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ENVIRONMENT AND CLIMATE: ROLE OF HUMANS AND TECHNOLOGIES

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An overview of atmospheric aerosol and their effects on human health

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Abstract

Epidemiologic investigations have previously been published in more than 200 papers, and several studies have examined the impacts of particle air pollution on health. The main conclusions now being made about the epidemiological evidence of particle pollution-induced health impacts are discussed in this article. Although there is no universal agreement, most reviewers conclude that particulate air pollution, particularly excellent combustion-cause contamination prevalent in many municipal and manufacturing environments, is a significant risk for cardiopulmonary sickness and mortality. Most epidemiological research has concentrated on the impacts of acute exposure, although the total public health implications of chronic acquaintance's outcome may be more extraordinarily significant. According to some reviewers, prolonged, repeated exposure raises the risk of cardiorespiratory death and chronic respiratory illness. A more general (but still universal) agreement is that short-term particle pollution exposure has been shown to aggravate pre-existing pulmonary and cardiovascular diseases and increase the number of community members who become sick, require medical treatment, or die. Several in-depth studies conducted in the global and Indian regions are addressed.

Keywords Air pollution · Health effects · Particular matter · Aerosol · Respiratory

Introduction

Environmental pollution is the unjustified elimination of energy or mass from the earth's renewable resource combination, which includes air, water, or land, resulting in either short- or long-term damage to the environment and its ecological wellness and having an adverse effect, both quantitatively and qualitatively, on people and their lives (Obulapuram et al. 2021a; Arfin et al. 2021a). This damage can be caused by various human activities, such as mining, farming, and manufacturing (Ahmad et al. 2022; Obulapuram et al. 2021b). The potential and benefits smart cities offer are brought to the forefront by the environmental issues brought on by growing urbanisation (Mathew et al. 2023; Mohammad et al. 2019). Because the level of air pollution at various locations and at multiple times might vary greatly, the temporal and geographical resolution of the information on air quality has to be raised to enhance the accuracy of the information used in epidemiological investigations (Arfin et al. 2021b). When an air quality monitoring infrastructure is finally up and running, cities can use the data collected by the system to improve their ability to prepare for and regulate air quality. The network has room for development; for example, intelligent systems may provide warning messages that urge motorists, walkers, or runners to explore other routes before approaching highly polluting regions (Groma et al. 2022). Nevertheless, to provide those in charge of making decisions with a significant chance to impose limitations on emitters, it is essential to locate and monitor the pollutants in the air that are the most changeable and hazardous.

According to the World Health Organization (WHO), poor air quality may contribute to heart disease, asthma, pregnancy, and stroke complications. Additionally, there is an indication that brief susceptibility to air pollution makes children's mental health worse (Deepthi et al. 2019). In other words, after exposure to a particular amount of air pollution, children had a greater risk of needing to progress to the crisis room for mental health-related difficulties during the following 1 to 2 days. Also, it has been shown that particles that

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get into the respiratory system interrelate with each other to touch cells in the blood and brain (Sah et al. 2019).

Since the industrial revolution or the Anthropocene era, a significant rise in air pollution has been noted on regional, national, and global levels (Finlayson-Pitts et al. 2017). The public's health is at risk from high levels of gaseous pollutants like ozone and nitrogen oxides since they may lead to respiratory, allergy, and cardiovascular illnesses (West et al. 2016). The lungs may get deeply coated with particular matter (PM) particles, leading to respiratory illnesses and oxidative stress. Observational data have demonstrated that air pollution may increase mortality (Dockery and Pope 1993). According to global analysis, approximately 3.3 million people died from air pollution in 2010 (Lelieveld et al. 2015). This figure has been revised to about 4.3 million annually (Lelieveld 2017). Ambient and indoor air pollution caused by air particulates and ozone were shown to be the main risk factors for the worldwide burden of illness.

Due to the complexity of the origins of aerosol health consequences, multidisciplinary research is needed to cover a variety of lengths and periods (Groma et al. 2022). Regional and global modelling studies focus on aerosols' long-term and widespread health effects. Such modelling studies and the basis for the connections between local health effects of air pollution and pollution levels are based on epidemiological data. In addition to being crucial for assessing air quality, long-term field observations of oxidants and $PM_{2.5}$ in urban air pollution are also necessary for undertaking epidemiological research and verifying regional and global models. The cellular analysis looks at the potential for inflammation and oxidative stress caused by $PM_{2.5}$ components to explain the mechanistic knowledge of aerosol health impacts. Studies without cells are often done to measure the oxidative capability and redox behaviour of $PM_{2.5}$. Laboratory studies show the chemical interactions between lung antioxidants and air contaminants, offering mechanistic and molecular-level insights.

Atmospheric aerosols are among the most significant environmental risks to human health today. Each year, they can cause several million deaths that could have been avoided (Oh et al. 2020). Numerous epidemiological studies have shown links between the consumption of $PM_{2.5}$ and the development of respiratory and cardiovascular illnesses, cardiopulmonary disorders, and other harmful health consequences (Pope and Dockery 2006). However, it has been noted that the deadly health consequences of airborne particles depend on their dimension and their chemical-physical characteristics, which are highly correlated with their emission sources. The precise processes that cause $PM_{2.5}$ toxicities are still unknown (Sun and Zhu 2019). Some aerosol constituents, including metals, organics, and black carbon, are thought to have pertinent toxicological effects. Population consumption and inhaled doses are crucial for aerosol's geographical and temporal patterns to impact health outcomes (Korhonen et al. 2021). One of the most challenging areas of the current study is creating efficient controls to lessen the environmental health concerns connected to aerosols. Therefore, it is becoming more critical to collect data about the contribution of various sources of pollution and measurements to health indicators to support thorough ecological planning and mitigation methods (Contini et al. 2021). In this review, we provide a broad overview of the health impacts of aerosols from a molecular viewpoint to a global one.

History of aerosol

More than 80 years ago, the term "hydrosol" was changed to "aerosol," and it now refers to either a floated liquid suspension or solid particles (Hinds 1999). An aerosol is a dispersion of microstructural solid or liquid particles in a gaseous medium with slow settlement velocities, such as smoke, fog, or mist. Aerosols resemble gases in their properties. The size and form of aerosols found in the atmosphere may vary, ranging from a few nanometres to several micrometres.

They are airborne suspensions of liquid or solid particles. "Atmospheric aerosol" refers to various particle types with varying compositions, dimensions, shapes, and optical properties. Even though aerosols make up a relatively small fraction of the Earth's atmosphere, they greatly influence the quality of the precipitation, air, clouds, and chemicals of the troposphere and stratosphere. Haze, smoke, and dust are all common visual manifestations of aerosols. Aerosol concentrations are affected by both natural and human-caused factors (Calvo et al. 2013). Aerosols may interact with nucleation, clouds, radiation, and condensation throughout a broad spectrum because of their diameter range of a few nanometres to a few hundred micrometres. "Atmospheric aerosol" refers to particle forms with various chemical compositions, sizes, shapes, and optical qualities.

The sources of aerosol

Aerosols from anthropogenic sources are found on land and in water, with urban and industrial regions being the primary contributors. Anthropogenic aerosols are produced by several processes, including land use changes, burning fossil and renewable fuels, industrial processes, transportation, and urban heating. Most of these processes are temporally and spatially discontinuous and subject to large-scale, abrupt changes. Organic carbon and black carbon are created by burning coal, oil derivatives, and sulphur dioxide that becomes sulphate aerosols. These particles, which are sub-micron in size, contribute to air pollution in developed nations. Because of their tiny size and dynamic character, anthropogenic aerosols have a significant role in the composition of atmospheric aerosols (Calvo et al. 2013).

The aerosol sources might be primary or secondary, depending on whether the particles are created directly or indirectly in the atmosphere. Terrestrial dust and sea salt aerosols are the primary or direct sources of aerosols and are usually of natural origin. Chemical processes that transform atmospheric gaseous species produced by both natural and human activities into solid or liquid particles are examples of secondary or indirect sources. This procedure is known as "gas-to-particle conversion." Gas-to-particle conversion results when natural and artificial gaseous exhausts interact in the atmosphere and form aerosol particles. Typically, gas-to-particle conversion results in particles less than 0.1 m radius. Terpenes are the primary organic, sulphate, and nitrogen chemicals used as gaseous precursors in transforming gas into particles (Heisler and Frieslander 1977). Aerosols come in various forms, sizes, and optical qualities since they are generated from several foundations. Once in the air, the particles are obligated to move with the atmosphere.

Numerous manufactured and natural processes may create aerosols. The sources determine the size, range, and form of the particles. These particles' capacity to interact with light of various wavelengths depends on their size spectrum. Aerosols created by natural processes are often more giant (> 1 m). However, those made by human activity are smaller and more spherical, as described in Fig. 1. Oceans, deserts, biogenic sources, volcanic eruptions, and biomass burning are the primary sources of natural aerosols. The most significant potential natural source of aerosols is the oceans, which make up over 70% of the surface of the Earth. Marine aerosols include sea salt and sulphate aerosols made when phytoplankton gives off dimethyl sulphide (Charlson et al. 1987).

Natural sources

The number of natural particles that contribute to ambient aerosols changes dramatically over time and as a consequence of how far away they are from the source areas. There are many different naturally occurring sources of primary and secondary airborne particles. These natural sources comprise semiarid or arid regions, seas, flora, and volcanoes. Determining the natural occurrences that affect air quality is a complicated process that requires various techniques, including information on the levels of particulate matter and the chemical makeup of the air.

