Air pollutants and effects of air pollution: A Review

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Abstract: When the quantum of air pollutants exceeds the self-cleaning properties of the ambient air, and its start causing harmful effects on the human health and surrounding abiotic environment. Air pollution can have serious costs, penalties and consequences for the health of human beings and also ruthlessly distress the natural bio-network and ecosystems. The principal aim of this paper is to summarize about various types of air pollutants such as particulate matter, sulphur dioxide, carbon monoxide, Ground level ozone, lead and volatile organic compounds. Besides, these effects of air pollution on human beings and effects of air pollution on environment also discussed. The major consequences of air pollution are global warming, acid rain, photochemical smog, ozone depletion.

Keywords: Abiotic Environment, Particulate matter, Sulphur dioxide, Carbon monoxide, Ground level ozone, lead, Volatile organic compounds, Global warming, Acid rains, Photochemical smog, Ozone depletion.

INTRODUCTION

Air is one of the most important constituents in the man's environment. Any change in the natural and normal composition of air, affect the living system, particularly human life, invariably causes air pollution. The environment is a coupling of the biotic (living organisms and microorganisms) and the abiotic (hydrosphere, lithosphere, and atmosphere). Air pollution defined as any solid, liquid or gaseous substance present in the atmosphere in such concentration that tends to injurious to human beings, or living creatures or plants or property or enjoyment. When the quantum of air pollutants exceeds the self-cleaning properties of the ambient air, and its start causing harmful effects on the human health and surrounding abiotic environment.

The nature of air pollution has changed over the millennia. No longer is air pollution predominantly smoke-related and sulfur-related but now it is associated with nitrogen oxides, volatile organic compounds, and PM connected with the growing traffic and industrial emissions (Morawska et al., 2008). Household air pollution deaths in low-income countries are therefore decreasing. Increased in ambient air pollution driven by the rapid expansion of megacities, globalisation of industrial production, proliferation of pesticides and toxic chemicals, and growing use of motor vehicles. Ambient air pollution deaths have been increasing worldwide since 1990, and increases are most substantial in the most rapidly industrialising countries (Pruss-Ustun A et al., 2016).

Air pollution mainly affects those are living in urban areas, where road emissions contribute the most to the degradation of air quality. There is also a danger of industrial accidents, where the spread of a toxic fog can be fatal to the populations of the surrounding areas. When air pollutant released in to atmosphere from a source, it dispersed into atmosphere various directions depending upon wind, temperature and pressure conditions in environment (Kelishadi R et al., 2010).

In developing countries, the problem of air pollution is more serious because of overpopulation, uncontrolled urbanization and development of industrialization. In such developing countries, however, huge economic and social disparities coexist. People in rural areas exposed high concentrations of indoor air pollution because of the use of biomass fuels (coal, wood, and other solid fuels) as an energy resource. Three billion people around the world are using the above sources of energy for their daily cooking or heating purposes (Pier Mannuccio Mannucci et al., 2010).

Air pollution is one of the most critical human and environmental health issues we face today. A recent WHO report entitled "Burden of disease from the joint effects of Household and Ambient Air Pollution for 2012" (WHO, 2014) attributes approximately 7 million deaths worldwide to the deleterious effects of air pollutants. This amounts to 1 in 8 deaths across the globe, with 3.7 million deaths resulting from poor ambient air quality and 4.3 million deaths attributed to indoor air pollutants (Selahattin Incecik et al., 2014)

Various pollutants causing air pollution and its effects on human beings

The atmospheric may air contains hundreds of air pollutants from the natural or anthropogenic (manmade) sources. All these pollutants which are emitted directly from the identifiable sources, either from the natural hazard events like dust storms, forest fires, volcanic eruptions etc, or from man-made activities likes burning of wood, coal, oil, in homes or industries or automobiles etc. called as primary air pollutants. The following five primary air pollutants contribute about 90% of global air pollution.

Important primary air pollutants:

1. Oxides of sulphur, Sulphur dioxide (SO_2)
2. Oxides of carbon likes carbon dioxide (CO_2) and carbon monoxide (CO)
3. Oxides of nitrogen like NO, NO_2, NO_3
4. Volatile organic compounds like hydrocarbons
5. Suspended particular matter(SPM)

These primary pollutants react with one another or with water vapour, abetted by sunlight, to form a new set of pollutants called secondary pollutants. Secondary pollutants are the chemical substances, which are produced from the chemical reactions of natural or anthropogenic pollutants or due to oxidation etc., caused by the energy of the sun.

Important secondary air pollutants:

1. Sulphuric acid
2. Ozone
3. Formaldehyde
4. Peroxy- Acyl-Nitrate (PAN)

Sulphuric acid formed by chemical reaction between sulphuric acid (SO_2) and water vapour (H_2O). Ozone, formaldehyde and PAN formed by the photochemical reactions, caused by sunlight between two primary pollutants.

