of industries nine prominent groups of industries are considered to be the major pollutant generating industries (1) (Table 1).

Table-1: Various industries with the pollutants released by them (1).

Sr. no.	Industries	Pollutants released
1	Steel mill	Particulates, smoke, CO, fluoride
2	Petroleum refinery	SO ₂ , hydrocarbon smoke, particulates and odour
3	Acid plant	SO ₂ , acid mist
4	Paper mill	SO ₂ , particulates, odour
5	Soap and detergent plant	Particulates and odour
6	Fertilizer plant	Particulates, ammonia, SO ₂ , NO _x , fluoride
7	Cement plant	Cement dust, SO ₂ , smoke
8	Thermal power plant	NO _x , SO ₂ , particulates
9	Metal smelter	SO ₂ , NO _x , particulates, smoke

3. Air pollution due to agricultural activities: Agriculture contributes to about 60% of the N₂O, 40% of the CH₄ and 1% of CO₂ of the total GHG emissions. The main



contributors of the air pollution due to agriculture are application of chemicals, use of tractors, the operation of water pumps, burning of dead plant parts, livestock management, shifting cultivation by clearing and burning forest (25) (Fig. 1).

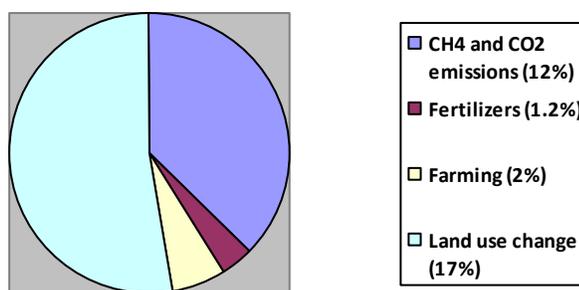


Fig-1: Emissions from agricultural sector (25).

4. Biological air pollution: Biological air pollution results from the natural causes of pollens and spores leading to allergies and asthma, wild fires, melting permafrost releasing CH_4 and volcanic eruptions adds CO_2 , CH_4 , SO_2 , smoke, soot etc to the atmosphere (10). The correlation between the CO_2 fluxes of the atmosphere–land and atmosphere–ocean are dependent on the climatic conditions. Bousquet et al. (2000) proposed that the amount of CO_2 in the atmosphere varies with the El Niño–Southern Oscillation (11,12,13,14).

5. Domestic air pollution: The domestic pollution results due to use of the aerosols, CFCs and HFCs releasing electric products and smoking. Pollution also occurs from fuels like coal, fuel wood, kerosene and other biomass fuels used for cooking in urban and rural areas (23).



India and air pollution

In a study conducted in 2010 by 80 scientists from 17 institutes confirmed on that India is the world's fifth-biggest polluter with more than 3% increase in its greenhouse gas emissions annually from 1994 to 2007 which has been attributed to the rapid industrialization, urbanization and vehicular growth (26). India ranked 101 in 2005 according to the Environmental Sustainability Index among 146 countries on the basis of its air quality (26).

Population: India is very mysterious in terms of population dynamics as it supports 15% of the global population having only 2.4% of the world's land area. The present population of India is around 1.15 billion and stands next only to China. It is estimated that by 2030, the population of India will be largest in the world. Population of India at the time of Independence was only 350 million and since then it has increased more than three times. The present rate of increase in population is 21.34% which was earlier as much as 30-35% (Fig-3) (27).

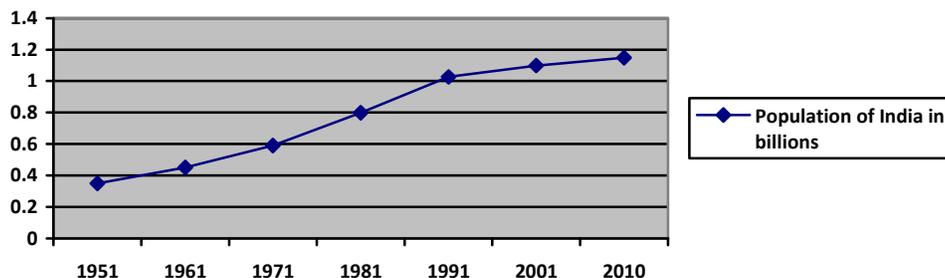


Fig-3: The rapid increase in the population of India since independence (27).

