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Review article

Impact of Particulate Matter Concentration on Human Health: A Glance of Review

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Abstract

Particulate matter (PM) concentration and its impact on human health attracted a lot of attention globally during the recent COVID-19 outbreak. Monitoring and analysis of PM concentration was being done but not to the extent required on the global scale. The covid epidemic caused more emphasis on the monitoring and analysis of PM concentrations due to their impact on the human respiratory system. Thus, an attempt was made to review the monitoring, analysis, and health effects of exposure to PM. It was reported that $PM_{2.5}$ concentrations not only impact human health via the respiratory system but also lead to Type II diabetes. This paper reviewed some of the mechanisms involved in the development of Type II diabetes on exposure to $PM_{2.5}$, and the impact of particulate matter on respiratory, cardiovascular, and neurological disorders. Furthermore, carcinogenicity effects on humans of exposure to PM in the atmosphere were briefly review.

1. Introduction

Air pollution is one of the environmental and health hazard, and needs to be monitored and analyzed. Air pollution has been monitored over the last four decades but its impact correlating human health attracted more research attention with the onset of the Corona Virus Disease 2019 (COVID-19) infection. Air pollution contaminates indoor and outdoor environments by modifying the natural characteristics of the atmosphere. Some common sources of air pollution include motor vehicles, household combustion devices, and industries. Outdoor or indoor air pollution cause respiratory diseases and is a cause of mortality. WHO data indicated that almost 99% of global population

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breathes air that exceeds the population limits given by WHO, with low- and middle-income population countries suffering from the highest exposures [1]. According to the reports of WHO [2], air pollution is a contribution of pollutants by natural or anthropogenic sources. Common pollutants include lead, CO, NO_2, O3, SO_2 and particulate matter (PM). We focussed mainly on PM concentration as it impacts more on human health. Particulate matter is a combination of minute particles of solid and liquid droplets whose size and composition changes with location and time. It may contain biological or organic compounds along with nitrates, sulphates and heavy metals. The PM concentration has been increasing everywhere but its impact on health is greater in underdeveloped or developing nations [2]. WHO reported that 90% of people are prone to polluted air globally [2]. In this context the report of SoGA-2020 (State of Global Air Report) is of prominence which mentioned that more than 90% of world population get exposed to $PM_{2.5}$ concentrations that exceed the WHO limits [3]. $PM_{2.5}$ refers to air pollutant with diameters of less than 2.5 µm that are of concern to human health when their level exceeds a limit.

Earlier literature on PM reported its impact on human health that includes heart attack, asthma, and respiratory problems [4-7]. Particulate matter can be categorically defined based on its origin and size. For example, $PM_{0.1}$, $PM_{2.5}$ and PM_{10} refer to PM of diameters of $\leq$ 0.1, 2.5 and 10 µm, respectively. PM_{10} consists in particles generated physically by dust, $PM_{2.5}$ refers to the condensation product of secondary compounds, and $PM_{0.1}$ particles refer to secondary ions from combustion sources that have short lifespans. It was a known fact that human inhalation of particulate matter damages the organs with smaller particles having more effects [8-10]. Table 1 displays the impact of various types of PM on the human respiratory system.

Table 1. Impact of particulate matter based on size on human respiratory system [11]

S. No	Type of PM	Particle Size (µm)	Respiratory Effect
1	Smog	0.01–1	Bronchial penetration
2	Household dust	0.10–100	Nostril to alveolar area
3	Cement dust	1.0–100	Nostril to bronchial area
4	Bacteria	0.7–10	Larynx to bronchial area

2. Air Quality

Air pollution is measured in terms of indexes, the maximum values of which are identified by statutory bodies such as WHO, Central Pollution Control Board (India), etc. WHO in coordination with various countries has set various standards for PM concentrations expressed as annual and daily averages, which are (20, 50) in case of PM_{10}, (20, 50) in case of PM_{10}, and (10, 25) in case of $PM_{2.5}$.

3. Origin of PM and Its Classification

Aerosols are made of tiny particles of solid or droplets of liquid dispersed in the atmosphere. They may either be natural or anthropogenic. PM originates from many sources including aerosols. Anthropogenic aerosols dominate in urban and industrial areas while biomass burning-related aerosols are dominant part of PM in rural areas. Aerosols are categorized into primary and secondary, based on their origin. Primary aerosols are emitted directly into the atmosphere through dust, while secondary aerosols form through oxidation of organic compounds. Generally secondary aerosols produce PM due to chemical reactions between volatile precursors [12]. Figure 1 shows various sources of particulate matter.