The World Health Organization (WHO) reports on six major air pollutants, namely particle pollution, ground-level ozone, carbon monoxide, sulfur oxides, nitrogen oxides, and lead. Air pollution can have a disastrous effect on all components of the environment, including groundwater, soil, and air (William E. Wilson et al., 1997).

SULPHUR DIOIXDE (SO_2)

Sulfur oxides are a group of air pollutants, which comprise both gaseous and particulate chemical species. There are generally four gas-phase compounds, namely, sulfur monoxide, sulfur dioxide, sulfur trioxide, and disulfur monoxide; but only sulfur dioxide (SO_2) occurs at sufficient concentrations in ambient atmospheres to be of public health concern (X Pan et al.,2011). Sulphur dioxide is a basic air pollutant among all the oxides of sulphur. Sulphur dioxide mainly originated from refineries and chemical plants, smelting operations, and burning of fossil fuels. Thermal power plants emit SO_2, as high as $\frac{1}{10}$ Th of the coal burnt. Open burning of garbage and municipal incineration plants also emits SO_2. The permissible limit of annual average concentration of SO_2 for residential areas is 60 $\mu g/m^3$ or 0.003 ppm at 20 ◦ C (US EPA, October 5, 2019).

It affects human, animal, and plant. When SO_2 inhaled, it affects the mucous membrane. The major health problem associated with SO_2 emissions are mucous membrane, bronchial-spasms, mucous membrane, and respiratory irritations. It affects breathing, lung defences, aggravation of existing respiratory and cardiovascular diseases, and death. Asthmatics and those suffering from chronic lung and cardiovascular diseases are sensitive to SO_2 exposure. Susceptible people as those with lung disease, old people, and children, who present a higher risk of damage (Chen TM et al. 2007).

Environmental adverse effects such as responsible acidity in fogs, smoke, and in rains and hence major source of corrosion of buildings and metallic objects. It may lead to photochemical smog in some areas by oxidising the hydrocarbons.

As per NAAQS, the maximum average annual concentration of oxides of sulphur as SO_2 in residential area and ecologically sensitive areas are 50 $\mu g/m^3$ and 50 $\mu g/m^3$, respectively.

GROUND LEVEL OZONE (GLO):

Ozone is a triatomic allotropic form of oxygen. Triplet oxygen is a highly reactive molecule. Naturally, it arises in the stratosphere, but it can as well develop through the chain reactions of photochemical smog in the troposphere. Photochemical smog occurs in highly polluted urban and industrial areas in the presence of high solar radiation. Ozone develops in the reaction of oxygen molecules with the singlet oxygen splitting off from nitrogen-oxides in the presence of UV-radiation. This reaction is quick and reversible, so the formation and degradation of ozone show steady-state balance. This happens when pollutants emitted by cars, power plants, industrial boilers, refineries, chemical plants, and other sources chemically react in the presence of sunlight (Crutzen et al., 1994).

Ozone and its precursors can float hundreds of kilometres from their sources and its formation often happens only during its moving with air masses. Since there are less chemical reagents by which its dissolution takes place far from the cities, the amount of ozone above cities is relatively small, while passing away from urban areas, this amount is gradually growing. Thus, ozone virtually originating from cities endangers natural vegetation and cultivated plants (Lorenzini and Saitanis, 2oo3).

Ozone shows short-term and long -term effects on cultivated plants. Ozone can cause short-term effects in plants such as the development of visible injury (fine bronze or pale yellow specks on the upper surface of leaves) or reductions in photosynthesis. If episodes are frequent, longer-term effects such as reductions in growth and yield and early scenescence can occur (Harmens et al., 2006).

Ozone damages vegetation and ecosystems by inhibiting the ability of plants to open the microscopic pores on their leaves to breathe. It interferes with the photosynthesis process by reducing the amount of carbon dioxide the plants can process and release as oxygen.

Elevated levels of ozone leads to reduced agricultural crop and commercial forest yields, reduced growth and survivability of tree seedlings, and increased susceptibility to diseases, pests and other stresses such as harsh weather.

Ozone is a highly oxidative compound formed in the lower atmosphere from gases (originating to a large extent from anthropogenic sources) by photochemistry driven by solar radiation. Owing to its highly reactive chemical properties, ozone is harmful to vegetation, materials and human health. In the troposphere, ozone is also an efficient greenhouse gas.(WHO, August 15, 2009).

Daily exposures to ozone increase mortality and respiratory morbidity rates. short-term studies on pulmonary function, lung inflammation, lung permeability, respiratory symptoms, increased medication usage, morbidity and mortality, ozone appears to have effects independent of other air pollutants such as particulate matter (PM). As to long-term exposures, new epidemiological evidence and experimental animal studies on inflammatory responses, lung damage and persistent structural airway and lung tissue changes early in life also indicate effects of long-term exposure to ozone.

Breathing ground-level ozone causes health problems, including chest pain, coughing, throat irritation, and congestion. It can worsen bronchitis, emphysema, and asthma. Ozone also can reduce lung function and inflame the lining of the lungs. Repeated exposure may permanently scar lung tissue (US EPA).