Industries: Industrial pollution has quadrupled in the past 20 years. The carbon emissions in India have increased nine times over the past 40 years due to use of coal



as the major energy source (26). IIT Delhi and Central Pollution Control Board (CPCB) have shown 10 industrial centers, Ankleshwar and Vapi in Gujarat, Ghaziabad and Singrauli in Uttar Pradesh, Korba in Chhattisgarh, Chandrapur in Maharashtra, Ludhiana in Punjab, Vellore in Tamil Nadu, Bhiwandi in Rajasthan and Angul Talcher in Orissa to be causing maximum environmental pollution (26).

Vehicles: In India, the vehicular population is growing at a rate of 5% per annum and today the vehicle population is approximately 40 million with the two-wheelers accounting for a share of 76% of the total vehicular population (23,24,29). 70% of the country's air pollution result due to the vehicular emissions. There has been an eight time increase in the vehicular exhausts over the last 20 years (26).

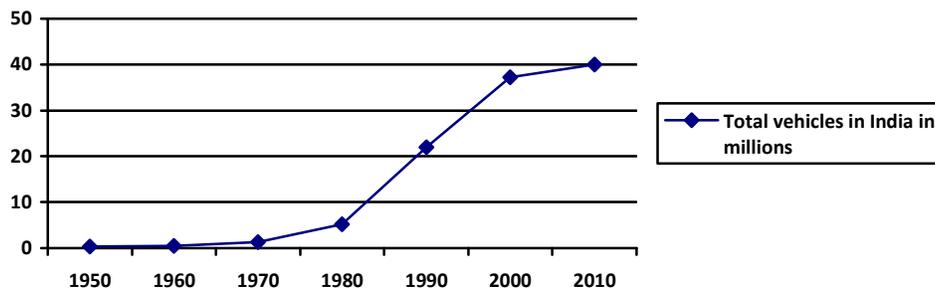


Fig-2: The increase in the vehicular population in India since 1950 (23).

Impact of air pollution

The most important impact of air pollution is that it increases the level of GHGs to exceed the optimum limit and causes enhanced greenhouse effect leading to global warming. Other than this it is hazardous to health of plants and animals. Exposure to particulate matter from combustion-related sources can aggravate chronic respiratory (asbestosis, silicosis and bronchitis) and cardiovascular diseases, alter host defenses,



damage lung tissue, lead to premature death and possibly contribute to cancer. In addition, changes in green plant distribution or pollen production could affect the timing of hay fever and other seasonal allergies. The air pollution also impacts the plants and causes chlorosis, necrosis, bleaching and bronzing. The animals are also influenced by the air pollution which results in suffering due to lung infections and other diseases (10). Sulfur dioxide, nitrogen dioxide and ozone cause a decrease in crop yield, acidification of lakes, damage to certain metals and monuments by acid rain. The Taj Mahal, Agra is turning yellow due to the oxidation of the CaCO_3 (limestone/calcium carbonate) reacting with other noxious chemicals. It also causes acidification and eutrophication of soil, lakes, pond etc damaging the fisheries and affecting animal and human health (23).

Air pollution causing climate change

Climate system is a complex interactive system consisting of atmosphere, land surface, snow and ice, oceans and other water bodies or in other words a climate system is an interactive system comprising of the atmosphere, lithosphere, cryosphere and hydrosphere. Climate change refers to a statistically significant change in either the mean state of the climate or in its variability (in terms of temperature, atmospheric pressure, precipitation status etc.) persisting for an extending period (typically decades or longer) (19). Climate change results due to both natural and anthropogenic causes.

