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Health effects and toxicological outcomes of exposure to inhalable particulate matter from urban air pollution: A mini review

Ali Talib Arif[1*]

[1]Kurdistan Institution for Strategic Studies and Scientific Research (KISSR), Sulaymaniyah, Kurdistan Region of Iraq.
*Corresponding author: ali.arif@kissr.edu.krd

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***Abstract*— *Inhalable air pollution consists of a complex mixture of solid PM (Particulate Matter) or liquid and gaseous components originating from a myriad of natural and anthropogenic sources that cause harmful to humans, animals or plants. From the environmental aspect, air pollutants include PM, carbon monoxide, ozone, nitrogen dioxide and sulfur dioxide. Ambient levels and composition often vary greatly depending on the emission sources and meteorological conditions. There are many hazardous air pollutants such as benzene, dioxin, asbestos and metals; however, the mass of PM is one of the most widely accepted indicators of air quality monitoring and regulation. Epidemiological and toxicological studies have identified an association between elevated levels of PM in the "respirable size fraction" and adverse health outcomes in the general population. For this reason, airborne PM has recently been listed as a potentially carcinogenic agent by the International Agency for Research on Cancer (IARC) because of its heterogeneity and variation of chemical composition over space and time.*

***Keywords*— urban air pollution, particulate matter, health effects**

I. INTRODUCTION

Ambient PM sources, composition and classification of particulate matter (PM_{10}, $PM_{2.5}$, $PM_{0.1}$)

Ambient PM is a complex mixture consisting of solid particles and liquid droplets of varying size and composition, which is dispersed in the air. PM mainly originate from three sources; (i) **natural sources** such as forest fires, windblown dust, soil erosion, volcanoes and seas, (ii) **anthropogenic** sources such as power plants, refuse incinerators, motor vehicles, construction activity and residential heating, (iii) **formation of secondary aerosols** in the atmosphere by transformation of gases into liquids or solids e.g. SO_2, NO_X, and NH_3 (Feng et al., 2016; Thangavel et al., 2022). Being emitted from various sources, PM therefore differs in its chemical and physical properties such as size, morphology, crystal structure, surface charge and chemical composition. These characteristics strongly impact on sedimentation time, i.e. persistence of PM in the air. More importantly, because of the great diversity of particle sources, the composition of ambient PM is complex (Li et al., 2022; Sarti et al., 2015; Valavanidis et al., 2008). The size of the PM varies and the term *ultrafine* particles, i.e. those < 0.1 µm in aerodynamic diameter, *fine* particles, i.e. those < 2.5 µm, and those with larger diameters as coarse particles and is generally referred to as $PM_{0.1}$, $PM_{2.5}$ and PM_{10}, respectively (Cho et al., 2022; ; Johnson et al., 2022; US EPA, 2016). $PM_{2.5}$ and ultrafine particles are essentially produced by combustion processes directly or indirectly from precursor substances, while coarse particles (PM_{10}) originate from biological and mechanical processes (e.g. pollen or dusts from opencast mining, dumping of debris and tailings, demolition processes, as well as sand storms or volcanic eruptions). The size of the particles determines the site in the respiratory tract they will deposit; PM_{10} particles mainly deposit in the upper respiratory tract, while $PM_{2.5}$ and $PM_{0.1}$ particle is able to reach lung alveoli. The adverse effects of inhaled PM are highly dependent on the deposition and retention of particles in the lung. Identifying and quantifying the influences of specific chemical components or source-related mixtures on measures of health-related impacts represents one of the most challenging areas of environmental health research (Byeon et al., 2015; Kelly and Fussell, 2012).