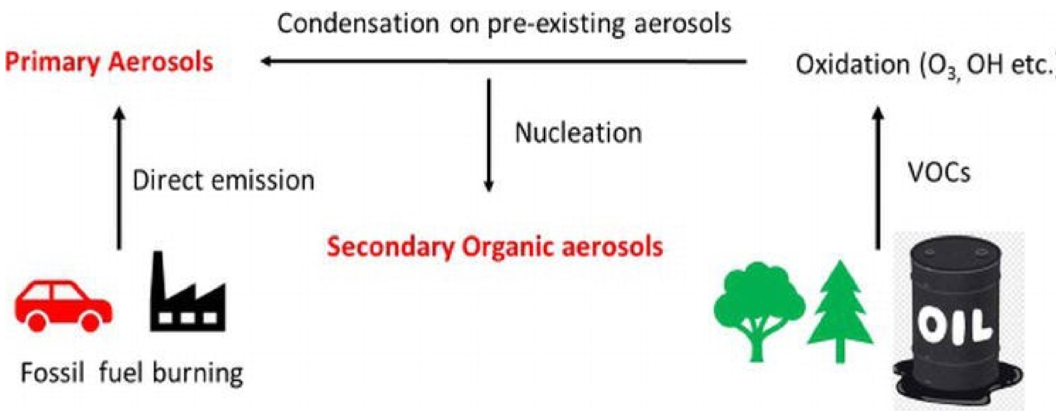

Figure 1. Sources of particulate matter courtesy [11]

4. Natural Sources of PM

Particulate matter may be classified into primary and secondary pm that originates naturally. It was reported that a dominant source of primary PM is sea salt [10, 12] along with soil dust, smoke, biomass burning. Secondary PM was mainly dominated by nitrates and sulphates where the conversion of gas to particle takes place with the interaction of organic molecules, sulfur, and nitrogen. It was reported that this process produces more particulate matter than direct emissions from anthropogenic activity [13].

4.1 Anthropogenic sources of PM

Anthropogenic PM is of two types. Primary PM is largely produced by the burning of fossil fuels by industry, transport, etc. Secondary PM is formed due to chemical reactions between gaseous precursors such as SO_2, NO_2, NH_3 during transportation. There is a probability that sulfur and nitrogen oxides may be converted into more secondary PM during the night where there is the presence of nitrate radicals.

4.2 Chemical constituents of PM

Particulate matter comprises of various chemical constituents such as sulfur, nitrogen, carbon, and so on, depending on its originating source. The majority of sulfate particles arise from combustion, with sizes ranging between 0.1 µm and 2 µm [14]. More than 70% of SO_2 emissions are due to global anthropogenic activities [15], and can mainly be attributed to fossil fuel combustion apart from biomass burning [16]. It was reported that international transport is one of the factors that increase SO_2 emissions [17]. Similar to sulfates, compounds of nitrogen arise due to reaction between natural and anthropogenic gaseous precursors. They give rise to aerosols with diameters of less than 2.5 µm [18, 19]. High temperature and humidity produce secondary nitrate precursor gases that are attributed to vehicles and biomass burning [20-22]. Carbonaceous particles constitute a major portion of atmospheric PM with 20%-50% in $PM_{2.5}$ and 70% of PM_1 [23, 24]. Table 2 displays the main elemental composition of PM as per diameter size [25-27].

Table 2. Elemental composition of particulate matter [11]

S.No	Composition	PM <1.0 µm	PM 1.0 µm -2.5 µm	PM 2.5 µm -10 µm
1	Elemental	Mg, Na, Al,S Si, Cl,Ca, K, Zn,Fe, Pb, V,Cr, Cu,Ni	Al,Na, Si,Mg, V,Cu, S, Cl, Ni,Ca,K, Fe, Zn, Cr,Pb	S,Si,Fe,Pb,Na, Mg, Ni, Al, Cr,Cl, K, Ca, Zn, V,Cu,
2	Ionic	Cl^-, $NO3^-$, $NO2^-$, $SO4^-$, $NH4^+$	$SO4^-$, $NH4^+$, Na^+, $NO3^-$ Ca^{++} , K^+,	Cl^-, $NO3^-$, $SO4^-$, Na^+,K^+, Ca^{++}
3	Origin	Secondary generated	Secondary generated	Terrestrial and sea salt

5. Impact of PM on Human Health

It was reported that PM exposure led to respiratory, neurological, cardiovascular diseases and premature mortality [28-32]. More hospitalization and mortality of covid patients recently might be related to the impact of PM.