Sea salt

Knowing that the seas have a substantial role in the atmospheric uptake of certain materials is good. When the wind direction over the sea waves is more than 10 m/s, a massive shower of droplets is produced (Hoppel et al. 1990). Air entrapped in waves rolling over creates bubbles that rupture at the air-sea interface and discharge a flurry of tiny jet droplets into the salt sky when there is minimal wind. These jet droplet sprays quickly dissipate, dispersing crystalline sea salt aerosols into the atmosphere (Moorthy et al. 1997). Another natural process over the ocean is the production of dimethyl sulphide by phytoplankton, which, with the help of sunlight, is converted into SO_2 and finally into sulphate aerosols (Charlson et al. 1987). These grow naturally in the marine environment. Under clear skies, sea salt aerosols are the primary driver of the planet's albedo (Winter and Chylek 1997).

Sea salt aerosols are produced by the impact of wind on the surface and are naturally produced by mechanical disintegration triggered by wind shear. Winds across the seas cause breaking waves, which shoot tiny water droplets into the air. Bubbles are made at the sea's top by breaking waves, and droplets are produced when the bubbles are broken. As these droplets evaporate, sea salt aerosols are produced (Fitzgerald 1991). The bigger particles only move

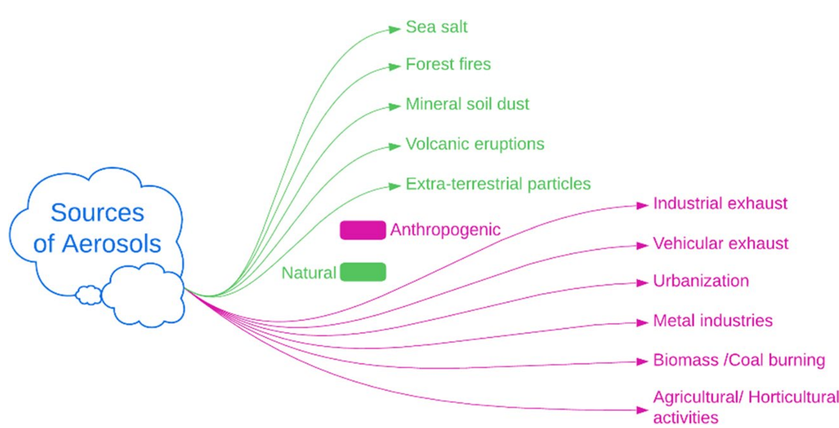

Fig. 1 Sources of aerosols

far, despite sizes varying from 0.03 mm to a few hundred millimetres. The concentration of sea salt rapidly decreases as they go inland.

Forest fires

Forest biomass burns when there are favourable environmental conditions. The dry biomass is ignitable under the right conditions. Pollen grains and other particles created by the condensation of volatile organic chemicals released by plants and trees and their reaction by-products are examples of biological aerosols (Pio et al. 2008). Significant volumes of biomass-burning aerosols, mostly made of organic carbon, are produced during natural forest fires. Smoke plumes make these aerosols more obvious, generally submicron in size. The flare may travel to more comprehensive locations if it ignites. A blaze that tore across sections of grasslands and bamboo woods provides a detailed picture of that source of aerosols. Because they may also be initiated by human activity, these fires are frequently seen as semi-natural sources of aerosol formation. Biomass burning emits smoke from an aerosol resembling soot (Chubarova et al. 2012).

Mineral soil dust

Mineral aerosols are often made up of earth-derived particles. These particles are a product of wind-induced soil deterioration (Alfaro et al. 1997). The action of wind on loose soil over challenging terrain may push large volumes of dust and sand to rise off the Earth's surface and be transported into the atmosphere. When turbulent air motion occurs, soil particles as large as 2 mm may be taken up at rates as low as 0.5 m/s and carried across great distances to a site distant from their initial location (Xia et al. 2021). The troposphere is where these particles are often generated near the surface. Due to rock withering, farming, and leaf withering, there is also much dust in the air.

Mineral dust is another essential natural aerosol that develops from the interplay of wind and soil particles. Arid and semi-arid regions are where mineral dust aerosols are most often formed. Mineral dust contains both mineral and biological components. The anthropogenic movement also contributes 20–50% of all mineral dust particles (Miller and Tegen 1999).

The source intensity of mineral dust aerosols varies with the properties of the surface and the wind patterns. The dust in the atmosphere varies seasonally in response to variations in wind speed, with the dry seasons having the most incredible amounts of dust (Kaufman et al. 2005). The particles range from 0.1 to 100 µm, but those more significant than 10 µm tend to fall out more rapidly. As a result of the comparatively high density (2.6 g/cc), dust is swiftly cleared from the atmosphere. Although dust particles typically have an atmospheric lifespan of 2 weeks, they travel hundreds of kilometres and engage in extensive interactions with the cloud system during this time.

The negative impacts of dust storms on the ecosystem and the health concerns they pose are mentioned (Goudie and Middleton 2006). The origins of dust around the planet have been located using satellite data (Prospero et al. 2002).

Volcanic eruptions

Volcanism periodically releases significant ash, soot, and other magma products into the atmosphere. A small portion of a volcanic eruption sometimes reaches the stratosphere and remains there for years (Flower and Strong 1969). It mostly remains in the troposphere and soon descends owing to gravity. Along with ash, volcanic activity produces HCl, SO_2, and H_2S in the atmosphere. It produces significant amounts of sulphate aerosols in the atmosphere as it oxidises. Due to the concentration of natural aerosols produced by volcanoes, their influence on ambient air is limited in time and space. During volcanic eruptions, many aerosols are discharged into the atmosphere; these particles are then immediately pumped into the stratosphere, where they have a very long lifetime. It includes both the immediate release of particles and the creation of particles from the reactions of the released gases (Hirtl et al. 2019).

Extra-terrestrial particles

One of the most basic atmospheric aerosols comes from extra-terrestrial sources and reaches the atmosphere of the Earth as comets and meteor debris (Millman 1979). It is most common at an altitude of 30–40 km and is mainly made up of iron-nickel or iron-silicate aerosols. Sulphate aerosols function as cloud condensation nuclei (CCNs) like sea salt, making them crucial for cloud dynamics and climate. The size distribution and the total amount of CCNs control clouds' microphysical and radiative characteristics. From the tropics to the poles, sulphate aerosol, made of liquid H_2SO_4, is expected in the lower stratosphere. In the stratosphere, H_2SO_4 is made when sulphur-containing gases from the troposphere, which are primarily in the form of carbonyl sulphide, are oxidised.

The chemical makeup of aerosol pollutants in metropolitan air is exceedingly complicated. By analysing the inorganic fractions chemically and spectroscopically, over 20 metallic elements have already been discovered. Fe, Si, Na, Ca, and Al are a few of the metallic elements that are most prevalent. Mn, Cu, Mg, Zn, and Pb are also present in high atmospheric concentrations. Depending on the region's characteristics and the types of industries there, these components will be concentrated in different ways. According to other investigations, 30–35 heavy metals were found in ambient particulate matter (Yoshizumi 1986). Almost all fractions of atmospheric aerosol size include trace metals. Trait metal concentrations over certain thresholds may harm terrestrial ecosystems (Berggren et al. 1990).

Allen et al. (2001) discovered the size dissemination of metals in atmospheric aerosols in rural and semi-rural areas of central England and southern Scotland. There is, however, a need for comparable data for other regions of the globe, such as the Los Angeles Basin, especially for the whole aerosol size range, which includes the submicron portion.

Anthropogenic sources

Aerosols are primarily produced by man's industrialisation and urbanisation activities from the sources listed below.

Industrial exhaust

Industries can produce a large number of particles in a variety of sizes, both directly and indirectly. As aerosols, these particles mix with the air and linger there long. A significant manufactured component of soot or black carbon particles is factory smoke. During nucleation, expelled nitrogen dioxide, sulphur oxide, and other hydrocarbon vapour produce aerosols simultaneously (Schaber 1995). Through condensation and coagulation processes, these newly created nuclei increase in size and generate accumulation mode particles in the atmosphere.

Vehicular exhaust

Partially burned fuel is emitted by transportation facilities all over the globe, which causes the discharge of various harmful compounds, including zinc, arsenic, and lead. Additionally, they release organic and inorganic carbon into the atmosphere (Albriet et al. 2010). Under the right temperature and pressure circumstances, the nitrates, sulphates, and ammonia that the vehicles produce are converted from gas to particles to create aerosols.

Metal industries

Copper smelters, incinerators, and other metal businesses may release toxic ultrafine aerosols. Although the inflow may be minimal, increasing such service stations is concerning. Other sources of harmful metals entering the atmosphere include welding, painting, and vehicle service stations.

Coal/biomass burning

The most significant anthropogenic source of harmful metals in developing countries is fly ash from coal combustion.

Coal burning for energy production is a significant source of aerosol emissions. When coal is burned, it releases various pollutants into the atmosphere, including fine particulate matter, SO_2, nitrogen oxides (NOx), and mercury. These pollutants can contribute to the formation of aerosols, which are tiny solid or liquid particles suspended in the air (Xu et al. 2019). The combustion process in coal-fired power plants produces large amounts of fly ash and other particulate matter. These particles can range from a few nanometres to several micrometres and can be directly emitted into the atmosphere. Fly ash primarily composes SiO_2, Fe_2O_3, Al_2O_3, and other elements.

SO_2 is another major pollutant emitted during coal burning. It is released when the sulphur present in coal reacts with oxygen during combustion. It can undergo chemical reactions in the atmosphere to form sulphate aerosols, contributing to smog formation and adversely affecting human health and the environment. Additionally, nitrogen oxides (NOx) are released during coal combustion due to the high temperatures and nitrogen content in coal. These gases can react in the atmosphere to form nitrate aerosols, contributing to air pollution and affecting human health (Feng et al. 2018).

