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Chapter

Atmospheric Pollution Interventions in the Environment: Effects on Biotic and Abiotic Factors, Their Monitoring and Control

Nukshab Zeeshan, Nabila, Ghulam Murtaza, Zia Ur Rahman Farooqi, Khurram Naveed and Muhammad Usman Farid

Abstract

Atmosphere is polluted for all living, non-living entities. Concentrations of atmospheric pollutants like $PM_{2.5}$, PM_{10}, CO, CO_2, NO, NO_2, and volatile organic compounds (VOC) are increasing abruptly due to anthropogenic activities (fossil fuels combustion, industrial activities, and power generation etc.). These pollutants are causing soil (microbial diversity disturbance, soil structure), plants (germination, growth, and biochemistry), and human health (asthma, liver, and lungs disorders to cancers) interventions. All the effects of these pollutants on soil, plants, animals, and microbes needed to be discussed briefly. Different strategies and technologies (HOPES, IOT, TEMPO and TNGAPMS) are used in the world to reduce the pollutant emission at source or when in the atmosphere and also discussed here. All gaseous emissions control mechanisms for major exhaust gases from toxic to less toxic form or environmental friendly form are major concern. Heavy metals present in dust and volatile organic compounds are converted into less toxic forms and their techniques are discussed briefly.

Keywords: air pollution, abiotic, biotic, control, devices, sensors

1. Introduction

Environmental pollution (EP) is successfully deteriorating our surroundings. Experts and major stake holders are trying to overcome it. EP not only effecting air, water, land but also plants, microbes, and humans. Atmospheric pollution (AP) is worse because it directly inhales by living organisms, particularly humans. Manmade activities increase the level of air pollution from preindustrial age [1].

Air pollutants are of many types and are classified on their suspension in the environment. Major air pollutants (AP) include suspended particulate which includes dust, fumes, mists, gases, vapors etc. The sources of these pollutants are diesel exhaust, coal fly-ash, mineral dust (asbestos, coal, cement and lime), metal dust (Cu, Fe, Pb and Zn), fumes, acid vapors (H_2SO_4), paints, pigments, black carbon and smoke from oil.

Ozone level of various sites of Northern Hemisphere has been increased from 10 to 50 ppbv since 1860 [2]. Sulfate aerosols increase from 3 to 4 folds [3].

Pollutants which are suspended in the air are responsible for different diseases like respiratory and Cancer, corrosion of metals and damage of plant biochemistry. Most of these pollutants deposited on the surface of the plants and cause naissance and disturb sunlight interaction with chlorophyll, the scattering of light from these pollutants produce smog and many surface chemical reactions. Many air pollutants are in gaseous form, like oxides of sulfers (SO_2 and SO_3), carbon (CO_2 and CO), and nitrogen (NO_2 and NO_3). Most of organic compounds are also present in the air like Hydrocarbons, Volatile organic compounds, poly aromatic hydrocarbons and different halogens and their derivatives. Chemical, Thermal and photochemical reactions of above mentioned pollutant caused secondary pollutants. A common example of thermal pollution is when the oxidation of SO_2 occurs to SO_3 by thermal reaction. If SO_3 further catalyzed in the presence of Mn and Fe in water than it give rise to sulfuric acid mist. Nitrogen oxides and reactive hydrocarbons when react. They produced ozone, per-oxy-acetyle nitrate (PAN). Some order causing agents are also produced which are known as hydrogen sulfide, carbon disulfide and mercaptan while others are very difficult to define chemically.

Chemistry of atmosphere totally depends upon the chemistry of pollutant present. The activities such as stream of traffic, industrial emissions, cleaning and washing of roads, painting, repairing are the causes of air pollutant generation. Because of their harmful effects, the air pollutants are now major concern of human talks [4]. Noise pollution is also the part of air pollution. Increase of traffic and other anthropogenic activities the noise pollution is increasing day by day. It is also causing swear health effects in humans (high blood pressure, sleeplessness, nausea, depressions are common). The study revealed that air pollution is responsible for

Some important terms and their definitions related to air pollution.