Legal thresholds for PM concentrations in ambient air

According to the preamble to Directive 2008/50/EC on ambient air quality and cleaner air for Europe of the European Union, the main goal of air quality control is "to reduce pollution to levels which minimize harmful effects on human health, paying particular attention to sensitive populations, and the environment as a whole". Therefore, air quality research focuses on particles which can cause damage to human health. From this point of view, it is of particular interest how the levels of ambient air particles are legally regulated based solely on their mass per cubic meter in the air for both daily and annual average concentration. Thresholds for $PM_{2.5}$ and PM_{10} have been indicated by the World Health Organization (WHO, 2021) to protect the health of the population. For PM_{10}, the permissible short-term guideline (24 h average) is 50 $\mu g/m^3$, while the value for $PM_{2.5}$ is 25 $\mu g/m^3$. The annual average concentration chosen as the long-term guideline value for $PM_{2.5}$ is 10 $\mu g/m^3$ and the annual average concentration chosen for PM_{10} is 20 $\mu g/m^3$. However, it might be more beneficial for public health stakeholders to focus on reducing emissions from specific sources.

II. DISCUSSION

Role of PM physical and chemical characteristics causing health effects

Epidemiological and experimental studies *in vivo* and *in vitro* provide increasing evidence for the importance of physical and chemical characteristics in particle-induced biological effects (Hadrup et al., 2020; Schwarze et al., 2007). The physical and chemical characteristics of inhaled particles both at urban and rural sites have shown that there is a strong link between exposure to coarse, fine, and ultrafine particulate matter and mortality (Arif et al., 2017; Hufnagel et al., 2021; Jiang et al., 2022; Petersen et al., 2019; Stafoggia et al., 2017; Valavanidis et al., 2008; Yorifuji et al., 2016). Moreover, small particles exhibiting a large surface area per mass have been found to induce a more pronounced pro-inflammatory response than larger particles of the same material because the deeper the deposition site in the respiratory tract, the slower the clearance rate and the higher the probability of particle-cell interactions (Schmid and Stoeger, 2016).

Ultrafine particles as compared to engineered nanoparticles

Ultrafine particles are defined as particles with diameters below 100 nm. They are chemically heterogeneous and polydisperse materials that can be engineered or naturally occurring, e.g. atmospheric ultrafine particles are formed during combustion. The physical and chemical properties of these particles play an important role in determining their health implications (Mossman et al., 2007). Engineered nanoparticles are described as inorganic ingredients of high uniformity with at least one critical dimension below 100 nm that are specifically engineered for commercial applications (Montes-Burgos et al., 2009). They are intentionally designed and created with physical properties to meet the requirements of a specific application. The physical and chemical properties of these particles are extremely important for determining their performance in the product where they are incorporated.

Chemical composition and source comparison of urban air particles

Particle composition is also responsible for particle-associated adverse health effects. Ambient particles are composed of thousands of chemicals and constituents, including inorganic ingredients, transition metals, crystal compounds, elemental carbon and various organic compounds, such as polycyclic aromatic hydrocarbons (PAHs), nitro-and oxy-PAHs and endotoxins have been reported to influence particle-induced inflammation (Arif et al., 2018; Becker et al., 2002; Borm et al., 2007; Donaldson et al., 2005; Maschowski et al., 2020, 2019; van Berlo et al., 2009). Therefore, different physical and chemical PM properties, including size, surface area, number, composition, crystal structure, and particle agglomeration/aggregation can play a significant role in initiating PM toxicity and can induce adverse health effects (Chen et al., 2016).

The main anthropogenic sources of airborne PM include combustion processes, especially those of high-sulfur fuels used extensively in gasoline-powered generators, traffic, construction and solid waste incineration (Zeb et al., 2018). Particles such as quartz and calcite may be originating from earth's crust and construction activities. Somewhat regular spherical shapes indicate anthropogenic origin e.g. traffic-related soot from vehicle exhaust. Therefore, understanding the properties, chemical compositions and origins of different - source-related urban air particles is significantly important both for an environmental and health risk assessment.

III. CONCLUSIONS

This review considers PM in ambient air and particles that can actually be inhaled in the environment. The WHO states that the presence of PM in ambient air is a problem in both big and small cities around the world. In addition, only with this information can strategies aimed at effectively addressing the threat of particulate matter in the environment can be developed, thereby ensuring environmental sustainability, can be developed. It will also provide evidence that will inform policy in the Establishing standard guidelines for the biological and chemical constituents of particulate matter components of particulate matter rather than for the total mass of particulate matter in the environment. further studies are needed to better understand to better understand the contribution of the combination of biological and chemical components of particulate matter to the documented health endpoints that have not yet been fully elucidated.

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