The emission of aerosols from coal burning has various environmental and health impacts. Fine particulate matter, including the aerosols generated from coal combustion, can penetrate deep into the lungs when inhaled, causing respiratory problems, cardiovascular issues, and other health complications. Aerosols can also affect visibility, reducing air quality and hazy conditions. Various technologies and strategies can be employed to mitigate the aerosol emissions from coal burning. These include installing pollution control devices such as electrostatic precipitators and fabric filters to capture particulate matter, flue gas desulphurisation systems to remove sulphur dioxide, and selective catalytic or non-catalytic reduction to reduce nitrogen oxide emissions. Additionally, transitioning to cleaner and more sustainable energy sources, such as natural gas, renewables, and nuclear power, can significantly reduce aerosol emissions associated with coal combustion.

Horticultural/agricultural actions

Large amounts of manufactured dust and pollutants are released into the sky when fields are ploughed, cereals are thrashed, and leftover harvests are burned, particularly during a region's cropping season. When herbicides, insecticides, and pollen are sprayed during horticulture operations, harmful aerosol precursor gases are released into the atmosphere.

Essential descriptions of atmospheric aerosols

Aerosols may be produced in a wide variety of forms. The following categories apply to aerosols based on the following criteria (McNeill 2017).

Isomeric particles

For example, symmetric or spherical crystalline particles are isomeric since they have similar shapes in all three dimensions (McNeill 2017).

Platelets

Aerosol-like platelets exhibit growth primarily in two extended dimensions, with the third dimension remaining comparatively small (McNeill 2017). A leaf fragment illustrates this aerosol type, being comprehensive and lengthy yet having minimal height.

Fibres

Fibres are solid particles of the thread-like kind, characterised by a much greater length in one direction and considerably smaller breadth and width (McNeill 2017). Fibres made of minerals are the most common form.

Size

According to conventional wisdom, aerosols have a spherical shape. Many theoretical investigations of aerosols model the particles as spheres, with the radius or diameter serving as the size indicator. All particles in a monodispersed aerosol system should be the same size (McNeill 2017). However, in the actual atmosphere, aerosols are always multi-dispersed, and particles of varying sizes participate in this naturally multi-dispersed aerosol system. The number of particles of varying lengths may be described regarding their geographical and temporal distributions, provided that knowledge of the size distribution function is accessible. However, the particles are not very spherical (McNeill 2017).

Structure

Depending on the circumstances, particles that make up aerosols may exist singly or in chains of spheres or cubes. Additionally, particles may form hollow shells that contain air inside them. Condensation of volatile gases on top of previously present aerosols often results in coated spheres forming. These spheres typically have an inner core and an outer shell, which have distinct characteristics (McNeill 2017). When estimating the optical characteristics of an aerosol, hollow shells and coated spheres provide a particularly challenging problem.

It is standard practice to consider aerosols to be internally mixed or to be regarded as having been combined outside. In an external mixture, it is thought that each particle has its unique qualities. In an internal assortment, conversely, each particle is believed to combine different parts of the aerosol (McNeill 2017).

The composition of aerosol

Particles in an aerosol may exist on their own or combine to create a cohesive conglomeration. There is a possibility that some particles have the structure of hollow shells (Jaenicke 2008). Condensation of effective gases on the surface of different aerosols often results in the formation of coated particles, in which the inner core and the outer shell have distinct chemical compositions. In terms of their optical qualities, spheres of this kind, which are both hollow and covered, are exceedingly challenging to comprehend (Jaenicke 2008).

For this discussion, aerosols are classified according to whether they are internally or externally mixed. Different particles with their properties are combined in an external mixture. In an internal assortment, each particle is treated as a mixture of all other aerosol elements.

Size distribution

In the natural world, aerosols in the atmosphere are polydisperse because many activities create them. The aerosol population comprises various particle sizes (Jaenicke 2008). It is necessary to grasp the diameter of aerosols in the air to comprehend the origins of these particles, the process behind their generation, and the optical behaviour of these particles. It has been discovered that particles of a certain size are related to a specific occurrence category, and this association varies according to mass, size, and nature. For instance, coarse particles play a significant role in the physics of clouds, whereas visual issues are caused by fine particles, which are also responsible for mist and fog. Ultrafine particles are to blame for respiratory difficulties. The size of an aerosol may range anywhere from 0.0001 to 100 microns, depending on the aerosol's source and the process by which it was generated. It represents nearly five orders of magnitude (Jaenicke 2008). The particles created by transitioning from gas to particles are in a transitional stage when they are in the smaller size range. Particles of a size greater than 100 μm would not be capable of floating in the atmosphere for a very long time and would fall to the ground.

Sinks

The aerosols cannot remain in the atmosphere permanently; instead, they are removed from the atmosphere via dry deposition at the surface and wet deposition caused by precipitation. The removal techniques are quite sensitive to the particle sizes that need removal. Every particle that is suspended is subject to the force of gravity. Because of their inertia, suspended particles may not be able to track the motion of a speeding gas (Zhang et al. 2012). Consequently, they are eliminated by gravity via a process referred to as inertial deposition, which involves the accumulation of particles on surfaces. It has a significant impact on particles with diameters greater than 1 μm. The mechanisms of effects, interception, and diffusive transmission to the surface are also essential components of the dry removal system. Depending on the situation, scavenging may occur either in or below the cloud. For in-cloud scavenging, aerosols either perform the function of cloud condensation nuclei or, via the impaction process, are absorbed by pre-established cloud droplets or snow crystals (Zhang et al. 2012). The first method is more effective and can remove most of the aerosol mass, but the second method moves slowly. In the process known as below cloud scavenging, aerosols are removed from clouds due to the dropping of hydrometeors (Zhang et al. 2012).

Clouds, which may function as a collector and a sink for aerosols, are another crucial part of the scavenging process. Because it results in fewer particles overall, the procedure of ultrafine particles coalescing into larger ones may also be seen as one that removes them because of this property. On the other hand, particles do not disappear from the atmosphere. Aerosols have a short lifetime in the atmosphere but come into contact with radiation during that time. This link is the most important thing to know about the effects of particles on climate, which depend on the particles' chemical, physical, and optical properties.

Elimination technique for aerosols

Aerosols are eliminated from the atmosphere by several different processes, and their lifespans may range from a few days to a few weeks, depending on the aerosol's physical nature and chemical makeup. Under the effect of gravity, larger aerosol particles sink to the ground in a relatively short amount of time. Aerosols may be removed from the atmosphere by a variety of processes, and these processes, in turn, are influenced by a wide range of climatic variables. These elimination mechanisms are to blame for the regular variations in aerosols' characteristics within a particular area. Many different sources and sinks of aerosols show the main ways to get rid of them, as described in Fig. 2.

Aerosols may be removed from the troposphere or lost by depositing on the ground or mixing with the higher atmosphere. However, the thermally stable density structure distinguishing the troposphere and stratosphere reduces the loss to the upper atmosphere under ordinary circumstances. Aerosols are mostly eliminated from the atmosphere in this manner, either by wet deposition during precipitation or a dry composition when no water is present, clouds, or rain; removal activities at the ground level are classified as either dry or wet processes.

Aerosol concentration in global

A variety of studies have been described on the subject of aerosol concentration in the global atmosphere. The following discussion will focus on the many exhaustive efforts that were carried out on an international basis.

Piedmont, situated in the northwestern part of Italy, was chosen to monitor atmospheric PM_{10} and the trace elements that are connected with it. This region resembles a piece of the Po Valley. Variability based on the season was noted, with a peak concentration in winter. In addition, the study

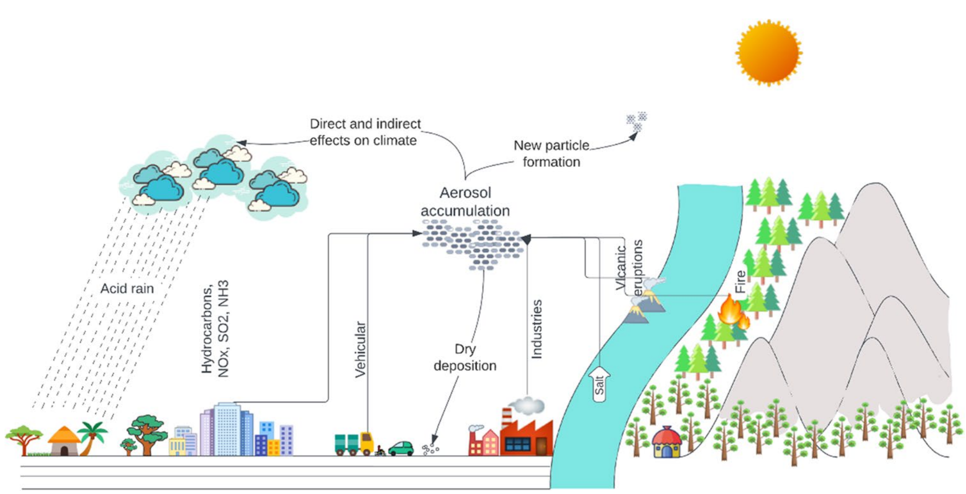

Fig. 2 Various aerosol sources and sinks

states that because the region under investigation is geographically located in a valley, major thermal inversions and ground-level fog trigger the lower levels of the environment in the valley floors to become stalled, which results in an accumulation of atmospheric pollution that does not disperse to the areas that are located nearby (Padoan et al. 2016).

Throughout the autumn and winter of 2008–2009, researchers in Mexicali examined the differences in atmospheric PM_{10} and related chemical constituents at rural and urban locations. PM_{10} levels in urban areas reached an average (range) of 54.5 (12.1–131.5 g/m^3) throughout the autumn season, but PM_{10} levels in rural regions reached a capacity of 57.8 (18.9–143.8 g/m^3). Furthermore, throughout the winter season, the average (range) concentration of PM_{10} in urban areas was 103.5 (0.49–237.19 g/m^3), while rural regions revealed 118.09 (12.72–285.05 g/m^3). The resuspension of dirt from unpaved roads, barren agricultural land, vehicle traffic, and the burning of wood and agricultural leftovers were thought to be the causes of the poor air quality recorded throughout both seasons (Canales-Rodriguez et al. 2015). These factors were cited in the study conducted to investigate the issue.