Term	Definition	Citation
Air pollution	Occurrence of dangerous particles and chemical species into the surrounding air beyond the permissible limit is known as air pollution e.g. $PM_{2.5}$, NO_X, SO_X etc.	[6]
$PM_{2.5}$	The inhalable particles present in the air of size 2.5 micrometer or smaller are categorize as PM2.5.	[7]
PM_{10}	The inhalable particles present in the air of size 10 micrometer or smaller are categorize as PM2.5.	[8]
CO	It is a colorless, odorless dangerous gas present in the environment. It is a silent killer and mostly produced in low oxygen.	[9]
CO_2	It is atmospheric gas essential for globe temperature balance but harmful at its high concentration. It is also colorless and 60% denser than air.	[10]
NO	It is known as oxides of nitrogen and known to general public as laughing gas.	[11]
NO_2	Oxides of nitrogen which enter into the environment from burning of fossil fuels.	[12]
SO_2	Atmospheric gas which has pungent smell. It natural sources are volcanic eruption and anthropogenic are fossil fuel exhaust.	[13]
VOC	Compounds of carbon and hydrogen which convert into vapor or gases phase and contaminate the surroundings are known as volatile organic compounds.	[14]
Aliphatic Hydrocarbons	Compounds with sigma bonds and delocalized pi electrons between carbon atoms forming a circle.	[15]

430,000 premature deaths in Europe and almost 10,000 deaths due to noise pollution have been recorded. Due to these statistics air and noise pollution is listed in the top two stressors in the environmental burden disease [5].

According to the above discussion it is clear that the study of air pollution monitoring, their impacts on biotic components and their control strategies are very necessary to discuss in the nut shell.

2. Effects of atmospheric pollutants on biotic components of environment

Figure 1 is showing the impacts of air pollution on Animals, Plants, Humans and Microbes.

The effect of these pollutants on the plants, humans, animals and microbes are comprehensively discussed in the following **Table 1**.

