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Organic Air Pollutants and Photochemical Smog: A Review of Sources, Atmospheric Transformation, Exposure Risks, and Mitigation Strategies

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ABSTRACT

Organic air Pollutants refer to harmful chemicals found in the air which are typically derived from living organisms or contain carbon atoms. These pollutants can come from various sources, such as fossil fuel combustion like vehicles, power plants, or industrial processes. Agricultural activities, natural sources etc. The common types of organic air pollutants include volatile organic compounds (VOCs), particulate matter, polycyclic aromatic hydrocarbon, etc. Photochemical smog, also known as ground level ozone, is a type of air pollution that forms when nitrogen oxides (NOx) and volatile organic compounds (VOCs) react with sunlight, thereby creating toxic pollutants such as ground level ozone (O_3), particulate matter (PM) etc. This seminar examines the sources, types, health effects, and environmental impacts of organic air pollutants and photochemical smog, the need for integrated strategies to mitigate their emissions, including transition to cleaner energy sources, implementation of emission controls, and promotion of sustainable transportation options, is advised. By understanding the dual threat of organic air pollutants and photochemical smog, we can develop effective solutions to protect public health and the environment, ensuring a cleaner, healthier future.

***Keywords*:** Organic air pollutants, Photochemical smog, Volatile organic compounds (VOCs), Ground-level ozone, Polycyclic aromatic hydrocarbons (PAHs), Atmospheric chemistry, Secondary air pollutants, Air pollution health effects, Air quality, Environmental pollution.

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1. INTRODUCTION

Air pollution is the contamination of air due to the presence of substances called pollutants in the atmosphere that are harmful to the health of humans and other living beings, or cause damage to the climate or to materials[1]. According to the World Health Organization (WHO), it is the contamination of the indoor or outdoor environment either by chemical, physical, or biological agent that alters the natural features of the atmosphere[2]. There are many different types of air pollutants, such as gases (including ammonia, carbon monoxide, sulfur dioxide, nitrous oxides, methane, and chlorofluorocarbons)[3,4], particulates (both organic and inorganic)[5] and biological molecules[6]. Air pollution can cause diseases, allergies[7], and even death to humans[8]; it can also cause harm to other living organisms such as animals and crops[9], and may damage the natural environment (for example, climate change, ozone depletion, or habitat degradation) or built environment (for example, acid rain)[10].

Air pollution can be caused by both human activities and natural phenomena[11]. Air quality is closely related to the earth's climate and ecosystem globally[12]. Although a majority of countries have air pollution laws, according to UNEP, 43 percent of countries lack a legal definition of air pollution, 31 percent lack outdoor air quality standards, 49 percent restrict their definition to outdoor pollution only, and just 31 percent have laws for tackling pollution originating from outside their borders[13].

National air quality laws have often been highly effective, notably the 1956 Clean Air Act in Britain and the US Clean Air Act, introduced in 1963. Some of these efforts have been successful at the international level, such as the Montreal Protocol, which reduced the release of harmful ozone depleting chemicals, and the 1985 Helsinki Protocol, which reduced sulfur emissions, while others, such as international action on climate change, have been less successful[13,14].

2. ORGANIC AIR POLLUTANTS

Organic air pollutants are a group of extremely toxic synthetic organic compounds, have a prolonged endurance under natural conditions in the environment[15]. To assess human exposure and health risk, the existence of such organic compounds has turned into a subject of major research[16]. As a result of this, the international community has created instruments to test the presence and regulate these pollutants to protect human health and the environment over the years. The most purposeful scheme is the Stockholm Convention of 2013; it aims to eradicate organic pollutants and, if that is not possible, control the emissions and discharges[17].

Recently, several treatment methods for the eradication of organic pollutants have been considered, including ozonation[18], photolysis and photocatalysis[19] etc.

2.1. Sources of Organic Air Pollutants

Although there are hundreds of sources of outdoor air pollution[20], the source categories that are the largest contributors to most air pollutants in many locations are: vehicle emissions; stationary power generation; other industrial and agricultural emissions; residential heating and cooking; re-emission from terrestrial and aquatic surfaces; the manufacturing, distribution, and use of chemicals; and natural processes[21]. Given the large differences in the number and density of these sources, as well as in their design, fuel source, and effectiveness of emission control technology, the relative contribution of these sources to air pollution concentrations and exposures varies considerably across locations. Vehiculer emissions, fuel oils and natural gas to heat homes, by-products of manufacturing and power generation, particularly coal-fueled power plants, and fumes from chemical production are the primary sources of human-made air pollution[22].

Nature releases hazardous substances into the air, such as smoke from wildfires, which are often caused by people; ash and gases from volcanic eruptions; and gases, like methane, which are emitted from decomposing organic matter in soils.