To explore the seasonal and diurnal change of $PM_{2.5}$ mass level, measurements of atmospheric $PM_{2.5}$ were taken continuously over 3 years at both a rural and an urban site in Beijing. The findings showed a significant seasonal fluctuation in urban locations, with an abundance throughout the winter (during 2006 and 2007, the level was 112 and 98 g/m^3, respectively) and a small amount throughout the spring and summer months. The rise in border layer elevation, strong winds throughout the springtime, and frequent rainfall throughout the summer were cited as the reasons for this phenomenon. Nevertheless, only certain dust occurrences throughout the spring caused an increase in the PM level. Springtime was found to have a higher $PM_{2.5}$ mass level in rural areas (between 2006 and 2007, the mean value was 101 and 60 g/m^3, respectively). It was reported to be the case throughout March. It has been convincingly confirmed that there was no excess throughout the winter. The increased concentration seen throughout the spring was due to dust storms and erosion by the wind, but the elevated level observed during the summer season was linked to the burning of biomass in the regions immediately around the study site (Zhao et al. 2009).

Between March 2003 and December 2006, $PM_{2.5}$ samples were obtained at a centrally placed urban monitoring location in Seoul, Korea, and then tested to determine their chemical components. The technique known as positive matrix factorisation (PMF) was used to locate the sources. The conditional probability function (CPF) findings indicated the possible locations of nearby sources such as automobiles, industries, and road salt. According to the potential source contribution function (PSCF) findings published by Heo et al. (2009), the prominent industrial locations in China were identified as the prospective source sites contributing to Seoul's high secondary particle concentrations.

Ikemori et al. (2021) utilised a positive matrix factorisation (PMF) model incorporating chemical element information such as levoglucosan, an important BB indication, at numerous urban, suburban, and experience places in central Japan throughout 2 weeks in October and November of 2014 and January and February of 2015 to assess the BB involvement. According to the findings of the source apportionment, BB was an essential contributor of particulate matter with diameters of under 2.5 m ($PM_{2.5}$), elemental carbon, and organic carbon at all of the locations throughout the autumn. According to the findings, some BB sources of emissions, including regional, tiny, and uneven open-space burning, influence air quality not just in suburban regions but also in metropolitan areas in the central region of Japan.

Aerosol concentration in India

The concentration of aerosols in Indian cities has been the subject of several kinds of research projects, which have been documented. The vast majority of the studies conducted about the particulate matter in the atmosphere have focused on quantifying the chemical species linked to the particulate matter. The following discussion will cover some extensive works that were completed in the India area.

In New Delhi, researchers under the direction of Balachandran et al. (2000) examined air particulate matter in various size fractions. The fine fraction was separated from the coarse fraction when the size fractions were broken down. The size range of the coarse fraction was regarded as being 2.1 to 10 m in aerodynamic diameter, whereas the size scale of the fine fraction was deemed to be 2.1 m. The standard concentration of atmospheric PM_{10} that was measured at Daryaganj was found to be 685.45 231.2 g/m^3, which was 1.4 times greater than the expected value measured at a background site known as JNU (454.7 106.2 g/m^3) and 1.1 times higher than the average value measured at a residential area known as Moti Nagar (553.8 225.7 g/m^3), respectively. The current research found that the concentration was much greater than the national criteria set by the CPCB of India, which are 100 μg/m^3 for residential areas and 150 μg/m^3 for industrial locations.

The quantities of water-soluble inorganic chemicals, organic carbon, main and minor elements, and elemental carbon were all evaluated in the atmospheric PM_{10} by Sharma et al. (2016), and the findings of the PM_{10} indicated high rates (249.7 103.9 g/m^3) with a variation of 61.4 to 584.8 g/m^3. In addition, the leading cause of PM_{10} was identified using a technique called positive matrix factorisation (PMF), which showed that the crustal source, subsequent aerosols, and emissions from biomass and wood burning all contributed to the pollution.

Khillare and Sarkar (2012) found that the 24-h yearly mean PM_{10} level in the atmosphere in New Delhi ranged from 166.5 to 192.3 g/m^3, according to their monitoring of the PM_{10} level. On weekdays, the mean PM_{10} mass concentration (186.4 41.8 g/m^3) was higher than the value measured on weekends, 160.9 70.2 g/m^3. The more significant number of pollutants observed during the weekdays was determined to result from vehicle pollution.

Pant et al. (2016) conducted research that assessed the size distributions of twelve different component elements and particulate matter at a heavy traffic location in New Delhi, India, during the winter of 2013. According to the findings, the daily average concentration of $PM_{2.5}$ ranged anywhere from 200 to 500 g/m^3. It was noted that $PM_{1.0}$, $PM_{2.5}$, and $PM_{2.5\text{-}10}$ each contributed 25% of the total PM, with $PM_{1.0}$ contributing 41.9%, $PM_{2.5}$ contributing 74.9%, and $PM_{2.5\text{-}10}$ contributing 25%. In addition, a tri-modal distribution was discovered, with two distinct patterns in the formation range (0.15 m and 0.55 m) and one pattern in the coarse category of PM (3.0 m).

Gupta and Elumalai (2017) analysed airborne PM in an urban outdoor and indoor environment employing an optical particle counter. Their research was conducted in Dhanbad. When contrasted to the indoor conditions, the level of particulate matter (PM) outside was shown to have a significantly different concentration than indoors. It was determined that the combustion of fossil fuels, transportation, and re-immersed dust particles were the leading causes of particulate matter in the outdoor environment. In addition, the study found a significant seasonal and weekly variance, which the researchers concluded might be attributable to both the weather conditions and the activities carried out by humans.

Karar and Gupta (2007) decided to collect samples of air particulate matter at two locations in Kolkata: a residential neighbourhood called Kasba and an industrial neighbourhood called Cossipore. The respirable dust sampler detected particulate matter in the atmosphere for 24 h at flow rates ranging from 0.80 to 1.40 m^3/min. According to the findings, the daily average level of PM_{10} was discovered to be within an acceptable range of 68.2 to 280.6 g/m^3 at the residential location, but at the industrial area, the region was 62.4 to 401.2 g/m^3.

Nucleopore polycarbonate filter sheets were used to capture the particulate matter (PM) in the atmosphere at Mumbai in two different size fractions, namely, 2.5–10 m (coarse fraction) and 2.5 m (fine fraction). According to the findings, the mean amount of coarse fraction PM was 107.85 g/m^3, which was determined to be the value. According to Kothai et al. (2008), the mean amount of fine fraction PM was 44.03 g/m^3.

Pathak et al. (2015) conducted research over a relatively short period in 2009 and 2010 to explore the influence of firecrackers exploding over the Diwali celebration on the air quality of Dibrugarh, which is located at 27.3° north, 94.6° east, and 111 m above mean sea level (AMSL). The findings indicated increased mass levels of $PM_{2.5}$ and PM_{10} throughout Diwali. When contrasting with the baseline levels during the peak hours of fireworks operation, the measured concentrations of atmospheric pollutants that were recorded on Diwali days in the years 2009 and 2010 demonstrated many times higher levels (5.74 and 2.65 times for $PM_{2.5}$, 1.21 and 1.66 times for BC, 5.33 and 2.50 times for PM_{10}). It was the case for $PM_{2.5}$, BC, and PM_{10}, respectively. An air mass return trajectory study was carried out with the help of the NOAA HYSPLIT model to evaluate the possibility of long-distance aerosol transport. It was done to determine how much fireworks-related activities contributed to increased air pollution. In addition to the air mass return trajectories, the collected MODIS fire maps for 10 days were also analysed to identify the impact of aerosols from emissions caused by biomass burning. According to the findings of these investigations, more significant amounts of pollutants were observed during the celebration, owing primarily to the local influence of events involving fireworks. These higher concentrations did not result from long-distance transit or operations involving agricultural or forest land burning.

Health effect

People subjected to high quantities of air pollution develop symptoms and moods of varying severity. The health consequences of these impacts may be broken down into two categories: short term and long term (Pope et al. 2002). The short-term effects are only transitory and may range from mild discomfort, including irritation of the eyes, throat, skin, and nose, to more severe conditions, including bronchitis, asthma, pneumonia, and heart and lung issues. Mild discomfort might include coughing, wheezing, and chest stiffness, while difficulty breathing can include chest tightness and wheezing. Headaches, dizziness, and nausea may result from minimal exposure to air pollution. Long-term contact with pollutants damages the nervous, reproductive, and respiratory processes, leading to cancer and, in sporadic cases, death (Mohanraj and Azeez 2004). These issues may worsen by prolonged contact with pollutants over an extended period. The long-term consequences are chronic, meaning they might endure for years or perhaps a person's whole lifetime, and they can even cause death. In addition, the carcinogenic potential of a number of the contaminants in the air has been linked to the development of a wide range of malignancies over time (Manisalidis 2020). Global epidemiological research has shown a link between fine particles, lung cancer, acute and chronic respiratory conditions, morbidity, and death (Wichmann et al. 2000). According to Pope et al. (2002), each 10 pg/m^3 increase in acceptable particle air pollution results in a 4, 6, and 8% higher risk of death from all causes, including cardiovascular disease and lung cancer, respectively (Pope et al. 2002). Sulphate, organic compounds, nitrate, soot, acidity, and transition metals are the fine particle elements that harm health (Mohanraj and Azeez 2004). The two main carbon components in $PM_{2.5}$ that cause the most adverse health consequences are organic carbon (OC) and elemental carbon (EC). While EC is connected to various adverse effects, including disruption of the lung clearance processes, OC is suspected of being mutagenic and carcinogenic. According to a study conducted in 33 Indian cities, people's exposure to particulate matter is to blame for a 28% increase in premature deaths over 3 years starting in 1992 (Mohanraj and Azeez 2004).