Because of the low water-solubility of ozone, inhaled ozone can penetrate deeply into the lungs (Hatch GE et al., 1994).

Healthy people also experience difficulty breathing when exposed to ozone pollution. Because ozone forms in hot weather, anyone who spends time outdoors in the summer may affect, particularly children, outdoor workers and people exercising. Some people who don't fall into any of these categories may also find themselves sensitive to ozone.

CARBON MONOXIDE (CO)

Carbon monoxide is a colorless, odourless, tasteless, non irritating and toxic gas that is produced by incomplete combustion of organic materials (Joseph Varon et al., 1999; Tim Meredith and Allister Vale,1988). Ambient CO primarily results from traffic or industry in urban communities, risks associated with CO modified by other traffic-related air pollutants, such as nitrogen dioxide (NO2), sulfur dioxide (SO2), ozone (O3) and fine particles (Yu Wang et al.,2019). Carbon monoxide is not detectible by humans either by sight, taste or smell. It is only slightly soluble in water, blood serum and plasma in the human.

Vehicular exhausts are the single largest sources of carbon monoxide. Poorly maintained vehicles and inefficient engine workings, vehicles being fitted with adequate pollution control devices, releases a greater amount of carbon monoxide.

In developed countries, the most important source of exposure to carbon monoxide in indoor air is emissions from faulty, incorrectly installed, poorly maintained or poorly ventilated cooking or heating appliances that burn fossil fuels. In homes, the burning of biomass fuels and tobacco smoke are the most important sources of exposure to carbon monoxide. Clogged chimneys, wood-burning fireplaces, decorative fireplaces, gas burners and supplementary heaters without properly working safety features could vent carbon monoxide into indoor spaces.

Incomplete oxidation during combustion may cause high concentrations of carbon monoxide in indoor air. Tobacco smoke can be a major source of indoor exposure, as can exhaust from motor vehicles operating in attached garages (Kleinman MT et al., 2009).

Carbon monoxide posses about 200-250 times more affinity for blood hemoglobin (Hb) than oxygen. Inhalation of carbon monoxide from tissue hypoxia (Douglas CG et al,.1912). When CO is inhaled, it bonds with hemoglobin, displacing oxygen and forming carboxy-hemoglobin (COHb) resulting in a lack of oxygen to the body cells. Carboxy-hemoglobin has no use in respiratory systems.

The severity of carbon monoxide poisoning depends on the concentration of carbon monoxide in the inspired air, the length of exposure, and the general health of the exposed person (Richard E. Burney et al., 1982). Infants, the elder people, and patients with cardiovascular disease, anaemia, and lung disease are at greater risk of carbon monoxide pollution (William Laing, 1985). The symptoms of repeated exposure to low concentrations of carbon monoxide include headache, fatigue, difficulty in thinking, dizziness, Paresthesia, chest pain, palpitations, visual disturbance, nausea, diarrhoea, and abdominal pain (John N. Kirkpatrick,1987). Higher levels of CO inhalation cause nausea, heart palpitation and difficulty in breathing etc. when extreme cases, when half of the hemoglobin of the blood is used up in forming Carboxy- hemoglobin, cause death. Presence of carbon monoxide in pregnant woman's blood causes still births deformed offsprings.

Neuropsychiatric problems likes intellectual deterioration, memory impairment, cerebral, cerebellar, Parkinsonism and akinetic mutism-and changes in personality typified by increased irritability, verbal aggressiveness, violence, impulsiveness, and moodiness are developing over weeks after recovery from carbon monoxide intoxication. (Gordon J. Gilbert & Gilbert H. Glaser,1959; Hugh Garland & John Pearce,1967; J. Sidney Smith & S. Brandon,1973).

Carbon monoxide is not a permanent pollutant, since natural process convert to other compounds that are not harmful. NAAQS prescribed maximum permissible concentration of CO on an hourly weighted average basis as equal to 4 mg/m^3 for residential areas, industrial areas and ecologically sensitive areas.

NITROGEN OXIDE (NO_2)

Atmospheric nitrogen combines with oxygen at highest temperature during fuel combustion forms nitric oxide (NO). Nitric oxide at a low level harmless, but at higher concentrations causes asphyxiations and respiratory discomfort. Nitric oxide combines with atmospheric oxygen to form nitrogen dioxide (NO_2). Vehicular emissions and fossil fuel emissions are the principal sources of outdoor nitrogen dioxide pollution (Jonathan M. Samet & Mark J. Utell, 1990). Combustion appliances and tobacco smoking constitute important indoor sources of nitrogen dioxide (NO2) exposure (Goran Pershagen et al., 1995). Outdoor nitrogen dioxide from natural and anthropogenic sources also influences indoor levels.