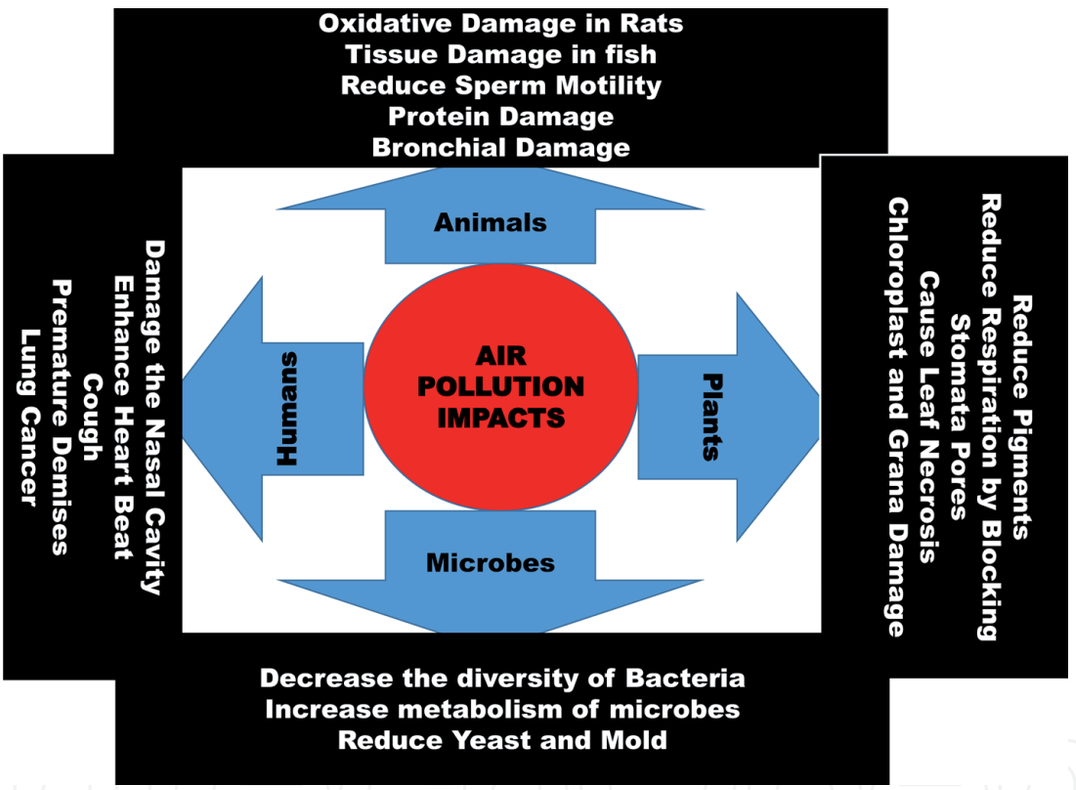

Figure 1.
Impact of air pollution on biotic components of the environment.

3. Air pollution and its control measures

Aerosols are classified into solid [SPM, Dust ($PM_{2.5}$ and PM_{10})], liquid (fumes, mist, vapors) and gaseous (smokes, gases) particles. Air pollutants are categorize the matter which is suspended in the air like road dusts, fumes of chemicals, mists, smoke from different emissions), gaseous pollutants (gases and vapors) and odors producing reagents.

4. Atmospheric pollution monitoring devices

In this **Table 2** the major monitoring devices with their technology is listed for detail review.

Pollutants	Plants	Humans	Animals	Microbes
Dust	Reduce the pigments, enzymatic activity and respiration. Also block the pores in plant leaf [16–18].	Enhance metals intake [19], damage the lining of nasal cavity and enhance secretions [20].	Damage the DNA of animals and increase protein oxidative damage in obese rats [21].	Decrease the diversity of bacteria at highly polluted dust [22].
CO2	C4 plants are less beneficial than C3 plants under high CO_2 environment [23]	Increase sleeping, blood circulation, heart beat when exposed to high CO_2 [24, 25]	High concentration leads to Zn accumulation and tissue damage in fish [26].	Elevated CO_2 effect metabolism, cell structure and diversity of microbes [27].
SO2	Leaf necrosis. Dwarfing and necrosis. 0.05 to 0.5 ppm of SO_2 damage the Spanish and cucumber while apple, barley and wheat are most sensitive to SO_2 [28].	Small exposures causes cough while long exposures causes asthma [29, 30]	Reduce the sperm motility in rats alter the seminiferous tubules in testis [31] and higher exposure induces cardiovascular problems [32]	In the open air fumigation study minute quantity meaningfully reduced respiration in both pine and deciduous litter [33].
NOx	It delays photosynthesis. Concentration of 100 ppm cause spotting to leaf and break down. Oxidative stress increased due to boost in deduced oxygen species [34]	Premature demises cause in humans [35], Long-term contact to NO_x is projected to lay foundation of 2119 respiratory demises and 991 lung cancer demises [36].	High level of protein damage was observed in tree sparrow when exposed to higher level of NO [37].	Not Yet Studied, a strong research gap exists here.
Ozone	Ozone causes foliar injury, reduce the stomatal conductance, enhance the foliar injury and ultimately decrease the plant total biomass [38]	Premature death is the major concern [39].	Ozone exposure to mice evidence the enhance air passage way inflammatory cell infiltration and bronchial hyper-responsiveness as compared to control [40]	Significantly reduced the mold or yeasts in yoghurts ozonated for 60s. *Escherichia coli* O157:H7 count reduced during vacuum cooling droplets of high ozone demand [41].
Aromatic Hydrocarbons	Cause fragmentation of nucleus and mitochondria and mitochondrion, chloroplasts and grana collapse [42].	White matter of left hemisphere reduced and related with slower information. Rapidity during intelligence testing [43].	Consuming the contaminated see food with heavy metals, PAHs and TPHs which is potentially poisonous [44].	Microbes are used mostly to remediate the site contaminated with PAHs.