2.2. Organic Compounds from Natural Sources

Natural sources are the most important contributors of organics in the atmosphere[23], and hydrocarbons generated and released by human activities constitute only about 1/7 of the total hydrocarbons in the atmosphere[24]. This ratio is primarily the result of the huge quantities of methane produced by anaerobic bacteria in the decomposition of organic matter in water, sediments, and soil.

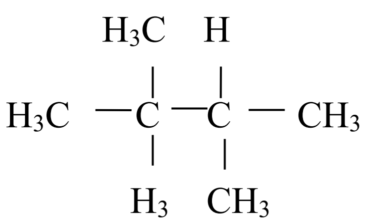
$$2(CH_2O) \xrightarrow{\textbf{bacterial action}} CO_2\,(g) + CH_4\,(g).$$

Flatulent emissions from domesticated animals, arising from bacterial decomposition of food in their digestive tracts, add about 85 million metric tons of methane to the atmosphere each year[25]. Anaerobic conditions in intensively cultivated rice fields produce large amounts of methane, perhaps as much as 100 million metric tons per year[26]. Methane is a natural constituent of the atmosphere and is present at a level of about 1.4 parts per million (ppm) in the troposphere[27]. Methane in the troposphere contributes to the photochemical production of carbon monoxide and ozone and water vapor[28].

2.3. Pollutant Hydrocarbons

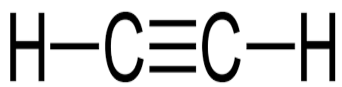
The damaging effect of hydrocarbon contamination are diverse and Far-reaching for example, methane is a hydrocarbon of particular concern due do it global warming concern which is why methane monitoring is a must for all government and industrial facilities[29]. Hydrocarbons and their derivatives are a significant environmental concern due to their extensive use and toxic mechanism action, and these products are highly available in aquatic medium [30]. Industrial activities and chemical plants produce polycyclic hydrocarbons PAHs, and they are considered as petrogenic and natural PAH sources [31]. During fat pyrolysis and incomplete combustion processes, anthropogenic emissions of PAHs are released into the environment [32]. The major classes of hydrocarbons are:

I) Alkanes (formerly called paraffins), such as 2,2,3-trimethylbutane



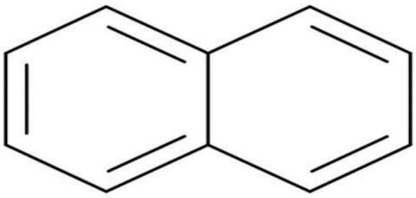
2, 2, 3-Trimethylbutane

II) Alkenes (olefins, compounds with double bonds between adjacent carbon atoms), such as ethylene; alkynes (compounds with triple bonds), such as acetylene;



Acetylene

III) Aromatic (aryl) compounds, such as naphthalene



Naphthalene

2.4. Polycyclic Aromatic Hydrocarbons

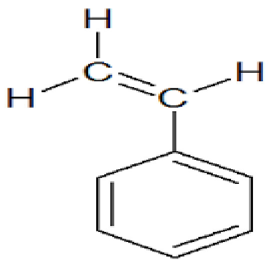
Polycyclic aromatic hydrocarbons (PAHs) are a group of more than 100 different chemicals that are released from burning coal, oil, gasoline, trash, tobacco, wood, or other organic substances such as charcoal-broiled meat[33]. While PAHs occur naturally in crude oil, and smoke and ash from forest fires, they are most often found as products of incomplete combustion, especially from incinerators[31]. Most regulations, analyses, and data reporting focus on only a limited number of PAHs, typically between 14 and 20 individual PAH compounds, such as: benezene, anthracene, naphthalene, toluene, ethylbenezene, styrene, cumene, 2,6-dimethylnaphthalene, phenanthrene, and pyrene[34].

A wide variety of polycyclic aromatic hydrocarbons (PAHs) are found in the environment as a result of the incomplete combustion of organic matter, automobile exhausts, stationary matter (e.g. coal-fired, electricity generating power plants), domestic matter (e.g. tobacco smoke and residential wood or coal combustion), area source matter (e.g. forest fires and agricultural burning) and also in food[35]. Massive relocation of natural materials to different areas of the ecosystem has taken place during the past several decades as a result of human activity, thus exposing living systems to these different compounds[30]. Some PAHs (e.g. naphthalene and phenanthrene) have also been used in the synthesis of different organic compounds in pesticides, fungicides, detergents, dyes, and mothballs[36].

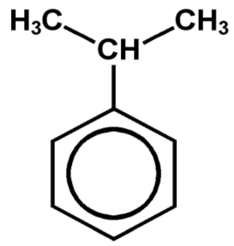
I) Naphthalene: the first member of the PAH group, is a common micro pollutant in potable water[37]. The toxicity of naphthalene has been well documented, and cataractogenic activity has been reported in laboratory animals[38]. Naphthalene binds covalently to molecules in liver, kidney, and lung tissues, thereby enhancing its toxicity; it is also an inhibitor of mitochondrial respiration[32]. Acute naphthalene poisoning in humans can lead to haemolytic anemia and nephrotoxicity[29]. In addition, dermal and ophthalmological changes have been observed in workers occupationally exposed to naphthalene[38].