Nitrogen dioxide exists in its gaseous form, and inhalation is therefore the major route of exposure at room temperature. Direct contact with the eyes and associated membranes may lead to eye and nasal irritations, respiratory problems. NO_2 exposure causes several types of health issues, including extensive lung injury. Extremely high concentrations of No_2 causes fatal pulmonary edema and bronchopneumonia and at lower concentrations bronchitis, bronchiolitis, lung cancer and pneumonia (Jonathan M. Samet & Mark J. Utell, 1990). Wheezing bronchitis is a common cause of hospitalization in infants, and these children run an increased risk of developing asthma (David Skoner & Lawrence Caliguiri, 1988).. Very high concentration of nitrogen such as about 50 μg/m^3, causes great respiratory discomfort, leading to quick death.

NO_2 exposure affected leaf (chlorophyll) Chl levels. NO_2 increased the levels of lipid peroxidation and protein dissolution, which was accompanied by the induction of POD activity and a change in antioxidant content. Plants injured from NO_2 exposure could recover and resume normal growth (Qianqian Sheng et al., 2019)

High levels of nitrogen dioxide are deleterious to crops and vegetation, as they have been observed to reduce crop yield and plant growth efficiency. NO_2 can reduce visibility and discolour fabrics (Chen T-M et al., 2007).

As per NAAQS, the maximum average annual concentration of oxides of nitrogen as NO_2 in residential area and ecologically sensitive areas are 40 μg/m^3 and 30 μg/m^3, respectively. Oxides of nitrogen become more significant because they are involved in them in the formation of ozone.

PARTICULATE MATTER

Particulate matter comprises a heterogeneous mixture of tiny particles, and liquid droplets suspended in air.

Particles are variable in relation to their concentration, as well as to their physicochemical and morphological characteristics. Particles can be products of combustion, suspension of soil materials, and suspension of sea spray, and can also be formed from chemical reactions in the atmosphere. It can be concluded that airborne particulate matter (PM) is a complex mixture of many different chemical species originating from a variety of sources (Ian Colbeck & Mihalis Lazaridis,2009).

An aerosol is defined as a stable suspension of solid and liquid particles in a gas. Aerosol particle sizes range from 0.001 to 100 μm, hence, the particle sizes span over several orders of magnitude, ranging from almost macroscopic dimensions down to near. molecular sizes (Seinfeld and Pandis 2006 ; Hinds 1999;). Particles size more than 100 μm do not stay airborne long enough to be measured and observed as aerosols. Atmospheric aerosols originate from either naturally occurring processes or from anthropogenic activity. Major natural aerosol sources include volcanic emissions, sea spray, and mineral dust emissions, while anthropogenic sources include emissions from industry and combustion processes.

Aerosols have diverse effects ranging from those on human health to visibility and climate forcing. They

scatter sunlight, provide condensation nuclei for cloud droplets, and participate in heterogeneous chemical reactions. Two important aerosol species, sulphate and organic particles, have large natural biogenic sources that depend in a highly complex fashion on environmental and ecological parameters and therefore are prone to influence by global change (Andreae MO & Crutzen PJ,1997)

Pollutants affecting air quality include inhalable particles. To put it simply, inhalable particles can be defined as those whose aerodynamic diameter is less than 10 μm (PM10), while fine inhalable particles are defined as less than 2.5 μm (PM 2.5) and coarse inhalable particles, between 2.5 and 10 μm. The size of the particle and surface and chemical composition of the particulate material determine the risk that exposure to this agent represents for human health. Fine particles, owing to their smaller size, penetrate deeply into the respiratory system and may affect the alveoli (Bayram H et al,2006). There is a strong association between particulate air pollution and impaired lung function, deficits in lung function growth, worsening of asthmatic symptoms, and increased emergency room visits for asthma and chronic obstructive pulmonary disease. (Atkinson RW et al, 2001).

Particulate matter (PM) in the atmosphere as a result of chemical reactions between the different pollutants. Particulate matter (PM) includes particles with diameters of 10 micrometers (μm) or smaller, designated as PM_{10}, and extremely fine particles with diameters 2.5 micrometers (μm) and smaller designated as $PM_{2.5.}$ Besides size, fine and coarse particles differ in sources, formation mechanisms, composition, atmospheric lifetimes, spatial distribution, temporal variability, and, probably, in biological effects. The penetration of particles closely depends on their size (William E. Wilson et al., 1997).

Particulate matter size is directly linked to their potential to cause health problems. Particles with diameter ≤ 10 μm are passing through the throat and nose and enter the lungs. They can affect various body organs, especially the heart and lungs, and may cause serious health effects. Based on particle size, particle pollution is grouped into: a) "inhalable coarse particles" which have a diameter of 2.5 μm to 10 μm, and are found near roadways and industries, and b) "fine particles" < 2.5 μm in diameter such as those found in smoke and haze; they can form when gases emitted from power plants, industries, and automobiles react in the air (Kelishadi R et al., 2010).

Fine particles can travel large distances (more than 100 km), with the potential for high background concentrations over a wide area. As a consequence, their composition may be extremely heterogeneous, depending on the meteorological conditions and human activities in a particular geographical area. Ultrafine particles are fresh emissions from combustion-related sources such as vehicle exhaust and atmospheric photochemical reactions and are recognized as important markers of exposure to traffic exhaust along main roads effects on health as they can reach the deepest portions of the airways or even reach the blood stream directly (Franchini, M et al, 2015). Fine and ultrafine particles are those associated with the worst effects on health as they can reach the deepest portions of the airways or even reach the blood stream directly (Franchini, M et al, 2011).