5.1 Respiratory effects

All air pollutants affect respiratory system. Earlier reports indicated the impact of enhanced SO_2, NO_2 and O_3 levels on chest and nose leading to severe conditions of asthma. People who already have respiratory problems are more aggravated by air pollution [33, 34]. In this context, it is important to analyze the extent of PM exposure on human health in terms of its deposition in the human body. It was confirmed that particles of diameter of less than 2.5 µm get deposited in the lungs and get transported to other parts of the body through blood, creating serious health concerns. However, particles of diameter greater than 2.5 µm get deposited in upper respiratory tract [35].

5.2 Cardiovascular effects

Cardiovascular effects relate to heart and blood. Many reports demonstrated cardiovascular effects were based on exposure to air pollutants. According to GBD (Global Burden of Disease) study in 2018, 19% of cardiovascular deaths in the year 2015 were due to air pollution. CO reacts with haemoglobin to form carboxyhaemoglobin, decreasing oxygen carrying capacity and leading to increased risk of ischemia. Exposure to traffic emissions for a long duration may lead to coronary arteriosclerosis, and exposure for a short duration may lead to stroke and hypertension. Furthermore, exposure to NO may lead to ventricular hypertrophy [36].

5.3 Neurological effects

Correlation between neurological effects in human body and exposure to heavy metals was reported. Lead, which is a heavy metal, when inhaled may lead to neurological damage. Likewise, another heavy metal such as methyl mercury, affects nerves leading to memory loss and decreased vision [37].

5.4 Carcinogenicity

Carcinogenicity is a phenomenon or tendency of producing cancer. Carcinogens are substances that promote this tendency. Heavy metals are harmful as they interfere with normal functioning of cells. These metals in ionic form strongly interact with biological systems to replace essential metals, thus initiating cancer cells [38].

5.5 Diabetes mellitus

Glucose is one of the prime energy sources of human cells. If it is not maintained at the required level, it leads to diabetes mellitus which indicates how effectively human body use glucose. Diabetes may be of various types such as Type I or Type II which leads to imbalanced blood sugar levels causing serious health problems. Diabetes is mainly associated with high energy food and may lead to various disorders in human body. As per a WHO report [2], nearly 422 million people globally are diabetic with cases increasing rapidly in low- and middle-income countries [39]. Apart from regular analysis of diabetes correlated to tension, stress and food intake, recent studies demonstrated high levels of air pollution may also lead to Type 2 diabetes [40]. It was also reported that air pollutants emitted from trafficis one reason with more common in women [41]. As mentioned above, air pollution in low- and middle-income countries with high levels of $PM_{2.5}$ and high population densities indicated industrialization and modern life style developed Type II diabetes [42-44]. ~~I~~t was also reported that $PM_{2.5}$ levels affected the development of Type II diabetes in elderly people, and the tendency of women in menopause to develope Type II diabetes was inferred [45].

5.6 Type II Diabetes correlated to $PM_{2.5}$

Scientific studies have correlated exposure to air pollution with a range of human diseases including respiratory, cardiovascular diseases, etc. Over the last few years, the correlation between air pollution and diabetes has been under a scan [46-48]. It was reported that exposure to $PM_{2.5}$ leads to abnormalities affecting insulin resistance leading to the development of Type II diabetes [49, 50]. Polluted air due to $PM_{2.5}$ leads to inflammation by toxicology mechanisms which lead to invasion of $PM_{2.5}$ into blood. Moreover, $PM_{2.5}$ induces glucose tolerance and insulin resistance [51], enhancing the risk of developing Type II diabetes [52]. It was reported that mice exposed to $PM_{2.5}$ for a three-month period had significant liver damage, and changes in glucose tolerance and insulin resistance [53]. Overall, studies confirmed that short-term exposure to $PM_{2.5}$ led to various damages and long-term exposure had chronic effects on human health. In view of health risks due to $PM_{2.5}$ in terms of Type II diabetes, it is very important to highlight the significance of possible reductions in air pollution [54]. However, the in-depth mechanism by which Type II diabetes and $PM_{2.5}$ are linked need to be further investigated. As of now, the available experimental and epidemiologic studies indicate that exposure to air pollutants may increase the incidence of Type II diabetes.

6. Conclusions

This paper reviewed research that correlated exposure to particulate matter and human health. Particulate matter contributing for adverse effects on human poses a major challenge to the scientific community. Continuous monitoring, and analysis, and better understanding of the processes involved are essential. The impact of air pollution on respiratory system, the neurological system, the cardiovascular system, and the development of Type II diabetes was reviewed. Since diabetes is related to various inputs like food intake, stress and other conditions, the correlation between these factors need to be further analyzed. The study of atmospheric aerosols requires an integrated approach. The impact of PM is more in developing nations where urbanization and industrialization are producing high levels of pollution. Even certain policies are being implemented, more control and stringent action are required to control pollution, especially PM.

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