II) Phenanthrene: known to be a photosensitize of human skin, a mild allergen, and mutagenic to bacterial systems under specific conditions[32]. It is a weak inducer of sister chromatid exchanges and a potent inhibitor of gap junctional intercellular communication[39].

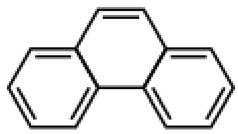
III) Styrene: is a monomer used in the manufacture of plastic and synthetic rubber. Cumene is oxidized to produce phenol and acetone, which are valuable by- product. Because of these applications plus production of this compound as combustion by products, aromatic compounds are common atmospheric pollutants[39].



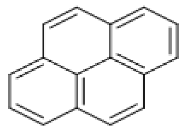
Styrene



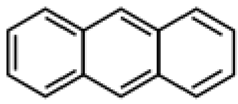
Cumene



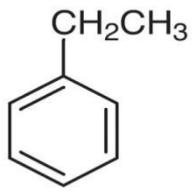
Phenantrene



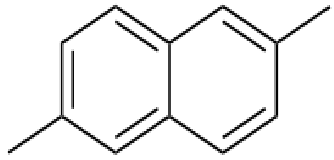
Pyrene



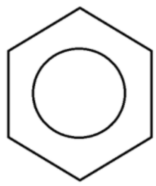
Anthracene



Ethylbenzene



2, 6 Dimethylnaphthalene



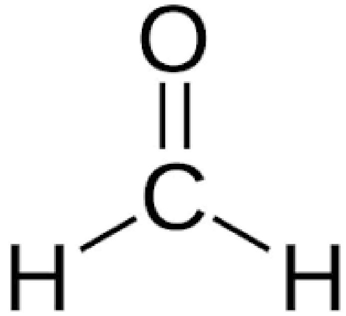
Benzene

2.5. Carbonyl Compounds

Atmospheric carbonyl compounds, including aldehydes and ketones, are a group of oxygenated volatile organic compounds (OVOCs), which are both important precursors for components of photochemical smog[40]. Carbonyl compounds can react with the hydroxyl radical (·OH) to generate HO_2 and RO_2 radicals, which can oxidize NO to NO_2 and further promote the formation of O_3 in the troposphere[41]. Carbonyl compounds are also important intermediates in the formation of secondary aerosols and widely distributed in the troposphere[42]. The primary source of atmospheric carbonyl compounds is direct emissions from human activities and natural processes, such as fossil fuel combustion, incomplete combustion of biomass, and vegetation emissions, and the secondary source is generation from volatile organic compounds from anthropogenic or natural emissions through atmospheric oxidation reactions[43]. The oxidation of carbonyl compounds could produce formic acid, acetic acid, and other acidic substances, which may enhance atmospheric acidity, intensify the formation of acid rain, and harm the environment[44]. In addition, most carbonyl compounds are highly irritating and toxic[45]. Some of them include;

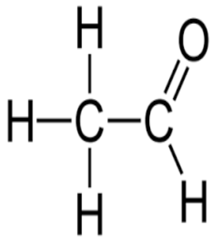
I) Formaldehyde: this is produced in the atmosphere as a product of the reaction of atmospheric hydrocarbons beginning with their reactions with hydroxyl radical, HO[46]. With annual global industrial production exceeding 1billion kg, formaldehyde is used in the manufacture of plastics, resins, lacquers, dyes, and explosives[47]. It is uniquely important because of its widespread distribution and toxicity[46].

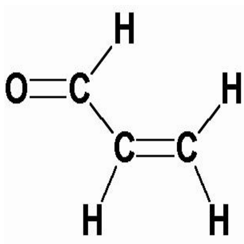
Humans may be exposed to formaldehyde in the manufacture and use of phenol, urea, and melamine resin plastics, and from formaldehyde-containing adhesives in pressed wood products such as particle board, used in especially large quantities in mobile home construction[48]. Generally, formaldehyde poses serious risks to the human eyes, skin, and respiratory system, and has been confirmed as a first-class human carcinogen[49].

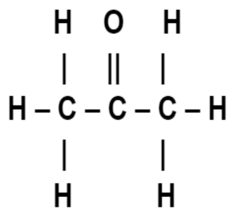


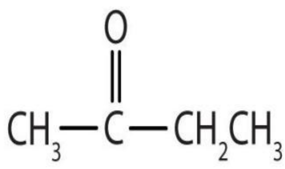
Formaldehyde

II) Acetaldehyde: is a widely produced organic chemical used in the manufacture of acetic acid, plastics, and raw materials. It is considered as a potential carcinogen[50]. Formaldehyde and acetaldehyde are produced by microorganisms, and acetaldehyde is emitted by some kinds of vegetation[51].