Particles size greater than 10 μ cab be trapped by hairs and sticky mucus in the lining of nose. Smaller particles of up to 10 μ can reach trachea-bronchial system, but get trapped in the mucus. They are sent back to throat by beating of hair like cilia, from where they can be removed by spitting or swallowing. Very fine suspended particles reach the lungs and damage the lung tissues, causing diseases like asthma, bronchitis, and lung cancer, when such particles bring with them toxic and carcinogenic pollutants attached to the surface of the pollutants.

As per NAAQS, the maximum average annual concentration of particulate matter (PM 2.5) in both residential area and ecologically sensitive areas is 40 $\mu g/m^3$.

LEAD

Lead has become widely distributed in the environment since humans discovered and used it for a long time (Sturge and Barrie 1989; Ingemar et al. 2000). Natural lead pollution occurs from volcanic explosions and forest fire. Non-natural sources were from human activities, mainly referring to the lead emission from the industry and transportation. The major sources of lead emissions to the environment today are from ore and the processing of metals, as well as leaded aviation gasoline (Lin et al. 2011). The highest air lead levels occur close to lead smelters. Other sources are from manufacturing batteries, coal burning, typecasting, and in older houses and buildings (American Academy of Paediatrics Committee on Environmental Health 2005; Woof et al. 2007; Zhang et al. 2009). Since lead is not degraded by microbial activity, it is persistent in the environment and accumulates in soils, water bodies and sediments through deposition, leaching and erosion (Shotyk et al. 1998; Maja-Lena et al. 1999).

Lead is a harmful xenobiotic, to humans and considered as one of the most hazards and cumulative environmental pollutants that affect all biological systems through exposure to air, water, and food sources (Patra, R.C et al.2011).

Lead, because of its variety of uses (e.g. leaded petrol, lead in paints, ceramics, food cans, make-up, traditional remedies, batteries), is present in air, dust, soil and water to varying degrees. Each of these media can act as a route of human exposure, through ingestion or inhalation Lead can assess directly to humans, through blood, teeth or bone and indirectly, in the environment (air, dust, food or water). (Annette Pruss- Ustun et al.)

Exposure of human populations to environmental lead was relatively low before the industrial revolution but has increased with industrialization and large-scale mining (A. Russell Flegal & Donald R. Smith (1992).

Since microbial activity can't degrade lead, lead is an environmentally persistent toxin, which accumulated upward the food chain. Once taken into the body, lead can distribute in the blood throughout the body and accumulate in the bones and soft tissues, leading to chronic toxicity. Depending on the level of exposure, lead can cause neurological (Thomson and Parry 2006), hepatic (Singh et al. 1994), renal, haematological, circulatory, immunological, reproductive, developmental (Davis and Svendsgaard, 1987), gastrointestinal, and cardiovascular pathologies (Patrick 2006a, 2006b). Chronic occupational exposure to lead was shown to increase the risk of Parkinson's disease (Gorell et al. 1999; Weisskopf et al. 2010). Chronic exposure to lead can also cause tooth loss and the damage of hard dental tissues (Cenic-Milosevic et al. 2013).

Lead pollution cause abortion and stillbirths. Polluted ecosystems have adverse effects such as the losses in biodiversity, community components alteration, decreased pollen germination and seed viability, reduced growth and reproductive rates in plants and animals (Myra et al. 2012).

High concentration of lead in children's blood is among the leading public health issues worldwide (Tong S et al., 2000).

Major sources of lead in the air are ore and metals processing and piston-engine aircraft operating on leaded aviation fuel. Other sources are waste incinerators, utilities, and lead-acid battery manufacturers. The highest air concentrations of lead are usually found near lead smelters.

Humans may be exposed to lead from air pollution directly, through inhalation, or through the incidental ingestion of lead that has settled out from the air onto soil or dust. Ingestion of lead settled onto surfaces is the main route of human exposure to lead originally released into the air.

Once taken into the body, lead distributes throughout the body in the blood and accumulates in the bones. Depending on the level of exposure, lead can adversely affect the nervous system, kidney function, immune system, reproductive and developmental systems, and the cardiovascular system. Lead exposure also affects the oxygen-carrying capacity of the blood.

Children particularly under age of 5 are vulnerable to harm from lead. It affects the development of the brain and nervous system, causing reduced postnatal growth and lifelong neurological, cognitive, and physical damage (National Institute of Environmental Health Sciences).

In adults, 5 to10% of the lead in contaminated food is absorbed by the digestive system and this rate is higher in children, which is approximately 40% (Liu X et al.2002). Ingestion of lead contaminated food in children can cause a metallic taste sensation, abdominal pain, vomiting, diarrhea, colorless stool, loss of appetite, irritability, fatigue and shock (Centers for Disease Control and Prevention (Centers for Disease Control and Prevention).Neurological disorders, including headache, insomnia, somnolence, and seizures are also common.