Aerosols have especially drawn attention due to worries about either emission from precise combustion origin or the pathogenic of particular organic compounds, in addition to their function as PM components. Several of these substances are among the 188 "hazardous air pollutants" (HAP) covered under the Clean Air Act. The bulk of HAPs are

(i) organic substances,
(ii) groups of substances, or
(iii) mixes that include substantial amounts of organic material.

One hundred sixty-seven organic compounds, classes, or mixes were among the 177 HAPs chosen for the US EPA (Msuderly and Chow 2008).

Criteria pollutants (CPs) are governed by ambient concentration-based National Ambient Air Quality Standards (NAAQS), while emission standards govern HAPs. In comparison to the receptor-focused NAAQS, these emission regulations have received less political and popular support, resulting in a reduced emphasis on research. The primary focus for most HAPs has been on cancer, potential impacts, or occupational and ambient-related brain effects rather than addressing the prominent issue of cardiovascular and respiratory outcomes associated with ambient CPs (Msuderly and Chow 2008).

Evidence of harmful consequences on health

Epidemiology studies are the best way to show that environmental factors and organic aerosols naturally affect health. Many unknowns about the revelations, the causes, and other factors could be confusing. Subordinate concrete validation comes from correlations based on harmful well-being consequences and mixtures containing toxic carbonaceous ingredients that are either specified as such or can be reasonably predicted to be so. Usually, these investigations must distinguish between the consequences of organic and other combinations of ingredients (Oh et al. 2020). These studies consistently employ concentration-time results, which have limited relevance to non-occupational contexts, for assessing occupational aspects. Subsequent in significance are investigations of fatally treated experimental organic compounds or mixtures containing organic components (Msuderly and Chow 2008).

High or unrealistic immediate dosages or dosing procedures sometimes make it challenging to extrapolate laboratory data to environmental risks and dangers. Experimental humans may not accurately reflect the most vulnerable subpopulations, and extrapolating from animals to humans is never straightforward (Groma et al. 2022). The significance of outcomes from research involving complete mammalian tissues, non-mammal animals, bacteria, cultured cell lines, predominant animal, and human cells in culture, and ultimately determining risk from a chemical composition without supporting evidence from functional conditioning steadily diminishes (Msuderly and Chow 2008)

Although there has been low to no consolidated demonstration that the organic constituent of the engine is condemned for the observed emissions, there is a high degree of complacency that organic engine outflow poses agility risks due to the unidentified noxious organic substances in the example mentioned above (Groma et al. 2022). Regarding the percentage of a health effect attributable to organic ingredients, the particular physical-chemical classification at fault, or the dosages posing a severe risk, this indirect data supports nothing more than conjecture. Because organic and inorganic substances constantly endanger individuals, a section demonstrates that a particular organic compound could be the outcome of that classification acting as an aspect index for other contaminants or configurations that generate particular or entire implications (Msuderly and Chow 2008).

Effects of biogenic aerosols

Primary biogenic particles, such as pollens, bacteria, spores, viruses, and animal and plant debris, offer much more definitive proof of the wellness consequences of ambient organic aerosols. This research must be addressed in debates on air quality and wellness connections. Many of these wellness concerns are predominantly of an indoor or occupational nature, and the majority are local in scope (Lai et al. 2006). Plant aversions are the most prevalent environmental example. Allergies to airborne plant pollen have a significant morbidity impact globally, especially in industrialised nations. Research on pollen revulsions and the connection of outcomes to pollen emissions from certain plant categories has frequently shown a specific OC's causative function in pollen proteins. One of the most significant environmental "natural experiments" with organic aerosols is pollen allergy. During Japan's post-World War II rebuilding, cedar trees were widely planted, which led to a rising issue known as "cedar pollinosis," which today impacts 16% of the population (Xiao et al. 2007). The wellness impact of OC aeroallergens has primarily escaped the consideration of studies because of the alleged difficulties of controlling their origins.

Effects of carbonaceous aerosol

Accomplishments or predictions of responses to carbonaceous categories have yet to be widely used in epidemiological investigations. The BS filter darkening technique estimates PM estates in BC, which have been associated with health in various studies (Lai et al. 2006). Even if BC significantly impacted the considered primary, similar investigations only provide evidence that BC and its related chemical accumulation honestly had a role in the health consequences. In a hospitalisation research study conducted in London (Atkinson et al. 1999), BS and PM_{10} were found to be profoundly interrelated with cardiovascular system hospitalisations. Still, BS had a more substantial relationship, as evidenced by the higher durability of its relationship when numerous contaminations were comprised in the reproduction. This finding made a strong case but did not prove that the carbonaceous elements of PM had a significant role in admission.

In their investigation of links between total non-accidental death and organic aerosol and cardiovascular mortality in Phoenix, AZ, between 1995 and 1997, Mar et al. (2000) included additional carbon speciation. The EC, OC, and $PM_{2.5}$ components were investigated. Only cardiovascular fatality results were presented for the $PM_{2.5}$ and gas elements. Mortality was positively associated with CO; soil-derived K, TC, EC, OC, and EC; as well as with NO_2, SO_2, $PM_{2.5}$, and PM_{10}. These findings suggest that the health importance of EC and OC might be comparable to or even more significant than other extensively studied pollutants.

Ostro et al. (2006) examined the correlations between EC-containing $PM_{2.5}$ elements and day death in nine CA counties. Cardiovascular morbidity was significantly correlated with EC, OC, and $PM_{2.5}$. These three factors have no real relationship with respiratory morbidity. Although the Ostro et al. (2006) investigations' findings did not show that carbonaceous $PM_{2.5}$ elements provided more significant impacts than other elements, they showed that EC and OC did. In the Mar research at 1- and 3-day delays and the Ostro trial at a 3-day lag, OC and EC were significant. Determining cause-effect correlations from epidemiologic studies is more difficult because different contaminants might have distinct delays between increases in dose and impact, as could happen due to various biological systems.

Smoke from vegetative burning is another combination that contributes to the ambient organic aerosol and contains carbon in the gaseous phases and particles (Laeher et al. 2007). There is compelling evidence that vegetation burning under the governor, wildfires, and native wood burning have negatively affected people's health. Absorption of wood smoke has been linked to loss, reduced lung capability, aggravated asthma, and respiratory indications. Due to the organic nature of wood smoke and its many specified irritants, carcinogens, and mutagens, the adverse health effects of smoke are probably caused by its carbonaceous portions.

The ambient organic aerosol may also include carbonaceous contaminants produced inside; the operations of heating and cooking cause the emission of carbonaceous combustion products into the atmosphere. Cafeteria exhaust has been shown to include significant quantities of carbonyls, including acrolein and formaldehyde, which might raise ambient concentrations (Ho et al. 2006). It is recognised that genotoxicity and oxidative stress are caused by heated animal and vegetable oils, respectively, in mammalian cells (Dung et al. 2006).

Dose-effect relationship

Dosage predictions from Aerosol Research and Inhalation Epidemiology (ARIES) are based on data from an urban monitoring station that observes a range of gaseous and particulate pollutants. The relations between specific PM constituents and species acting as markers for physical-chemical types are being investigated.

Using province-level data for $PM_{2.5}$, traffic density, and CP gases, Lipfert et al. (2006) investigated relationships between veteran morbidity and these variables. Nevertheless, single-pollutant and multipollutant results predict that traffic density correlates most strongly with morbidity. EC was the PM constituent with the highest morbidity correlation; OC had a weaker, non-significant correlation. These findings highlight the significance of traffic pollutants, particularly the EC part. The research should have discussed the significance of VOCs or other non-PM organic pollutants with a PM.

Traffic and health

Numerous epidemiological studies have demonstrated that exposure to organic chemicals at work, also present in ambient air at tiny concentrations, may negatively impact health (Brunekreef et al. 1997). Based on this, many HAPs are mentioned. However, they do not prove that consumption of lower concentrations of environmental pollutants harms public health. The consequences of occupational exposure may be concrete proof of a possible ecological danger. Few of these chemicals have information on human dosage interactions at ambient exposures.

Numerous epidemiological research studies have linked health outcomes to doses of known-to-be-toxic carbonaceous pollutants that were present in enough amounts to have reasonably caused the consequences. Acquaintance with combustion-derived mixtures with organic gases and particles includes contact with the engine exhaust. The closeness of residences and schools to busy roads is significantly associated with many harmful health effects in children and adults. Brunekreef et al. (1997) found a substantial correlation between school-aged children's impaired lung occupation and their houses' and schools' proximity to high traffic, with truck traffic being more strongly related to vehicle traffic. According to Hoek et al. (2002), among persons aged 55 to 69 between 1986 and 1994, residing near a major highway was linked to relative threats of 1.95 and 1.41 for cardiopulmonary and overall demise, respectively. Similar findings have been obtained from other conceptually related research conducted in various nations. Tonne et al. (2007) discovered strong correlations between severe myocardial infarctions and MA residents' intimacy with traffic.

Although overall persuasive, the connections with automobile exhaust do not specifically link the carbonaceous elements. The significance of BS in Brunekreef et al. (1997) indicated the relevance of EC, even though EC might have served as an indicator for unquantified emissions. The findings strongly indicate that EC and OC emissions most probably contributed to the effects even though virgin diesel, gasoline, and natural gas emission levels, as discovered close to roadways, comprise considerable quantities of gaseous and particulate organics, many of which are specified to be harmful at a particular composition.

Effect on lung

Particles in the air may cause acute respiratory issues, but they can also worsen persistent health conditions, including congestive heart disease (Brook et al. 2003). The adverse effects on health produced by vulnerability to ultrafine particles and $PM_{2.5}$ may manifest themselves in a spectrum of ailments, including a decrease in the diversity of heart rate. Diabetes (Lei et al. 2005), which has lately been highlighted as one of the variables, may produce more vulnerability to small particles. Various health concerns may also create increased susceptibility.