Ethyl methyl ketone

Acetaldehyde Acrolein Acetone

2.6. Miscellaneous Oxygen Containing Compounds

Oxygen containing compounds consist of aliphatic alcohols, phenols, ethers, and carboxylic acids. They have the general formulas as given below

R — OH	Ar — OH	R — O — R'	R — C(=O) — OH
Aliphatic	Phenols	Ethers	Carboxylic acids

R and R' represent hydrocarbon moieties (groups), and Ar stands specifically for an aromatic moiety, such as the phenyl group (benzene less an H atom).

2.7. Chlorofluorocarbons and Stratospheric Ozone Depletion

Chlorofluorocarbons (CFCs) are anthropogenic compounds that have been released into the atmosphere since the 1930s in various applications such as in air-conditioning, refrigeration, blowing agents in foams, insulations and packing materials, propellants in aerosol cans, and as solvents[52]. Although quite inert in the lower atmosphere, CFCs undergo photodecomposition by the action of high-energy ultraviolet radiation in the stratosphere, which is energetic enough to break their very strong C-Cl bonds through reactions such as:

$$Cl_2CF_2 + hv \longrightarrow Cl\cdot + ClCF_2 \quad 2.1$$

thereby releasing Cl atoms. The Cl atoms are very reactive species. Under rarefied condition of the stratosphere, one of the most abundant reactive species available for them to react with is ozone, which they destroy through a process that generates ClO:

$$Cl + O_3 \longrightarrow ClO + O_2 \quad 2.2$$

In the stratosphere, there is an appreciable concentration of atomic oxygen by virtue of the reaction:

$$O_3 + hv \longrightarrow O_2 + O \quad 2.3$$

Nitric oxide, NO, is also present. The ClO species may react with either O or NO, regenerating Cl atoms and resulting in chain reactions that cause the net destruction of ozone:

$$ClO + O \longrightarrow Cl + O_2 \quad 2.4$$

$$Cl + O_3 \longrightarrow ClO + O_2 \quad 2.5$$

$$O_3 + O \longrightarrow 2O_2 \quad 2.6$$

$$ClO + NO \longrightarrow Cl + NO_2 \quad 27$$

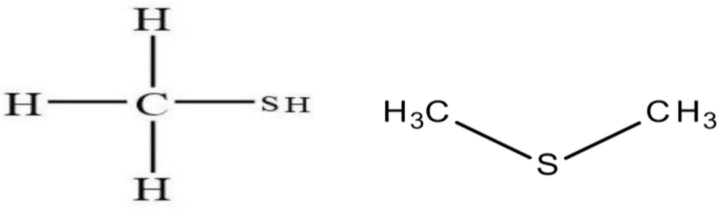
$$O_3 + Cl \longrightarrow ClO + O_2 \quad 2.8$$

$$O_3 + NO \longrightarrow NO_2 + O_2 \quad 2.9$$

Both ClO and Cl involved in the above chain reactions have been detected in the 25 to 45–km altitude region. Also involved as an intermediate in the stratospheric ozone destruction caused by chlorofluorocarbons is the $(ClO)_2$ dimer.

2.8. Organosulfur Compounds

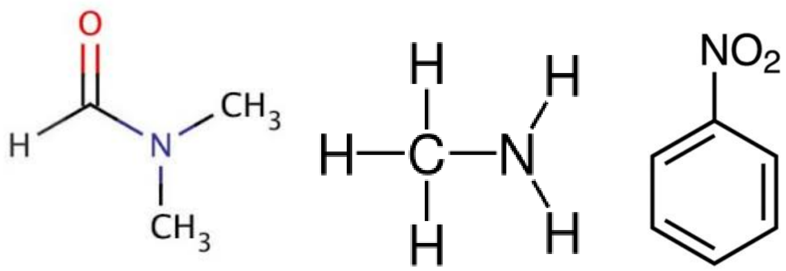
These are organic molecules that contain sulfur-containing functional groups and are known for their potential to improve cardiovascular health and inhibit carcinogenesis[53]. They are commonly found in vegetables such as watercress, Chinese cabbage, and broccoli[54]. The most significant atmospheric organosulfur compound is dimethylsulfide, produced in large quantities by marine organisms, and introducing quantities of sulfur to the atmosphere comparable in magnitude to those introduced from pollution sources[55]. Organic sulfur compounds can cause local air pollution problems because of their pungent smell[56[. Its oxidation produces most of the SO_2 in the marine atmosphere[57].