As per NAAQS, the maximum average annual concentration of lead in both residential area and ecologically sensitive areas is 0.5 μg/m³.

VOLATILE ORGAIC COMPOUDS (VOCs)

Volatile organic compounds are compounds that have a high vapour pressure and low water solubility. Volatile organic compounds (VOCs) are considered as crucial parameters for examining the air quality in both indoor and outdoor because of their ubiquitous nature. The volatile organic compounds (VOCs) include a large group of air pollutants such as benzene, toluene, xylene, hexane, heptanes, trichloroethane, perchloroethane and cyclohexane. Exposure to VOCs is associated with allergies and adverse respiratory effects, frequently expressed as asthma or chronic obstructive pulmonary disease (COPD) (Lerner et al. 2012).

Vehicular and industrial exhausts, petroleum refineries, and solvent usages are major sources of VOCs in ambient air (de Blas et al. 2012).

Furthermore, volatile organic compounds (VOCs) are found in building materials, pesticides, office equipment, paint and varnishes, paint stripper, cleaning supplies, moth repellents, air fresheners, carpet and dry-cleaned clothes. VOCs cause eye, nose and throat irritation, headaches, nausea. Prolonged exposure of VOCs result in kidney, liver or central nervous system damage (Gibb T et al 2013).

The health effects caused by VOCs depend on the concentration and length of exposure to the chemicals. Most people are not affected by short-term exposure to the low levels of VOCs found in homes.

As per NAAQS, the maximum average annual concentration of benzene in both residential area and ecologically sensitive areas is 5.0 μg/m³.

ENVIRONMENTAL EFFECTS OF AIR POLLUTION ON

Air pollution can have serious costs, penalties and consequences for the health of human beings and also ruthlessly distresses the natural bio-network and ecosystems. The main consequences of air pollution are global warming, acid rain, smog, ozone depletion etc (Ashfaq A et al., 2012).

Global warming:

Global warming is defined as an increase in the average temperature of the Earth's atmosphere. The term global warming is synonymous with an enhanced greenhouse effect, implying an increase in the amount of greenhouse gases in the earth's atmosphere, leading to entrapment of more and more solar radiations, and thus increasing the overall temperature of the earth. Fossil fuels are being continuously used to produce electricity. The burning of these fuels produces gases like carbon dioxide, methane and nitrous oxides which lead to global warming. Deforestation is also leading to warmer temperatures (Marc Lallanila, 2015).

Global warming produces many negative effects such as floods and droughts in the regions where increased evaporation process is not compensated by increased precipitation. In some areas of the world, this will cause crop failure and famine, particularly in areas where the temperatures are already high. The warmer climate will probably cause more heat waves, more violent rainfall and also amplification in the severity of hailstorms and thunderstorms.

Rising of sea levels is the most deadly affect of global warming. The rise in temperature is causing the ice and glaciers to melt rapidly. This will lead to the rise of water levels in oceans, rivers and lakes that can pilot devastation as floods.

Global warming can severely affect the health of living beings. Excess heat can cause stress, which may lead to blood pressure and heart diseases. Warmer oceans and other surface waters may lead to severe cholera outbreaks and harmful infections in some types of sea food. It is a fact that warmer temperatures lead to dehydration, which is a major cause of kidney stones. Valley fever infections have been on the rise, probably because of warming climates and drought causing dust storms. Dry soil and wind can carry spores that spread the virus. Hotter and drier climates are projected to increase the amount of dusting carrying this disease. Rise in mosquito-borne disease like dengue fever and malaria because of warmer and longer summers (Umair Shahzad & Riphah, 2015)

The unprecedented peaks in temperature across the world affect the conditions of everyday life in subtle ways. This is particularly true among people with fewest resources. People who live in poorly constructed houses and shacks, often without ventilation, and in old inner city dwellings, are at heightened risk of heat-stress health problems that can be fatal. These include dehydration, heat stroke and asthma. Where there is no ready access to potable water, their health is at an even greater risk (Manderson L, 2019).

• **Formation of photochemical smog:** Photochemical smog is formed due to photochemical oxidation of hydrocarbons and nitrogen oxides. Photochemical smog is a complex mixture of several compounds. Among its various constituents, ozone and PAN (peroxy acetyl nitrate) are significant. Photochemical smog shows effects on human beings, materials, and plants (Ajay Bhartendu, 2013). The following are the effects of photochemical smog-

Eye irritation: Formaldehyde, acrolein, PAN and peroxy benzoyl nitrate are the responsible compounds for eye irritation.

Vegetation damage: The effects observed are silvering and bronzing of underside of leaves followed by collapse of cells, and necrosis. Growth retardation has also been reported. The three principal phytoxicants are ozone, nitrogen dioxide and PAN. This has resulted in economic loss.