Lung cancer is one possible consequence of the longer-term impacts, as described in Fig. 3. The American Cancer Society began recruiting participants for research on cancer treatment in 1982, and Pope et al. (2002) tracked these individuals throughout the study. According to their research, there is an essential link between being visible to $PM_{2.5}$ and having a higher risk of dying from lung cancer or cardiac reasons. Even though the biochemical processes contributing to these consequences are still unknown, epidemiological research by Pope et al. (2002) identified intriguing connections between $PM_{2.5}$ acquaintance and atherosclerosis, pulmonary inflammation, and systemic and impaired cardiovascular output.

This concise overview will look at recent breakthroughs in how aerosols arise, travel, and settle in the lungs. The presentation will focus on the most recent trends in identifying credible biochemical processes for health impacts. The corpus of literature that addresses the numerous elements of this subject is extensive; thus, it is essential to offer just a selection of the results that are considered to be the most pertinent and fascinating. Combustion-derived fine particles, rather than particles sourced from the Earth's crust, are generally believed to be responsible for a significant portion of the elevated mortality (Laden et al. 2000). This content will focus on the part fossil fuel

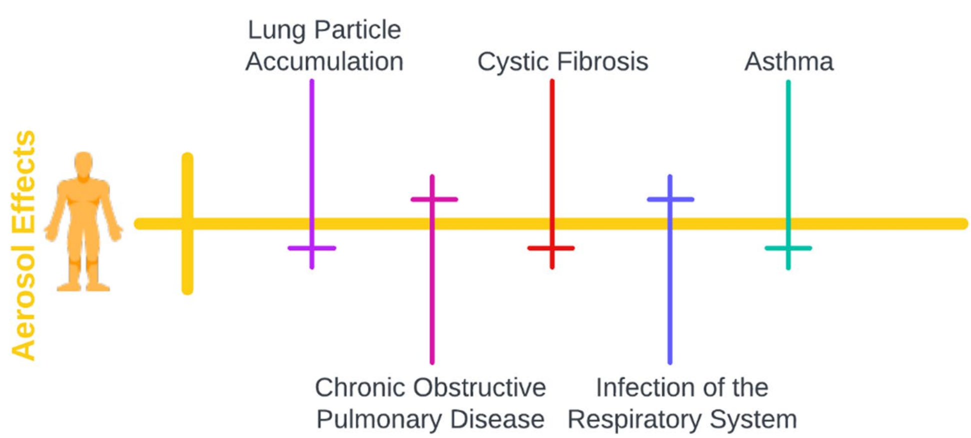

Fig. 3 Communicable lung diseases from aerosol

combustion shows in subsidising this issue and potential solutions.

Lung particle accumulation

Using tobacco smoke as an example, we can see that most smoke falls into the aerosol size range. Most people also know that people who smoke tobacco and other illegal drugs feel "high" quickly, which means that the aerosols have gotten into their bloodstream and are to blame.

Dublin was the site of most of the original aerosol investigations and Nolan's condensation nucleus counter (CNC) development (Nolan 1972). He says that a person breathes in more aerosols than they exhale. Some of this difference is due to coagulation processes, but some aerosols are "caught" in the body.

Researchers have examined how aerosols are deposited in healthy and sick lungs. For instance, Wiebert et al. (2006) demonstrate no distinction between normal and ill lungs and significant preservation of UFPs. According to Moller et al. (2008), there is little to no UFP elimination 24 h following exposure, indicating that the particles are maintained in the system. Although the processes are poorly understood, the preliminary suggestion is that UFP may be transplanted or moved to specific other organs through the blood (Geise and Kreyling 2010). However, this has yet to be shown for bigger particles.

If we consider tobacco smoking as an instance of aerosol intake, we can see that it is a leading cause of illness and mortality worldwide, accounting for 95% of lung tumour cases and that people who smoke are at a much higher risk of developing many other types of coronary heart illness. It demonstrates how a portion of aerosols, in this case, by-products of combustion from tobacco smoke, end up in the lungs and bloodstream, where they eventually cause harm. Although not all aerosols will have such adverse effects on health, this shows how well they may penetrate the body.

In their assessment of the effects of banning smoking, Goodman et al. (2009) exhibited that the overall population's health has enhanced reasonably quickly following the bans' adoption, primarily concerning a decrease in cardiovascular health occurrences. This analysis examined smoking prohibitions on many continents and discovered similar findings, indicating that the bans reduced public exposure to smoking while people were out socialising. According to Goodman et al. (2009), several studies have shown improvements in employee health.

Several events must occur when an individual inhales aerosol-containing air for those particles to be linked to harmful health consequences. First, the aerosols must be capable of reaching the lungs, where they either have to be stored or incorporated into circulation. The International Commission on Radiation Protection (ICRP) has made significant progress in understanding how aerosols settle in the lung tissues, and the depositing simulations it has created are regarded as the gold standard in this field. Although the ICRP primarily focused on forming radioactive particles, the findings apply to all aerosols.

The first version of the ICRP framework for dispersion uptake appeared in 1994. According to this paradigm, there are five subregions and three main areas of the human respiratory system (alveolar, thoracic, and extrathoracic). Coarser particles likely accumulate in the nasal area, while UFPs accumulate on the alveolar surface. Although even supermicron particles have significant depositing efficiency in the alveolar space, they also readily dominate mass-based particle absorption in the alveolar surface owing to their enormous masses in contrast to ultrafine. Due to their unique forms, UFPs frequently have lower densities. UFPs dominate in terms of particle quantities and the percentages of deposition in all respiratory system locations.

In his review of various models developed to describe particle accumulation in the respiratory system, Hofmann (2011) demonstrated that despite significant variations in the modelling approach, the differences between the models are comparatively minor compared to the overall variation in particle-size-specific deposition performance.

Asthma

Wheezing and breathlessness are the most conspicuous symptoms of asthma, a chronic illness of the air sacs of the lungs. The condition is brought on by non-cellular and cellular inflammatory processes that cause chronic inflammation, which causes bronchial hypersensitivity and, eventually, airflow blockage. There are 300 million individuals who have asthma, and all signs point to a rising global incidence of the condition, making it a substantial source of morbidity and mortality (Dharmage et al. 2019a). Asthma causes 180,000 deaths globally yearly https: ginasthma.org/ (n.d.); despite rising incidence, pharmaceutical interventions successfully lower mortality in industrialised countries. For instance, 250 million daily accustomed life years are predicted to be lost due to the condition in the UK, where 5.2 million individuals have asthma.

Bronchodilators, which lessen breathlessness, make it simple to treat bronchoconstriction, the foundation of asthma therapy. The root causes of bronchoconstriction must also be addressed, and corticosteroids are used for hyperresponsiveness and chronic inflammation. For many centuries, advancements in asthma medication focused on changing the physicochemical characteristics of drug molecules to produce stronger, longer-lasting, or more targeted effects on lung function. Although it is widely acknowledged that inhaled therapy provides excellent symptomatic relief for people with asthma (Corrigan et al. 2009), a decrease in lung function is still seen in patients with the disease because there is no successful therapy to change lung renovation, which is brought on by chronic inflammation in the air passages (Hanania and Donohue 2007).

Chronic obstructive pulmonary disease

A wide variety of illnesses with persistent airflow restriction that is not recoverable are included in COPD. Due to the types of comorbidities and challenges with diagnosis, it is difficult to determine the exact incidence of COPD; however, it was estimated that 3.28 million fatalities occurred in 2008 (WHO 2011). Due to particle consumption in emerging nations and older societies, COPD is predicted to be the leading cause of mortality by 2020. Permeation of particulate matter has been linked to biochemical alterations consistent with COPD pathology (Schwarze et al. 2006). Since COPD is a long-term condition, patients often have a hospitalisation-instigated, highly infectious worsening of the illness (Gartlehner et al. 2006). For example, 21.9 million regular days were missed in 1994–1995 owing to COPD, costing the UK's National Health Service a total of £1 billion annually. COPD also has a significant adverse effect on the broader economy (National 2004).

The primary location of airflow restriction in COPD is the tiny peripheral bronchi, which significantly differs from asthma (Burgel 2011). Inflammation and obstructive bronchiolitis, associated with COPD, are shown by an overabundance of lymphocytes and neutrophils (Hogg 2004). Increased mucus production, activation of the extracellular medium, the disintegration of parenchymal nerves, and fibrosis of the small airways are outcomes of the concomitant release of elastase, oxygen radicals, and numerous cytokines (Adcock et al. 2011). The administration of bronchodilators, which increase inspiratory capacity, is a vital component of the current pharmacological treatments for COPD. Long-acting bronchodilators like salmeterol and formoterol are often used. Bronchodilators are less effective in COPD than asthma (Sturton et al. 2008). However, antimuscarinic medications (O'Donnell et al. 1999) and long-acting tiotropium (Cooper 2006) have emerged as a pharmacological category that is very helpful in reducing dyspnoea and increasing exercise capacity. The inflammatory approach in COPD airways differs from that in asthma, and the effect of corticosteroid treatment is unclear (Gartlehner et al. 2006), probably due to the disease's phenotypic variation. In the subsequent years, pharmacological medicines with new disease-modifying activities are anticipated to be brought into the hospital due to the rising worldwide prevalence of COPD (Donnelly and Rogers 2008).