Table 1.
Effect of the pollutants.

Sr. No	Device	Technology used with pollutant	Citation
1	Portable Monitoring Device for indoor air Pollution	For humidity and temperature complementary metal-oxide semiconductor (CMOS) technology, particulate matter by Laser-based light scattering, volatile organic compounds by Metal oxide gas sensor, CO_2 by Non-dispersive infrared (NDIR), CO by Amperometric gas sensor, light by Infrared-responding photodiode and sound by Electret microphone with amplifier.	[45]
2	Home Pollution Embedded System (HOPES)	Internet of thing (IOT) device which is the grouping of gas semiconductor devices and an Infrared particulate matter sensor.	[46]
3	IoT Based system of Solar Power Environmental Air Pollution and Water Quality Monitoring System	Cheap system for sensing of alcohol, benzene, CO_2, and NH_3. When it is connected it to Arduino then it is able to sense the gases, and provide readings in PPM (parts per million).	[47]
4	A raspberry Pi controlled cloud based air and sound pollution monitoring system with temperature and humidity sensing	It is based on four modules which are 1. Module for monitoring Air Quality Index Monitoring, 2. Module for detection of Sound, 3. Module for Cloud-based Monitoring 4. The Anomaly Notification Module	[48]
5	The Next Generation Air Pollution Monitoring System (TNGAPMS)	Static Sensor Network (SSN), Community Sensor Network (CSN) and Vehicle Sensor Network (VSN) based on the carriers of the sensors.	[49]
6	The Ozone Monitoring Instrument (OMI)	OMI is an ultraviolet/visible (UV/VIS) nadir solar backscatter spectrometer, used to measure UV irradiance, trace gases of tropo-spheric and strato-spheric chemistry.	[50]
7	Wireless distributed sensor networks	It is based on three metal oxides (MO) chemo-resistive sensors for O_3, NO_2 and TVOC, an optical (IR based) total (TSP) sensor, noise sensor and a dual semiconductor sensor for temperature and humidity (RH) measurement.	[51]
8	TEMPO	It measures the spectra required to recover O_3, NO_2, SO_2, water vapors, ultraviolet radiation, and foliage properties.	[52]
9	Amperometric electrochemical gas sensors	It is used for the monitoring of inorganic gases	[53]

Table 2.
Air pollutants monitoring devices along with technologies.

5. Particulate pollution control devices

The burning of diesel causes emissions. These emissions contain toxic gases and particulate matter (PM). Due to which there is a need to control these gases and particulate. For particulate control the diesel particulate filter is used to bind the PM which mostly is the combination of soot particles and organic fraction (soluble). The one bad thing with this system is the accumulation of soot particles in the filter lowers the activity of filtration [54]. To control the particulate matter from commercial cooking three technologies are used. The technologies named as Control technologies (CT) 1, 2 and 3. CT2 is the removal of grease technology

which is based on the boundary layer momentum theory. Particulate matter was the significant higher in base line (CT1) than CT2. CT3 technology is Electrostatic precipitator based and is use full to reduce the volatile organic compounds like acetaldehyde and formaldehyde produced during commercial cooking [55]. The efficiency of Electrostatic precipitators is reduced if the temperature of the flue gases increases. The low-low temperature EP (LLTESPs) is more effective in particulate matter removal in coal fired plants. This temperature can be control by using Wet flue gas desulfurization (WFGD) in ESP. The study was conducted to check the effectiveness of the LLTESPs and WFGD. The outlet samples indicate that the concentration of PM decreased with the decrease of temperature. The concentration of soluble ions like mainly SO_4^{-2}, Cl^- and NH_4^+ decreases in the outlet of LLTESPs (0.3 to 0.8 mg/m^3) with respect to WFGD because the addition of gypsum slurry in WFGD (4.7 to 0.8 mg/m^3) [56]. Preventive measures have been taken by individuals to get rid of polluted air. The facemasks are most commonly used by the Chinese people during the extremely high days. The model showed that 100-point increase in air quality index increases 54.5% consumption of facemasks. 187 million dollars could be save if control on air pollution has been achieved and it can be used for the social welfare of the habitants [57]. To combat with the particulate pollution there is a need of the hour to control the emission sources of particulate pollution with improved technologies [58].