Visibility reduction: This is perhaps the most commonly observed effect of photochemical smog. The aerosol particles causing the photochemical smog contain compounds of carbon, oxygen, hydrogen, nitrogen, sulphur, and halides.

Cracking of rubber: An important economic effect of smog is deterioration of the side walls of automobile tyres. This is primarily due to the ozone constituents of photochemical smog.

• **Formation of acid rain:** Acid rain was one of the most important environmental issues during the last decades of the twentieth century. During 1980s acid rains considered as one of the largest environmental thrust (Peringe Grennfelt et al, 2020). Acid rain is a rain or any other forms of precipitation like acid snow, acid dew, acid fog, acid frost, acid hail and acid dust that is usually acidic (Dondapati Naveen et al., 2013).

Acid rain is caused by the emissions of sulfur dioxide (SO_2) and nitrogen oxides (NO_x; mainly nitric oxide NO and nitrogen dioxide NO_2) through the combustion of fossil fuel, which react with the water molecules in the atmosphere (oxidation) to produce H_2SO_4 and HNO_3 acids respectively. (Schwartz, 1989). Rain water p H value falls below 5.6 when it reacts with acids (Dondapati Naveen et al., 2013).

Acid rain is a dangerous ecological factor, which strongly influences the decreasing of forest ecosystem productivity and reproduction. Acid rain not only affects on ecosystems but also affects human health. Sulfur dioxide and nitrogen oxide emissions from acid rain create eye, nose, and throat irritations, and lung disorders, such as dry coughs, asthma, headaches, and bronchitis . Use of urea and animal manure causes ammonia (NH_3) accumulation in the atmosphere and long-term addition may cause acid deposition (Zhao-hui Wang et al., 2004).

Acid rain affects ponds, rivers, streams, lakes, gulfs, seas, oceans, etc. by increasing their acidity. Because of acid rains, fish and other aquatic creatures can no longer live (Haradhan Kumar Mohajan, 2018). Acid rain affects on fishes directly or indirectly. Direct effects are the alteration of blood chemistry, retardation of egg development, etc. Indirect effects are the reduction in the kinds and supply of food available to fish, the creation of toxic to fishes, etc.

Acid rain reduces plant growth and yield due to foliar injury. It decreases vital nutrients of soil that is formed by nitrogen (N), calcium (Ca), magnesium (Mg), and potassium (K), etc. Abundant of aluminum (Al), mercury (Hg), manganese (Mn), cadmium (Cd), and lead (Pb) in the soil is in the non-toxic form; in the presence of acid rain these becomes toxic in soil and cause damage or death to plants and trees (Xuejun Liu et al., 2011). Acid rain changes the chemistry of leaf surfaces, decreases pollen germination, fertilization and seed development, and fruit formation. Some plants can survive in the effects of acid rain but, become very weak and unable to survive in natural calamities like heavy rainfall, strong winds, and drought. Herbaceous plants are more sensitive to direct injury by acid rain than trees. Leaf surface wax layer, chlorophyll and other constituents of the cells are destroyed by acid rain.

Acid rain of pH value 3 - 5 is known as 'stone cancer'. It is observed that lots of buildings, historical monuments are harmed worldwide because of acid rain. At present both railway and airplane industries have to spend a lot of money to repair the corrosive damage done by acid rain. Marble, limestone, sandstone, and ancient monuments are dissolved by acid rain. Metals, paints, textiles, and ceramic can readily be corroded due to acid rain. It can downgrade leather and rubber. In building and monuments, acidic water reacts with calcium carbonate ($CaCO_3$) to form powder type calcium sulphate (gypsum), and calcium nitrate, and destroy the structures (Gene E. Likens and F. Herbert Bormann, 1974).

Man-made structures such as the Taj Mahal in India, St. Paul's Cathedral in London, Westminster Abbey in England, the Sphinx in Greece and Egypt, the Parthenon in Greece, the Statue of Liberty in New York, and the Cathedral Cologne in Germany are also affected, as they corrode and dissolve in the face of acid precipitation. Acid rain can destroy stained glass windows, steel bridges, and railway tracks. It corrodes metal, ruins the paint color, weakens leather, and forms a crust on glass surfaces of the modern structures.

The discharged toxic metals due to acid rains are absorbed by the water, crops, or animals that human consumes that cause severe nerve damage, lung problems (asthma and bronchitis), brain damage, kidney problems, cancer, and Alzheimer's disease, that may cause death (Okita, 1983).

• **Depletion of Ozone:** The ozone layer is a layer in Earth's atmosphere which contains relatively high concentrations of ozone (O_3). This layer absorbs 93-99% of the ultraviolet light, which is potentially damaging to life on earth (Albritton, Daniel, 1998). The build up of oxygen in the atmosphere led to the formation of the ozone layer in the upper atmosphere or stratosphere. This layer filters out incoming radiation in the "cell-damaging" ultraviolet (UV) part of the spectrum (Sivasakthivel.T and K. K. Siva Kumar Reddy, 2011).