Methanethiol **Dimethylsulfide**

2.9. Organonitrogen Compounds

Organonitrogen compounds are a class of organic compounds composed of one or more nitrogen atoms[58]. The organic nitrogen compounds that may be seen as atmospheric contaminants are classified as amines, amides, nitriles, nitro compound, or hetrocyclic nitrogen compounds[59]. Decaying organic matter, especially protein wastes, produces amines[60]. Aromatic amines are of particular concern as atmospheric pollutants, since they are known to cause bladder cancer in exposed individuals[61]. Aromatic amines of potential concern are aniline, benzidine, 3,3' dichlorobenzidine, naphthylamine, 2-naphthyl-amine, and phenyl-2-naphthyl-amine[62]. They are widely used as chemical intermediates, antioxidants, and curing agents in the manufacture of polymers, drugs, pesticides, dyer, pigments, and inks[63]. These amines also can react with hydroxyl radicals to give rise to harmful products. The important nitro compound produced by the photochemical oxidation of hydrocarbon in urban atmospheres is peroxy acetyl nitrate (PAN)[64].



Dimethylformamide Methylamine Nitrobenzene

Above are Organonitrogen compounds that can be encountered as air pollutants.

3. SMOG

The term smog is derived from the words smoke and fog. At least two distinct types of smog are recognized: sulfurous smog and photochemical smog[65]. Sulfurous smog, which is also called "London smog," results from a high concentration of sulfur oxides in the air and is caused by the use of sulfur-bearing fossil fuels, particularly coal[66]. This type of smog is aggravated by dampness and a high concentration of suspended particulate matter in the air [67].

3.1. Photochemical Smog

Photochemical smog, which is also known as "Los Angeles smog," occurs most prominently in urban areas that have large numbers of automobiles[68]. It requires neither smoke nor fog[69], it can also be defined as a mixture of various gases with dust particles[70].

Photochemical smog is a type of smog produced when ultraviolet light from the sun reacts with nitrogen oxides in the atmosphere. It is visible as a brown haze, and is most prominent during the morning and afternoon[71].

3.1.1. Formation of Photochemical Smog

Nitrogen oxides (the mixture of NO and NO_2 together referred to as NO_x) and volatile organic compounds (VOCs) are primary air pollutants, released in the atmosphere by automobiles and industrial processes[72]. Nitrogen dioxide absorbs ultraviolet light, and formation of nitric oxide and atomic oxygen takes place. Ozone is generated by the reaction of oxygen gas with this atomic oxygen.

Ozone, aldehydes, and peroxyacetyl nitrate so formed are thus secondary air pollutants[73]. Photochemical smog is a mixture of primary and secondary air pollutants[74]. Motor vehicles are responsible for production of exhaust gases rich in oxides of nitrogen, which include nitrogen dioxide (NO_2) and nitric oxide (NO)[75]. At the high temperatures in a car's combustion chamber (cylinder), nitrogen and oxygen from the air react to give nitric oxide:

$$N_2 + O_2 \longrightarrow 2NO \quad . \quad . \quad . \quad . \quad 3.1$$

Some of the amount of NO so formed then reacts with oxygen and NO_2 is formed

$$2NO_2 + O_2 \longrightarrow 2NO_2 \quad . \quad . \quad . \quad 3.2$$

In the presence of sunlight, nitrogen dioxide molecule present in high concentration breaks up and gives oxygen atom

$$NO_2 + hv \longrightarrow NO + O \quad . \quad . \quad . \quad 3.3$$

This atomic oxygen (O) reacts with oxygen molecules present in the atmosphere, and ozone (O3) is formed:

$$O + O_2 \longrightarrow O_3 \quad . \; . \; . \; . \; . \quad . \quad . \quad 3.4$$

Ozone so formed then reacts with NO to form NO_2 and O_2:

$$NO + O_3 \longrightarrow NO_2 + O_2 \quad . \; . \; . \; . \; . \; . \quad . \quad 3.5$$

The reaction in which ozone forms is dominant when the ratio of NO_2 to NO is more than 3. If the ratio is less than 0.3, however, the nitric oxide so formed results in destruction of ozone at the same rate as that of its formation and results in lowering the concentration of ozone to less harmful levels. The reactions of hydrocarbons (from unburned petrol) with nitric oxide and oxygen in the presence of sunlight generate aldehydes, ketones, and peroxy compounds[76].