6. Gaseous pollution control

CO: Catalytic converter (CC) is a device which is used to convert the hazardous exhaust gases to non-hazardous exhaust gases by using the simple technique of redox reaction. The working of CC is totally based on the catalyst used. For CO control the Silver is used as a catalyst. The more the catalyst, the more the active site and fast reaction.

Catalysts were identified by BET, FTIR, SEM- EDX, XRD, XPS technologies [59]. A study revealed that ZnO–CuO created hetero-composites show selective CO detecting with T_{100} is in close vicinity to T_{opt} to yield simultaneous CO detecting together with its 100% catalytic oxidation for detection devices. The initiated oxygen reacts immediately with adsorbed CO to provide desired CO detecting together with 100% CO oxidation [60]. Evidences showed that oxidative desorption of CO enhance if oxygen species are present. Fast slaking of platinum in water boost the oxidation by two processes. One of the processes is chemical oxidation by using molecular oxygen and other is Langmunir-Hinshel wood surface oxidation [61].

SO2: The usage of segmented multistage ammonia-based liquid spray with different oxidation potentials to remove sulfur compounds from gas. MnO_2 filter are used to absorb the SO_2 from the exhaust. There are many sources of SO_2 production like agricultural heavy machinery, vehicles etc. In this technology MnO_2 along with ozone gas is introduced and found that 90% SO_2 absorption is possible with the addition of ozone. This system also has the ability to improve the NO_2 exhaust [62]. The alternative methods to reduce sulfur emissions are the use of low sulfur fuel, scrubbers to lower the emissions from sulfur rich fuel. Low sulfur in fuel and use of CNG reduce the SO_2 emission [63].

Oxides of sulfur (SO_x) are produced and exhausted during the operations of petrochemical industry and cause harmful effects on environment. One of the technique is sulfur recovery unit (SRU) which is made up of Claus process for removal of huge amount of sulfur removal and afterward a tail gas treatment unit (TGTU) for the remaining H_2S removal (SCOT process, Beavon sulfur removal (BSR) process, and Wellman-Lord process) and flue-gas desulfurization (FGD) processes

(once-through or regenerable) [64]. Conversion of H_2SO_4 from SO2, which could be a great impact on reducing pollution [65]. Various approaches for controlling SO_2 emissions include.

7. Wet scrubber

In this technique, SO_2 is absorb by the slurry of an alkaline chemical reagent, and $SO_{2\ (g)}$ is either converted to liquid or solid.

Lime/limestone scrubbing: There are many sorbents but limestone is efficient for desulfurization process. Gypsum scaling is common when the $CaSO_4$ is more than 15%. To avoid this scaling lime stone forced oxidation process is used. In this scaling oxidation of $CaSO_3$ $CaSO_4$ by blustering in the air (usually in the reaction chamber) [66].

Sodium (hydroxide) scrubbing: Sodium scrubbing liquor is very efficient in absorbing emitted SO_2. It is usually used in industrial broilers.

Ammonia scrubbing: It is a unique and new technology, commonly used for desulfurization (DS) of flue gases, in this ammonia is used for DS and commercial grade crop fertilizer is produced. It is currently using by Dakota Gasification Company's (DGC) Synfuels Plant [67]. Further, electrostatic and electro-fabric precipitators are used to remove SO_3 from the flue gases of coal power plants [68].

8. Chlorine emission control

Chlorine emission control technologies are necessary to meet the low emission standards of the USEPA. A study showed that flue gases were samples and analyzed by different emission control technologies (Selective non catalytic reduction, Electrostatic precipitators and fabric filters) and found that 86.1% of chlorine is exhausted in the form of gas. HCl is found significant in samples. The exclusion efficiencies of total chloride are 15.6% by ESP and 19.0–19.7% by FFs, respectively [69].