Natural causes: The contribution of plants, animals, and humans naturally to global warming by respiration and also due to their death and decomposition come under this category. A significant part of the earth's climate variability is also caused by changes in the solar emissions, which are due to changes in the sun-earth geometry (Milankovitch cycles). The volcanic eruptions liberate a huge amount of smoke and contribute in increasing the global temperature. Simultaneously, contradictory to the fact that the sulphur oxides so released has a high albedo and hence cools the Earth by reflecting



the solar radiations. The 1991 volcanic eruption of Mount Pinatubo in Philippines had released 20 million tons of SO_2 into the atmosphere cooling the Earth by 1°F (0.33°C) (15,28).

Anthropogenic causes: The human activities imparting a negative impact on the existing climate resulting in climate change are included under this category (Fig-5). It involves **Industrialization** which contributes about 19.4% of the total GHG emission (3). **Deforestation** contributes to 17.4% of the total GHGs emissions (3) released into the atmosphere each year which is more than from planes, trains and automobiles (33). **Transportation** accounts for 13.1% of the total GHGs emissions (3,22,23). **Urbanization** is responsible for 7.9% of the total GHGs emission (3). **Agricultural practices** contribute about 13.5% in the total emission of the GHGs (3). **Energy supply** sector is the major contributor of GHGs to the atmosphere contributing to 25.9% of the total emissions (3) as a result of power generation by coal burning (26).

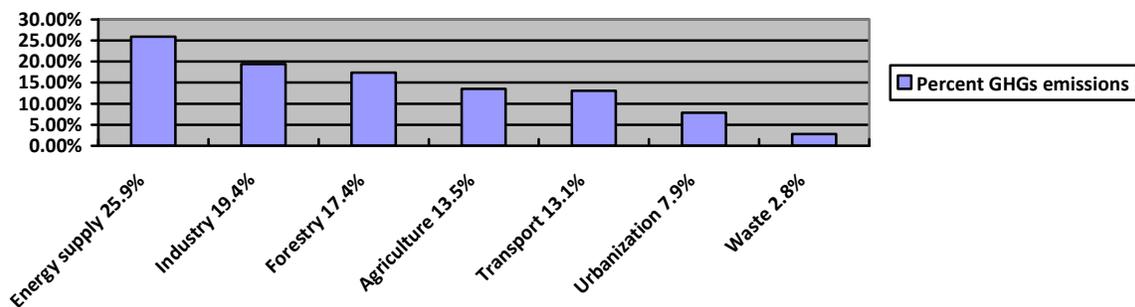


Fig-5: The percent GHGs emissions by the various sectors (3).

Greenhouse gases from air pollution



The main natural greenhouse gases are CO₂, CH₄, N₂O, water vapour (H₂O), and ozone (O₃) (1). Further human activities in recent decades have also added HFCs (hydrofluorocarbons).

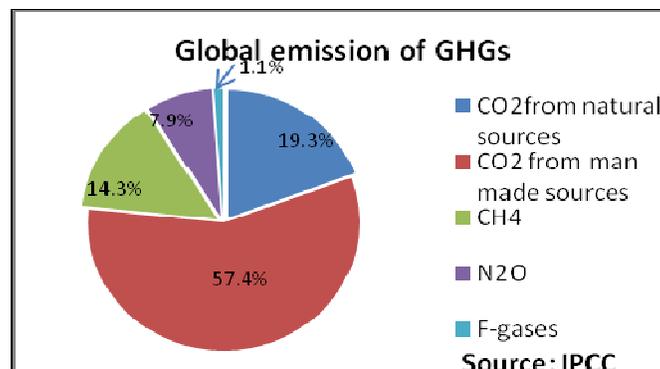


Fig-3: Global Emissions of GHGs (3).

Carbon dioxide (77%), nitrous oxide (8%), and methane (14%) are the three main greenhouse gases along with 1.1% of the fluoro gases that trap infrared radiation and contribute to climate change (3,5,6,7,17) (Fig-2). The earth's global temperature in the past years has increased due to an increase in the greenhouse gas concentrations, hence causing what is called as **Global warming** (1,2).