A part of the ozone formed above reacts with volatile organic compounds (VOC) such as hydrocarbons, especially olefins, also released from automobile exhaust, giving carboxyl free radicals (RCO_2)[77]:

$$O_3 + RH \longrightarrow RCO_2 + RCHO + R_2COH + RCO_2 \quad 3.6$$

The free oxygen atoms formed react with hydrocarbons to produce alkyl/aryl free radicals (R') well as acetyl free radicals (RCO)

$$O + RH \longrightarrow R' + RCO. \quad 3.7$$

Similarly, some of these acetyl free radicals react with atmospheric oxygen giving acylperoxy radicals (RCO_3):

$$RCO + O_2 \longrightarrow RCO_3 \quad 3.8$$

Acylperoxy radicals may also be formed by the reaction of carboxyl radicals and oxygen atoms:

$$RCO_2 + O \longrightarrow RCO_3 \quad 3.9$$

Any acetylperoxy radicals formed further react with nitrogen dioxide giving peroxyacetyl nitrate (PAN):

$$RCO_3 + NO_2 \longrightarrow RCO_3NO_2 \quad 3.10$$

Example:

$$H_3C\text{-}CO_3 + NO_2 \longrightarrow H_3C\text{-}CO_3NO_2 \quad 3.11$$

(PAN)

If the peroxy radical reacting with nitrogen dioxide has an aromatic ring as substituent, peroxybenzoyl nitrate (PBzN) is formed:

$$C_6H_5\text{-}CO_3 + NO_2 \longrightarrow C_6H_5\text{-}CO_2NO_2 \quad 3.12$$

3.2. Types of Pollutants Causing Photochemical Smog

I) Primary pollutants: The two major primary pollutants, nitrogen oxides and VOCs, combine to change in sunlight in a series of chemical reactions to create what are known as secondary pollutants[78].

II) Secondary pollutants: The secondary pollutant that causes the most concern is the ozone that forms at ground level. While ozone is produced naturally in the upper atmosphere, it is a dangerous substance when found at ground level. Many other hazardous substances are also formed, such as peroxyacetyl nitrate (PAN)[79].

3.3. Sources of Photochemical Smog

I) Biogenic Sources: In nature, bushfires, lightning, and the microbial processes that occur in soil generate nitrogen oxides[80]. VOCs are produced from the evaporation of naturally occurring compounds, such as terpenes, which are the hydrocarbons in oils that make them burn. Eucalypts have also been found to release significant amounts of these compounds[81].

II) Anthropogenic Sources: Nitrogen oxides are produced mainly from the combustion of fossil fuels, particularly in power stations and motor vehicles[82]. VOCs are formed from the incomplete combustion of fossil fuels, from the evaporation of solvents and fuels, and from burning plant matter such as backyard burning and wood burning stoves[83].

3.4. Effect of Weather and Location

Normally the layer of air closest to the earth's surface is warmer than the air higher in the atmosphere because the heat of the sun is re-radiated (warmed by the earth's surface)[84]. The higher level cool air sinks and is then warmed and displaced upwards in a convection cycle (Figure 1). This condition is called 'unstable' and helps to carry pollutants upwards, where they are dispersed and diluted.

This cycle is usually assisted by higher wind speeds. However, when the opposite occurs, cities can experience prolonged periods of photochemical smog[85]. An inversion is formed when a ceiling of warmer air traps the cooler layer of air, which contains the pollutants, near the ground's surface. This hinders the ability of the pollutants to rise to the atmosphere and be dispersed[86]. After an inversion has formed, it keeps any smog that is present close to the ground, maximising its detrimental effect[87].

There are two major processes that enable an inversion to happen, and both are usually accompanied by low wind speeds. The first, advection, is when an upper layer of warmer air is blown in, trapping the layer of cool air below it. This 'stable' condition may last for several days. A variation of this is when a cooler layer of air, such as a sea breeze, is blown in underneath a warmer layer, creating the same effect. The second process, radiation inversion, usually occurs overnight. The ground cools and, in turn, cools the air layer closest to it, resulting in the lower air layer being cooler than air above it, forming an inversion[88].

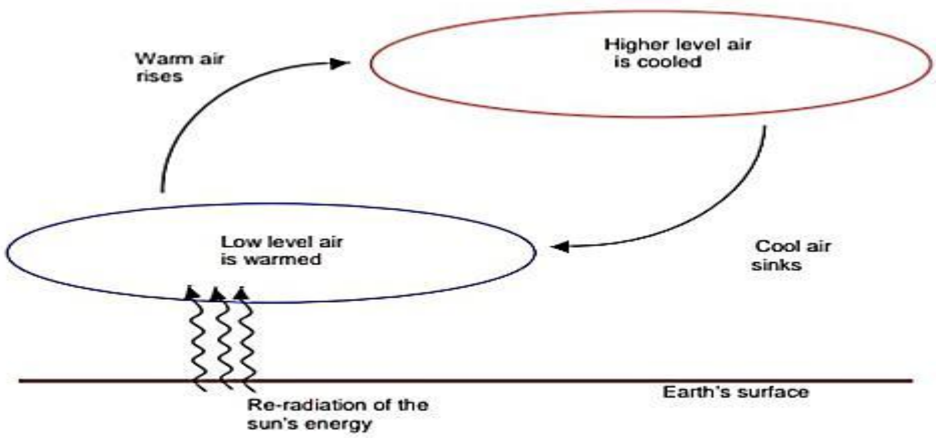


Figure 1. Convection Cycle.