Cystic fibrosis

One in every 2500 babies born in White communities has cystic fibrosis (CF), the most prevalent inherited genetic illness (Davies et al. 2011). Even though CF is a complicated lung illness, the multiorgan disease is responsible for 85% of fatalities (Flume et al. 2007). The cystic fibrosis transmembrane regulator (CFTR) gene, which controls chloride movement across the lung epithelium's apical membranes, is the source of CF, an autosomal recessive illness (Rowe et al. 2005). Chloride transport is compromised, which results in less liquid lining the respiratory epithelium. Because the microglia on the cell exteriors need enough mucociliary evacuation, periciliary fluid volume is compromised (Satir et al. 1990). Progressive lung deterioration is brought on by coagulated lung secretions, excessive inflammation, and bronchial infections caused by bacteria and allergens that cannot be eradicated.

While cystic fibrosis is primarily a genetic disorder, some evidence suggests that exposure to certain environmental factors, including ambient aerosols, may play a role in the progression and severity of the disease.

Several studies have investigated the effects of ambient aerosols on individuals with CF. These studies have explored the relationship between air pollution and CF exacerbations, lung function decline, and increased respiratory symptoms. Pollutants such as fine $PM_{2.5}$, nitrogen dioxide (NO_2), and SO_2 have been implicated as potential contributors to respiratory issues in CF (Rowe et al. 2005).

It is important to note that the impact of ambient aerosols on individuals with CF may vary depending on factors such as specific genetic mutation, overall health, and exposure levels. Furthermore, while evidence suggests a correlation between ambient aerosols and CF-related respiratory symptoms, it is still an area of ongoing research and further investigation is needed to fully understand the mechanisms and potential causative factors (Davies et al. 2011).

In any case, individuals with CF should follow the recommendations provided by healthcare professionals to manage their condition effectively. It includes maintaining good respiratory hygiene, avoiding exposure to respiratory infections, and following prescribed treatments and medications. Regular discussions with healthcare providers can help determine appropriate strategies for minimising exposure to environmental factors that may aggravate CF symptoms (Davies et al. 2011).

Infection of the respiratory system

Most respiratory illnesses are often identified and responsive to brief regimens of oral antibiotics. Nevertheless, specific patient populations might benefit from localised delivery of antibiotic drugs that are not well accepted or accessible by systemic administration, such as those with immune system compromises or long-term lung colonisation (such as CF patients). Producing localised medication concentrations to treat TB infections may be challenging. Localised administration may provide a strategy that results in reasonably high local concentration levels (Smaldone 2006).

Pharmaceutical aerosols for the treatment of disease

The intercostal muscles and diaphragm are contracted during the enlargement of the chest cavity to draw air into the lungs to accomplish gaseous exchange at the alveolar surface. The upper respiratory tract performs particle filtration through inertial impaction (Forbes 2000). The lower airways are divided into two groups: the central conducting airways, which include the bronchioles and bronchi responsible for heating and humidifying the inhaled air, and the peripheral connecting airways, encompassing lung bronchioles, terminal bronchioles, and alveoli. The mucus-secreting goblet cells that make up the ciliated epithelium that lines the conveying airways are protected by a two-layer membrane of a mucus gel with high viscoelasticity and a low-viscosity solution. The epithelium of the lower bronchioles and alveoli, devoid of mucus and possessing a notably flattened surface, consists of squamous-type cells (Patton 1996) and is coated with a layer of pulmonary surfactant (Forbes 2000). As a result, airway diseases may manifest through changes in airway anatomy or pathophysiology, such as altered mucus clearance and pulmonary surfactant synthesis. The gold-standard therapy approach for obstructive lung illnesses is topical pulmonary delivery administered directly into the airways; it maximises a drug's pharmacological effectiveness while minimising systemic toxicity and the ensuing adverse effects.

Cardiovascular disease

Epidemiological investigations have shown an uninterrupted increase in the danger of cardiovascular incidents in response to both short- and long-term exposures to the current levels of ambient particulate matter. Current amounts of ambient particulate matter cause risk. Pollutants in the air are linked to an elevated probability of death and hospitalisation due to cardiovascular illness. This is particularly true for those with frequent arrhythmias, congestive heart failure, or both conditions (Pope et al. 2004). The widely acknowledged causal correlations between active and passive smoking and heart attack and stroke support the possibility of a negative impact of PM on the cardiovascular structure. These epidemiological statistics may not accurately represent the detrimental impact of particle pollution on the cardiovascular system, but a new study by Suwa et al. (2002) offers experimental proof that backs up the premise that this is the case. Following this, an explanation of the connection between exposure to second-hand smoke (SHS) and the development of heart disease will be presented; this will serve as an applicable paradigm for the cardiovascular consequences of air pollution. This study acknowledges the substantial scientific indication that offers a biological explanation for the practical relationships between prolonged exposure to SHS and a higher likelihood of cardiovascular disease (Samet et al. 2000). The body of data and the quantity of research establishing a connection between air pollution and cardiovascular disorders have grown significantly throughout the last 15 years (Brunekreef et al. 2002). A few documented publications demonstrate the influence of contaminants in the air on cardiovascular hemodynamics. These investigations provide credence to the data's significance (Ibald-Mulli et al. 2001). Reducing HRV predicts a greater chance of cardiovascular morbidity and death in older adults and individuals with substantial heart disease.

Neurodegeneration disease

Adults and children have shown signs of neurological impacts after being exposed to air pollution for long periods. While the aetiologic agents of neurodegenerative illnesses such as Alzheimer's and Parkinson's are not yet understood, it is generally accepted that prolonged exposure to polluted air may play a role in developing these conditions. In particular, dietary variables, insecticides, and metals have been suggested as potential aetiological contributors. Environmental variables, including contact with air pollution, metals, pesticides, and dietary factors, are frequent risk indicators for neurodegenerative illnesses. Oxidative stress, inflammation, protein accumulation, and mitochondrial dysfunction in neurons are the pathways that contribute to the development of neurodegenerative illnesses (Genc et al. 2012). In human adults, researchers discovered that a fast reaction to PNC on the IL-6 concentration led to a rise in the levels of indicators of systemic inflammation, which may have contributed to the creation of acute-stage proteins (Ruckeri et al. 2007). There is an accumulation of data to imply that being subjected to air pollution may activate the common factors associated with neurodegenerative illnesses, resulting in neuropathology. It is essential to observe the build-up of alpha-synuclein in the brains of young individuals exposed to air pollution their whole lives (Calderon-Garciduenas et al. 2008). These results, taken as a whole, indicate the need for more research in epidemiology, forensics, and toxicology to understand better the connection between chronic contact and the possibility of neurodegenerative illnesses. These initiatives could create prophylactic therapies for these debilitating illnesses in specific populations at risk.

Air pollutants can potentially hurt brain function at any age; however, the growing brain is more susceptible to these effects due to the rapid pace of neuronal propagation and variation, an undeveloped metabolism, and a poor blood-brain barrier (Sunyer 2008). Alterations to how the stages of brain development take place might result in irreversible defects that manifest themselves at some point in life.

Reproductive system

Toxic effects on reproduction are becoming increasingly recognised as an integral component of the study of systemic toxicology. On the other hand, extensive research on the impacts of $PM_{2.5}$ on reproductive health began very recently. Currently, the most debated processes include oxidative stress, inflammation, the induction of apoptosis, and barrier component degradation. These mechanisms can potentially contribute to reproductive toxicity, but the particular molecular pathways are not entirely understood (Liao et al. 2020). The reproductive system comprised several intricate physiological systems that are highly reactive to the presence of chemical contaminants. One of the most significant challenges in terms of public health that people all over the globe are confronted with today is dysfunction in reproduction and progress (Liao et al. 2020).

In recent decades, investigators have shown a growing curiosity about the impacts that $PM_{2.5}$ has on reproductive organs as a result of their extra-depth study of $PM_{2.5}$. Studies on animals and epidemiological research have both indicated that exposure to air pollution lowers the quality of sperm in several ways, involving volume, quantity, strength, and shape of the sperm. Research has revealed that exposure to $PM_{2.5}$ and the different elements of $PM_{2.5}$ may raise a woman's chance of having a baby with a low birth weight, delivering the baby prematurely, and experiencing a drop in the quality of her sperm (Li et al. 2019). According to Kim et al. (2015), both long- and short-term contacts with $PM_{2.5}$ may damage the makeup of cell lines at the blastocyst phase of growth in females, which may affect the formation of embryos.

These results also imply that quantitative research on persons engaged in particular vocations, including traffic police, highway toll collectors, and coal burners, has connected air pollution to lower sperm motility and counts (Deng et al. 2016). These findings were found in people inhaling high levels of air pollution on the job. According to the findings, $PM_{2.5}$ disrupts the balance of hormones in vivo and most likely poses a danger to male fertility. These results suggest that exposure to $PM_{2.5}$ may affect spermatogenesis and provide compelling evidence that an imbalance in hormone concentrations may cause the disease. The findings of this study were subsequently backed up by Ogliari et al. (2013). The study conducted by both teams points to the possibility that $PM_{2.5}$ is an indicator of risk, and as a result, we should express our worry over the connection between air pollution and female fertility. These results also imply that quantitative research on the level of exposure threshold that causes harm to the human reproductive organs should be carried out as soon as possible.

Other supporting evidence

Experiments in which people, animals, and cells were subjected to doses of constituents prevalent in ambient organic aerosol have presented evidence of these constituents' significance to human health. Real-time exposure levels include things like being in the presence of the following:

(1) entire atmospheres,
(2) atmospheric aspects,
(3) designed to simulate environmental mixtures, and
(4) specific chemical molecules.

The results show that several organisms have biological processes that may harm human health. However, only a few of these species have had their exact environmental doses or dosages shown to be harmful. There have been a few concerted efforts to introduce animals directly to the air in the surrounding environment at sites with significant pollution levels or symbolise various microenvironments. Detecting meaningful impacts at ambient levels has proved difficult, and descriptions of exposures have rarely incorporated EC or OC. Although the following investigations are examples of those most likely impacted by carbonaceous categories, research has yet to prove that the carbonaceous constituents originated the results.