Another pollutant 'black carbon' a product of incomplete combustion of fossil fuels and biofuels causes global warming by darkening the surface of ice and snow by getting deposited on them. It has been revealed that black carbon on snow warms earth three times more than that by carbon dioxide (8). The CO₂ levels in the pre-industrial time were only 270 ppm which increased to 385 ppm in 2009. In the last four hundred thousand years, the amount of CO₂ concentration has never been larger than 290 ppm.



The speed with which it is increasing clearly states that human influence is the cause (20).

Global warming potential of the greenhouse gases

Global warming potential (GWP) may be defined as a gas's heat-trapping power relative to CO₂ over a particular time period. Global warming potential allows the observers to compare the contribution to global warming made by various greenhouse gases that have a varying warming effects and life spans (Table-2) (3).

Table-2: Global warming potential of some greenhouse gases (3).

Sr. no.	Greenhouse gases	Global warming potential
1	Carbon dioxide, CO ₂	1 (=100 years)
2	Methane, CH ₄	25
3	Nitrous oxide, N ₂ O	298
4	Hydro fluoro carbons, HFCs	124 – 14,800
5	Per fluoro carbons, PFCs	7,390 – 12,200
6	Sulphur hexa fluoride, SF ₆	22,800

Impacts of climate change

The GHG emissions have increased by 70% from 1970 to 2005 due to which the global temperature has risen by about 0.74°C from 1906-2005 (9). The change in hydrological cycle and ENSO (El Nino Southern Oscillation) (23) is impacting the monsoon circulation and resulting in extreme events like floods and droughts. The general circulation models have predicted that if the atmospheric concentration of carbon dioxide doubles, the mean annual temperature may increase from about 2 to 4.5°C. The rise in temperature at higher latitudes will be greater than at low latitudes and that the



temperature changes will be greater in winter than in summer (9,15). The rise in temperature is leading to melting of the glaciers and ice caps and also thermal expansion of water which has resulted in a sea level rise of 1.8mm/year from 1961-2003, but from 1993-2003 this pace has almost doubled (9). This is resulting into the salinity ingress and also the submergence of the low lying areas and islands. Around 2 million square km of the permafrost has declined by the year 2000. An increase in the incidence of heat waves, thunderstorms, cyclones, hurricanes etc have also been registered (9). The Scientists believe that global warming resulting in a rise in the temperature, will lead to cooling of the stratosphere along with the ozone leading to a slow pace of ozone hole repairing (32). Crop and rice yields have declined owing to GHG and air pollution (21). The desertification will increase (9). There will be water crises and the human health is also going to suffer due to an increase in the tropical diseases like vector borne diseases (malaria, dengue, chikangunia), rodent borne diseases, water borne disease (cholera, diarrhoea, dysentery) (10).

Controlling air pollution

Air pollution can be reduced either by switching over to renewable sources for energy generation which will lead to energy efficiency and would reduce emissions of GHGs to 100%. India has established small hydropower projects of 1,423 MW capacity. The photovoltaic (PV) system using solar energy is being used for rural electrification, railway signaling, microwave repeaters, solar lanterns, home and street-lighting systems, standalone power plants, pumping systems, power to border outposts and TV transmission and reception. Until now 9,20,000 Solar PV systems, with a total capacity of 82 MWp have been established in India. India stands fifth in the world in wind power generation with a total capacity of 1,507 MW (9).



By using efficient fuels like biofuels, substituting coal and petrol by natural gas and by installing mechanical devices by the industries to reduce particulate pollutants (by gravity settling chambers, cyclone collector, dynamic precipitators, spray towers) and to reduce gaseous pollutants (by spray/packed towers and venturi scrubbers with absorbent like activated alumina, silica gel, activated carbon) (1).