4. HEALTH AND ENVIRONMENTAL EFFECTS OF ORGANIC AIR POLLUTANTS AND PHOTOCHEMICAL SMOG

4.1. Health Effects of Organic Air Pollutants

Air pollution exposure is associated with oxidative stress and inflammation in human cells, which may lay a foundation for chronic diseases and cancer[89]. In 2013, the International Agency for Research on Cancer of the World Health Organization (WHO) classified air pollution as a human carcinogen[90]. Many studies have established that short-term exposure to higher levels of outdoor air pollution is associated with reduced lung function, asthma, cardiac problems, emergency department visits, and hospital admissions[91]. Mortality rates related to air pollution are also a concern[92]. Public health concerns related to high air pollution exposures include cancer[93], cardiovascular disease[94], respiratory diseases[95], diabetes mellitus[96], obesity[97], and reproductive, neurological, and immune system disorders[98].

I) Cancer: A large study of more than 57,000 women found living near major roadways may increase a woman's risk for breast cancer[99]. Occupational exposure to benzene, an industrial chemical and component of gasoline, can cause leukemia and is associated with non-Hodgkin's Lymphoma[100]. A long-term study, 2000-2016, found an association between lung cancer incidence and increased reliance on coal for energy generation. Using a national dataset of older adults, researchers found that 10-year long exposures to PM2.5 (Particulate matter 2.5) and NO_2 increased the risks of colorectal and prostate cancers[101].

II) Cardiovascular Disease: Fine particulate matter can impair blood vessel function and speed up calcification in arteries[102]. National Institute of Environmental Health Sciences (NIEHS) researchers established links between short-term daily exposure by post-menopausal women to nitrogen oxides and increased risk of hemorrhagic stroke. For some older Americans, exposure to Traffic Related Air Pollution (TRAP) can result in lowered levels of high-density lipoprotein, sometimes called good cholesterol, increasing their risk for cardiovascular disease. According to a National Toxicology Program (NTP) report, TRAP exposure also increases a pregnant woman's risk for dangerous changes in blood pressure, known as hypertensive disorders, which are a leading cause of pre-term birth, low birth weight, and maternal and fetal illness and death[103,104].

III) Respiratory Disease: Air pollution can affect lung development and is implicated in the development of emphysema, asthma, and other respiratory diseases, such as chronic obstructive pulmonary disease (COPD)[105]. Increases in asthma prevalence and severity are linked to urbanization and outdoor air pollution[106]. Children living in low-income urban areas tend to have more asthma cases than others[107].

4.2. Environmental Effects of Organic Air Pollutants

Along with harming human health, air pollution can cause a variety of environmental effects:

I) Acid Rain: Is precipitation containing harmful amounts of nitric and sulfuric acids formed primarily by nitrogen oxides and sulfur oxides released into the atmosphere when fossil fuels are burned[108]. These acids fall to the Earth either as wet precipitation (rain, snow, or fog) or dry precipitation (gas and particulates). Some are carried by the wind, sometimes hundreds of miles. In the environment, acid rain damages trees and causes soils and water bodies to acidify, making the water unsuitable for some fish and other wildlife. It also speeds the decay of buildings, statues, and sculptures that are part of our national heritage[109].

II) Eutrophication: Is a condition in a water body where high concentrations of nutrients (such as nitrogen) stimulate blooms of algae, which in turn can cause fish kills and loss of plant and animal diversity[110]. Although eutrophication is a natural process in the aging of lakes and some estuaries, human activities can greatly accelerate eutrophication by increasing the rate at which nutrients enter aquatic ecosystems[111]. Air emissions of nitrogen oxides from power plants, cars, trucks, and other sources contribute to the amount of nitrogen entering aquatic ecosystems[112].

III) Ozone Depletion: Ozone is a gas that occurs both at ground-level and in the Earth's upper atmosphere, known as the stratosphere. At ground level, ozone is a pollutant that can harm human health. In the stratosphere, however, ozone forms a layer that protects life on Earth from the sun's harmful ultraviolet (UV) rays[113]. But this "good" ozone is gradually being destroyed by man-made chemicals referred to as ozone-depleting substances, including chlorofluorocarbons, hydro chlorofluorocarbons, and halons. These substances were formerly used and sometimes still are used in coolants, foaming agents, fire extinguishers, solvents, pesticides, and aerosol propellants. Thinning of the protective ozone layer can cause increased amounts of UV radiation to reach the Earth, which can lead to more cases of skin cancer, cataracts, and impaired immune systems[114].