The term "ozone hole" should be applied to regions where stratospheric ozone depletion is so severe that levels fall below 200 Dobson Units (D.U.). Such ozone loss occurs every springtime above Antarctica and to a lesser extent the Arctic due to man-made ozone depleting chemicals (AFEAS), Washington, DC, 1995.).

Ozone depletion occurs when the natural balance between the production and destruction of stratospheric ozone is tipped in favour of destruction. Although natural phenomena can cause temporary ozone loss, chlorine and bromine released from man-made compounds such as CFCs are the main cause of this depletion (Angell, J. K., and J. Korshover, 2005).

Increased penetration of solar UV-B radiation shows impact on human health with potential risks of eye diseases, skin cancer and infectious diseases (Peter M. Morrisette ,1995). UV radiation is known to damage the cornea and lens of the eye. Chronic exposure to UV-B could lead to cataract of the cortical and posterior sub capsular forms. UV-B radiation can adversely affect the immune system causing a number of infectious diseases. In light skinned humans, it is likely to develop non melanoma skin cancer (NMSC).

Increased UV-B radiation affects the physiological and developmental processes of plants. In forests and grasslands increased UV-B radiation is likely to result in changes in species composition (mutation) thus altering the bio-diversity in different ecosystems. UV-B could also affect the plant community indirectly resulting in changes in plant form, secondary metabolism, etc.(D.H. Stedman et al.,1981).

Increased levels of UV exposure can have adverse impacts on the productivity of aquatic systems. High levels of exposure in tropics and subtropics may affect the distribution of phytoplanktons. UV-B radiation cause damage to early development stages of fish, shrimp, crab, amphibians and other animals, the most severe effects being decreased reproductive capacity and impaired larval development.

Increased UV-B radiation, changes in the production and decomposition of plant matter; reduction of primary production changes in the uptake and release of important atmospheric gases; reduction of bacterioplankton growth in the upper ocean; increased degradation of aquatic dissolved organic matter (DOM), etc. Aquatic nitrogen cycling can be affected by enhanced UV-B through inhibition of nitrifying bacteria and photodecomposition of simple inorganic species such as nitrate. The marine sulphur cycle may also be affected resulting in possible changes in the sea-to-air emissions of COS and dimethylsulfied (DMS), two gases that are degraded to sulphate aerosols in the stratosphere and troposphere, respectively.

Reduction of stratospheric ozone and increased penetration of UV-B radiation result in higher photo dissociation rates of key trace gases that control the chemical reactivity of the troposphere. Increased troposphere reactivity could also lead to increased production of particulates such as cloud condensation nuclei from the oxidation and subsequent nucleation of sulphur of both anthropogenic and natural origin.

An increased level of solar UV radiation is known to have adverse effects on synthetic polymers, naturally occurring biopolymers and some other materials of commercial interest. UV-B radiation accelerates the photo degradation rates of these materials thus limiting their lifetimes.

Ozone depletion and climate change are linked in a number of ways, but ozone depletion is not a major cause of climate change. Atmospheric ozone has two effects on the temperature balance of the Earth. It absorbs solar ultraviolet radiation, which heats the stratosphere. It also absorbs infrared radiation emitted by the Earth's surface, effectively trapping heat in the troposphere. Therefore, the climate impact of changes in ozone concentrations varies with the altitude at which these ozone changes occur.

CONCLUSIONS

Air pollution is a global problem and has become one of the major issues of public health as well as climate and environmental protection. The effects of air pollutants are at a high level of interest for scientific, governmental, and public communities. Air pollution has adverse effects on our lives in many different respects. Children are more vulnerable to air pollution. Usually respiratory effects of air pollutants are considered, but the importance of other health hazards should also be highlighted. In addition to short-term effects, exposure to criteria air pollutants from early life might have long-term risks principally for chronic non-communicable diseases such as cardiovascular diseases and cancers. Diseases associated with air pollution have not only an important economic impact but also a societal impact due to absences from productive work and school. Climate change due to environmental pollution affects the geographical distribution of many infectious diseases, famines, floods and many natural disasters.

Women and children living in severe poverty have the greatest exposure to indoor air pollution from solid fuel use as they spend a lot of time near stoves. As a consequence, such vulnerable populations have an increased risk of developing short-term and long-lasting adverse effects related to air pollution and thus need a closer follow-up.

The only way to tackle these problems is through public awareness coupled with a multidisciplinary approach by scientific experts; national and international organizations must address the emergence of this threat and propose sustainable solutions. a successful solution could be envisaged for anthropogenic environmental pollution, as a tight collaboration of authorities, government and private bodies, and doctors to regularize the situation. Governments should spread sufficient information and educate people and should involve professionals in these issues so as to control the emergence of the problem successfully.

Global elimination of ambient air pollution will require courageous leadership, substantial new resources from the international community, and sweeping societal changes. Cities and countries will need to switch to non-polluting energy sources, encourage active commuting, enhance their transportation networks, and redesign industrial processes to eliminate waste. These changes will not be easy. They will need to overcome strong opposition by powerful vested interests.

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