Elder et al. (2007) performed an experimental study comparing the consequences of exposure to the atmosphere and the filtered environment. They concluded that no significant distinctions were observed between both situations. The average rate of the heart and changes in the individual rate decreased when the material was exposed to the whole environment. The concentration was in UP; even so, the correlation of filtered versus unfiltered environments demonstrated that non-PM constituents prompted the impact, and both SVOCs and VOCs might have been visible in considerable concentrations. It was determined by looking at the difference between filtered and unfiltered environments.

Carbonaceous atmospheric materials have been presented to animals or cells grown in a laboratory setting. Most of this research has focused on mammalian cells or exposing bacteria to solvent isolates of the organic phase of PM, with mutagenicity as the primary criterion for determining whether or not a substance can cause cancer (Lewtas 1988). The majority of research sought to accomplish one of the following three objectives:

(1) when calculating the carcinogenic possible,
(2) identifying the causative chemical sort, or
(3) assessing the possessions of various combustion circumstances.

The relative mutagenicity was employed for establishing potency search engine ranking for identification of human carcinogen and then estimating the danger arising from it or also to find out about the risk caused by the emission for which the epidemiologic study was found to be insufficient and inaccurate (Schuetzle and Lewtas 1986). It was done to fill in any gaps in our knowledge regarding these hazards or risks. The calculation of carcinogenic hazards from diesel exhaust is a famous example. This assessment was based on comparing the tobacco smoke isolates, roofing tar emissions, and coke oven emission levels (Albert et al. 1983).

A method known as "directed fractionation" has been utilised for a very long time to determine the chemical categories and chemicals in isolates of combustion PM that are the most likely to cause mutations. Extracts are successfully broken down into subclasses and particular chemicals using chemical fractionation. These individual compounds are tested to determine their unique mutagenesis activity (Schuetzle and Lewtas 1986). One recent example is the research conducted by DeMarini et al. (2004), who demonstrated that the chemical categories responsible for the bacterial teratogenic effects of DPM extracts varied according to the source of the samples. In addition, experiments have been carried out to investigate the factors that affect the genotoxicity of DPM extracts, such as the kind of engine, the fuel used, and the running conditions (Clark et al. 1984).

There are a few things to remember while the biological action of pulls documents the significance of PM-borne OC. Generally, the dosages administered to the biological process are relatively high compared to the background values (Molinelli et al. 2006). It is unknown to what degree the material extracted using solvents, ultrasonics, heat, and other methods replicates the stuff that would be discharged from PM in vivo (also known as "bioavailability"). There needs to be more confidence in the ability to extrapolate from single-cell structures to individual dangers and risks. Additionally, the extracts can include inorganic components and compounds (Molinelli et al. 2006).

Various studies were conducted in the laboratory on PM, undertaken from the environment and ecological system. Some researchers were eager to find out the effect of the carbonaceous component on the material. They extracted PM by employing methanol from the collected medium and experimentally examined it. Later, they were acknowledged by a series of different tests, such as in vivo and in vitro studies of cytotoxic, inflammatory, and synergistic possibilities, releasing thirteen outputs and their specific responses (Steerenberg et al. 2006). No information was provided on the fractional quantities of OC and EC; nevertheless, 28 extracted OC varieties were evaluated. There were reports of correlations between every component and the response variables, and type and concentration segmentation were utilised to predict the primary PM sources. Correlations varied across response and composition factors in a complicated way that defies easy summarisation; nonetheless, correlations were identified with the OC constituents (Steerenberg et al. 2006).

The dithiothreitol assay revealed that the UP portion had the highest levels of PAH composition and the possibility of connecting reactive oxygen categories. UP had the highest levels of both. The UP fraction was likewise responsible for the highest levels of oxidative stress in a cultivated cell line of mouse macrophages (Li et al. 2003). It was hypothesised by Li et al. (2003) that PAHs were substantially to blame for the oxidative damage that occurred. In vitro, bronchial epithelial cells took up both UP and $PM_{2.5}$ for internal processing. On the other hand, $PM_{2.5}$ was only identified in the cytoplasm, whereas UP had already entered the mitochondria and was causing harm there. The study provides proof for the mortality of ambient OC, even though the investigation did not resolve the most dangerous chemical variety.

Research conducted in the laboratory has also considered a variety of constituents in ambient organic aerosols. In their study, the lung inflammatory possibility of PM, SVOC, and the aggregate masses taken from a traffic tunnel were analysed and compared by Seagrave et al. (2001). SVOC and PM were collected using filters, whereas a resin trap (XAD or PUF) was used to capture SVOC. In this experiment, rats received an intratracheal instillation of the merged SVOC-PM mass in the initial collection proportion or an intratracheal instillation of either material individually. Lung inflammation was assessed via BAL after 24 h. However, the efficacy of the SVOC per mass unit was fourfold that of PM, indicating that SVOC in the proximity of current engine emigrations possesses inflammatory capability that may approach or even surpass that of PM. Both portions were inflammogenic, and their collective impact was nearly additive. The disclaimers regarding dosage, bioavailability, and extrapolating to human risk remain in effect (Seagrave et al. 2001).

Although PM has been the primary focus of most pollutant surveys undertaken over the last decade, there is a strong and rising indication that non-PM constituents of combustion productions are essential to various health consequences. Adding a ceramic particulate matter filter did not affect the irritating and inflammatory responses caused by single diesel fume exposure (Rudell et al. 1999).

Ingredients of organic aerosols created in the lab and investigated as individual portions or straightforward mixtures can potentially have diverse impacts on living organisms. Even though these studies do not look at aerosols in the air directly and often use doses that are too high, they show that similar environmental factors probably cause air pollution.

Seagrave et al. (2005) were identified as potential culprits in a study that used exhaust from newer, used, and old city buses that relied on natural gas compression. Although the statistical interactions discovered in this study and previous research did not prove that Seagrave and his team were the causes of the toxic effects, they did point to the consequence of PM-borne OC in overall and cylinder oil emission levels in particular in the lung harmful effects of engine outflows.

The findings obtained by Campen et al. (2005) more explicitly demonstrate the significance of the vapour-phase VOC and SVOC constituents in engine emissions. After bubbling new diesel emissions through a salt solution, the solution was filtered, and it was discovered that the emissions included a significant number of alkanes and volatile carbonyls and only small amounts of semi-volatile PAHs. In this experiment, fresh samples of mouse coronary arteries were infused with either untreated saline or saline handled with diesel, and the vascular reactions to medicines that restrict or dilate blood vessels were examined. The exposition to the diesel-prepared saline did not change the basal vascular tone; however, it did elicit elevations and reductions in the responsiveness to vasoconstrictors and vasodilators, respectively. Campen et al. (2005) came up with the hypothesis that VOC constituents induced the effects.

Various biological impacts of DPM created in the lab and gathered from filters have been examined without further emission constituents. DPM has been administered to humans, cells, or animals in experiments with little information on the chemical itself and a broad description of its source. It is crucial to interpret these outcomes with caution due to artefacts that can happen in filter compilations. These artefacts include the absorption or desorption of VOC and SVOC and the oxidative revolution or nitrosylation of PM-borne organic compounds (Arey et al. 1988). Only a few of these studies give information about the variables responsible for the results.

A considerable body of research demonstrates that many particular organic categories and substances prevalent in the environment are harmful to some biological processes at some level. These findings come from a variety of different organisms. The scope of the substances researched and the bodily reactions revealed are much too extensive to be included in this article; nonetheless, several instances are outlined in toxicology textbooks (Klassen 2001). Verifying individual chemicals' safety may prove that a possible health hazard exists. However, this knowledge does not, on its own, lead one to assume that environmental factors pose significant health hazards. Establishing a connection between biological activity and conditions such as temperature (concentration multiplied by time) is necessary to put environmental consequences into perspective.

Challenges and future directions

The possibilities for aerosol research are promising, and collaboration across many groups will be very beneficial in addressing the challenging research problems. The aerosol formation is essential in extrapolating the natural environment and producing health data. The place and degree of deposition in the respiratory system and the pharmacology of the medications being breathed all affect how well inhalation treatment works. The primary processes influencing the transit and deposition of inhaled aerosol in the human lung are reviewed in this article. Based on human research findings utilising non-imaging methods, aerosol deposition in healthy and sick lungs is primarily detailed. According to the data, the localised deposition must be evaluated to predict therapy success since overall lung deposition is a poor predictor of clinical outcome. Particle size significantly impacts the geographical distribution of deposited particles and, therefore, the efficacy of drugs. The quantity of medication that may be administered to the lung is limited by the tendency of large particles (> 6 m) to lodge mainly in the upper airway. While particles in the size range of 2–6 m are most adapted to treat the central and small airways, smaller particles (2 m) deposit primarily in the alveolar area and are likely the most likely to act systemically.

Conclusion

Human aerosol exposure and its implications on health were examined based on the size-selective aerosol concentration. This work provides a health-effect evaluation based on aerosol properties and demonstrates that size-selective aerosol concentrations may be utilised as a fundamental indication of health concerns (aerosol viability and aerosol size). The hazards to one's health vary significantly depending on the environment in which one is exposed to inhalable aerosols. In order to gather quantitative exposure data for varied human contexts and to take into account the age and likely source of pollution, exposure to inhalable aerosols will thus be essential. Moreover, viability may be crucial in assessing the health impact when considering the sources and determinants of indoor pollution. Health effect analyses and ongoing data on aerosol exposure will be required for inhalable aerosol exposure based on size-selective aerosols; continuous exposure studies of PM and aerosols are required, considering health impacts and pollution control in childcare facilities and schools. In conclusion, this collection of papers provides a comprehensive update on research concerning how aerosol sources influence health effects and toxicity indicators in various scenarios. It shows where the field is now and how much work still needs to be done to get there.

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