9. NO_X control

An exhaust system is designed (patent) which has the ability to store NOx at temperature below 200° C and release the NOx above 200° C [70]. Rising trends of Nitrate aerosols were observed in china. The main cause is day time nitrate emissions. These can be controlled if the day time emissions of NH3 and O3 be under-control [71]. NOx emissions are very common from the burning of dried sewage sludge. It is studied that if the combustor physical and operation condition maintained than NOx emissions can be controlled about 75%. Further argued that moderate or intense low oxygen dilution is best suited option to reduce NOx with the cyclone type furnace [72]. Another study suggested that air staging can lead to higher reduction of NOx [73]. NOx can further be controlled from the diesel exhaust by controlling the temperature. It could be 90% less emission if the temperature is minimized. Flue gas treatment with ozone oxidation technology is used to remove NOx. Increase in solubility and bond breakage is the key to success for this technology [74]. The three leading stack gas treatment techniques for NO_x control are catalytic reduction with ammonia, non-catalytic reduction with ammonia, and direct scrubbing of NO with simultaneous absorption of SO_2. The wet processes are much less developed than the dry processes [75].

10. Control of heavy metals pollution in exhaust gases

Study showed that heavy metals show different fate. The control devices which are used in incinerators and other pollution control devices. Some heavy metals like cadmium and plumbum stick in fabric filter ash while chromium, copper and nickel were predominant in the ash present in bottom of the boiler. Zn was found at the bottom and in the ash of fabric filter with a ratio of 07: 03. Though, very minute Hg was found furnace ash, boiler, and SDR and fabric filter; most of Hg crossed through the fabric filter and occurred in an oxidized form. The wet scrubber showed high level control efficacy for mercury which is oxidized, and the addition of commercial stimulated carbon at a rate of 0.2 g/Sm3 resulted in 93.2% mercury removal efficiency [76]. One study revealed that, a high-gravity method using alkaline wastes, i.e., fly ash from petroleum coke, was planned for control of air pollution, containing NO_X, CO_2 and aerosols. Further reacted fly ash can be used for additional cementations material [77].

11. Odor pollution and its control

Odor pollution control is very important for industries and domestic processes because it also caused disputes among neighbors. There are many order producing compounds which includes, organic ammonia, mercaptans and sulfides. Organic and inorganic amines are also very common [78]. NH3 scrubbers are used. The modified scrubber contains two parts. One part use water to remove dust pollution and other part contain dilute acid solution for removal of ammonia and VOCs. Different acidic salts which include aluminum sulfate (alum), sodium bisulfate, potassium bisulfate, ferric chloride and ferric sulfate were found to work as well as strong acids (hydrochloric, phosphoric and sulfuric) for capturing NH3. This technique could result in the capture of a significant amount of the N lost. It also improves the environmental acceptance by the neighbors due to odor control [79].

12. Biodegradation

The degradation of organic pollutants by using the natural force (microorganisms) to water and carbon-di-oxide is known as biodegradation (BD). In artificial technique heat is used but in BD microorganism were utilized. BD efficiently occur at optimum moisture conditions, If plenty of moisture is available than bacteria grow efficiently and BD process speedup and vice versa [80].

13. Conclusions

Anthropogenic accelerated atmospheric pollution is very much dangerous to biotic as well as abiotic factors of the environment. There are different air pollutants ($PM_{2.5}$ and PM_{10}, dust, NOx, Sox, CO, CO_2, and VOCs) have different ways to cause damage to soil, plants, humans, and animals. Sometime this is even lethal for living things and cause pulmonary disorders to even cancers. As pollution is originated from all the anthropogenic activities like industrial processes, power generation and traffic vehicles and are part of economic externalities. These activities cannot be stopped but their life so there are many control technologies which minimize pollutants release into the atmosphere and save the biotic and abiotic components from damage.

Conflict of interest

This not a commercial activity so there is no conflicts of interests between the authors.

Notes/thanks/other declarations

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Appendices and nomenclature

There is no appendices or nomenclature.

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