Air pollution control for automobiles can suitably be done by installing catalytic convertors, diesel particulate filter and also changing fuel quality. According to a report of RCEP (2000) increasing the fuel prices has lead to the energy savings as in case of UK where a 10% increase in fuel price lead to decrease in the vehicular consumption of the fuel by 6% (16,17,18). PCRA (Petroleum Conservation Research Association) has been established to increase awareness and to develop fuel-efficient equipments (9). Comparison of fuels supports biofuels to be most efficient (Table-4) (33). Introduction of BRTS (Bus Rapid Transport System) in Ahmedabad, Gujarat is another major initiative to combat climate change.

Table-4: Comparison of the efficiency of the various fuels (35)

Fuel	Carbon content (kg C /kg fuel)	Energy content (kWh /kg fuel)	CO ₂ emissions (kgCO ₂ /kWh)
Gasoline	0.9	12.5	0.27
Diesel	0.86	11.8	0.24
LPG-Liquefied Petroleum Gas	0.82	12.3	0.24
Natural gas	0.75	12	0.23
Bioenergy	0	0	0

The government of India has formulated a number of legislations, policies, and programmes for protecting the environment. Some of them related to air pollution are



the Air (Prevention and control of pollution) Act, 1981 and the Environment (Protection) Act, 1986. Ambient air quality standards (both short term for 24 hours and long-term for a year) have been put forward for industrial, urban and other sensitive areas with respect to pollutants such as SO₂, NO_x, SPM (Suspended Particulate Matter), RPM (Respiratory Particulate Matter), Pb (lead), CO (Carbon mono-oxide) and NH₃ (ammonia). Environmental impact assessment (EIA) of the various industries and SEZ (Special Economic Zone) is done prior to its establishment (23).

Increasing the plantation of fast growing trees help improve environmental condition by acting as lungs of the city purifying the air (31) as some trees act as sinks of air pollutants like SO₂, N₂O, CO and O₃ (30).

Global warming mitigation strategies

Global warming mitigation involves reducing the intensity of radiative forcings so as to reduce the effect of global warming and it can be made possible by two aspects; Geo-engineering and Carbon sequestration. Geo-engineering are the proposals to manipulate the earth's climate so as to decrease the impact of global warming from the greenhouse gas emission. It comprises of a) sulphur dioxide spraying in the atmosphere to cool the earth; b) establishment of artificial trees to suck in excess of CO₂; c) cloud seeding ships; d) iron fertilization of the oceans; e) limestone fertilization of the oceans; f) space mirror in the space to reflect sun rays (2, 28).

Another technology comprises of the various methods of carbon sequestration. Carbon dioxide emissions can be captured and stored in underground geologic formations, helping in lowering the severity of climate change. Carbon Capture and Storage (CCS) technologies are already in use widely in industries producing fertilizers, hydrogen and in natural gas processing (10). The world's largest plant for geological CO₂ sequestration has been established as Otway project in Australia. The oldest CCS plant



in the world to store CO₂ on industrial scale is Sleipner gas field in Norway. The carbon capture and storage technology is also being implemented in the Badarpur power plant, Delhi (9,10).

The National Action Plan of India on Climate Change as released in Delhi (2009) involves eight missions; national solar mission, national mission for enhanced energy efficiency, national mission on sustainable habitat, national water mission, national mission for sustaining the Himalayan ecosystem, national mission for a Green India through massive tree plantation, national mission for sustainable agriculture and national mission on strategic knowledge for climate change by establishing a knowledge platform on climate change (9). Successful implementation of all these plans would surely help reduce global warming.

CONCLUSION

Air pollution and climate change are thus correlated. An increase in the practices like large scale industrialization, deforestation, urbanization, changing agricultural practices and other human practices add to air pollution. Air pollution enhance the level of greenhouse gases in the atmosphere resulting in global warming which simultaneously causes climate change owing to the changes in the variability in the temperature ranges, precipitation levels and increasing number of cyclones, hurricanes, heat spells, cold waves, droughts and floods. Reducing the level of air pollution at the grass root level by cutting off industrial and vehicular emissions will surely bring down the levels of greenhouse gases in the atmosphere and thus make earth a better place to live in.

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