IV) Global Climate Change: The Earth's atmosphere contains a delicate balance of naturally occurring gases that trap some of the sun's heat near the Earth's surface[115]. This "greenhouse effect" keeps the Earth's temperature stable[116]. Unfortunately, evidence is mounting that humans have disturbed this natural balance by producing large amounts of some of these greenhouse gases, including carbon dioxide and methane[117]. As a result, the Earth's atmosphere appears to be trapping more of the sun's heat, causing the Earth's average temperature to rise - a phenomenon known as global warming[118].

4.3. Economic Effects

Air pollution costs the world economy $5 trillion per year as a result of productivity losses and degraded quality of life. These productivity losses are caused by deaths due to diseases caused by air pollution[119]. One out of ten deaths in 2013 was caused by diseases associated with air pollution, and the problem is getting worse[120].

5. EFFECTS OF PHOTOCHEMICAL SMOG

5.1. Effects on Environment: Photochemical smog has devastating effects on the environment. The collection of chemicals found in photochemical smog causes problems for plants and animal life[121].

5.2. Effect on Plants: Deposition of particulate matter containing toxic metals affects the growth of plants. The particulate matter, after deposition in plants, leaves block stomata opening of plants and reduce growth. Decrease the pH of the soil which makes the soil infertile. Can lead to extensive damage to crops, trees, and vegetation[122]. Some plants such as tobacco, tomato, and spinach are highly responsive to ozone, so photochemical smog can decimate these sensitive crops, trees, and other vegetation[123].

5.3. Effects on Human Health: It can cause anything from minor pain to deadly diseases such as lung cancer, wheezing[124]. High levels of smog also trigger asthma attacks because the smog causes increased sensitivity to allergens, which are triggers for asthma, eye irritation, problems with heat, and lungs[125].

6. CONTROL OF ORGANIC AIR POLLUTANTS AND PHOTOCHEMICAL SMOG

I) Reduction of Nitrogen oxides: The main method of lowering the levels of nitrogen oxides is by a process called 'catalytic reduction," which is used in industry and in motor vehicles[126]. For example, a catalytic converter fitted to a car's exhaust system will convert much of the nitric oxide from the engine exhaust gases to nitrogen and oxygen. Nitrogen is not in the actual fuels used in motor vehicles or power stations; it is introduced from the air when combustion occurs. Using less air in combustion can reduce emissions of nitrogen oxides[127]. Temperature also has an effect on emissions the lower the temperature of combustion, the lower the production of nitrogen oxides[128[. Temperatures can be lowered by using processes such as two stage combustion and flue gas recirculation, water injection, or by modifying the design of the burner[129].

II) Reduction of VOCs: There are various ways to reduce VOC emissions from motor vehicles. These include the use of liquefied petroleum gas (LPG) or compressed natural gas (CNG) rather than petrol, decreasing distances vehicles travel by using other modes of transport, such as buses and bikes, and implementing various engine and emission controls now being developed by manufacturers[130]. The other major contributor to VOC emissions, however, is not as simple to regulate because solvent evaporation occurs in many different places, from large factories to backyard sheds[131]. Control strategies to reduce these emissions must be widely varied. Some include;

a) Other small actions, such as tightly sealing the lids of chemical products like garden chemicals, solvents, and household cleaners.
b) Use energy efficient appliances and Look for the Energy Star logo when buying an electricical Appliances.
c) If renovating or buildings, use energy-efficient designs and materials. Turn off unnecessary electrical appliances.
d) Limit your wood fires at home.
e) Certain plants, example Pinus, Juniparus, Quercus, Pyrus, and Vitis, can metabolize nitrogen oxide and therefore their plantation could help in controlling this pollutant.

7. CONCLUSION

Air pollution threatens the health of humans and other living beings in our planet. It creates smog and acid rain, causing cancer and respiratory diseases, reducing the ozone layer atmosphere, and contributes to global warming. The many sources of pollution today are unregulated parts of industrialization. To mitigate air pollution a multi-pronged approach is required, stricter regulations on industrial emissions are needed to reduce pollution from factories and other facilities. Civic engagement and advocacy for stronger air pollution policies are also impactful. The findings of this air pollution project highlight an urgent public health issue. Concerted efforts are required to enact solutions that will improve air quality and protect the wellbeing of all residents.

8. RECOMMENDATIONS

The detrimental effects of air pollution on human health, the environment, and the economy are well-documented and cannot be ignored. It is imperative that governments, industries, and individuals take proactive measures to reduce air pollution and protect the well-being of current and future generations. This can be achieved through the implementation of stringent regulations on emissions, promotion of sustainable energy sources, and the adoption of cleaner technologies. Public awareness and education on the impact of air pollution are crucial in catalyzing widespread support and behavioral change.

Individuals can also play a part in combating air pollution by making conscious choices in their daily activities, such as reducing energy consumption, using public transportation, and supporting environmentally friendly products. Collaboration and collective efforts across all sectors of society should prioritize planetary health in addressing the complex and interconnected issues associated with air pollution.

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